MIL-W-1366F
2 October 1975

SUPERSEDING
MIL-W-1366E
2 June 1970

MILITARY SPECIFICATION

WINDOWS, OPTICAL SENSOR

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers windows and window assemblies for optical sensors through which useful imagery can be obtained from airborne vehicles. It describes windows having specific limits on factors tending to limit the resolution and performance of the optical systems with which the window is to be used.

1.2 Classification. The windows shall be classified according to requirements into categories containing as subsets, types and groups. Category 1 windows are primarily plate glass windows classified as to type and to group. Category 2 windows are of high quality glass that are made-to-order for a particular application or set of applications. Category 3 windows have special requirements such as electro-conductive coatings or special laminated configurations.

2. APPLICABLE DOCUMENTS

2.1 The following specifications and standards, of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Federal

UU-P-553	Paper, Wrapping, Tissue
PPP-B-601	Boxes, Wood, Cleated-Plywood
PPP-B-621	Boxes, Wood, Nailed and Lock-Corner
PPP-C-843	Cushioning Material, Cellulosic
PPP-C-1120	Cushioning Material, Uncompressed Bound Fiber for Packaging
PPP-T-45	Tape, Gummed, Paper, Reinforced and Plain for Sealing and Securing
PPP-T-60	Tape, Packaging, Waterproofing

Military

MIL-G-174 Glass, Optical
MIL-O-13830 Optical Component for Fire Control Instrument, General Specification Governing the Manufacture, Assembly, and Inspection of

STANDARDS

Military

MIL-STD-129 Marking for Shipment and Storage
MIL-STD-130 Identification Marking of U. S. Military Property
MIL-STD-810 Environmental Test Methods

(Copies of specifications, standards, drawings and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following document forms a part of this specification to the extent specified herein. Unless otherwise specified, the issue in effect on date of invitation for bids or request for proposal shall apply.

UNIFORM FREIGHT CLASSIFICATION COMMITTEE

Uniform Freight Classification Rules

(Application for copies should be addressed to Uniform Freight Classification Committee, Room 202, Union Station, 516 W. Jackson Blvd., Chicago, Ill 60606.)

3. REQUIREMENTS

3.1 Category 1 windows

3.1.1 Materials. The material shall be clear glass of adequate quality to meet the requirements specified in 4.2. A slightly greenish tint shall not be cause for rejection.

3.1.1.1 Laminated or fused glass. Laminated glass or fused silica is acceptable if it meets the requirements specified herein.

3.1.2 Indentation hardness. The glass shall be of maximum possible hardness consistent with the other requirements specified in 4.2.2. The indentation hardness number for the glass to be used shall be provided upon request of the procuring activity.

3.1.3 Striae. Striae shall not be visible to the unaided eye, or corrected vision, when observed as specified in 4.3.1 and under the conditions of table I. The severity of the striae test increases with an increase in the screen-to-sample distance. Glass passing a more severe test than specified is acceptable.

Table I. Striae

Glass	Distance from screen to sample
Group A	60 inches
Group M, B, C	40 inches
All types	60 inches

3.1.4 Foreign particles and bubbles. The usable section of the glass shall be free from all opaque and translucent foreign materials and from bubbles greater than 1/32 inch in diameter. Defects that are between 1/64 and 1/32 inch diameter shall not be more frequent than one per square inch.

3.1.5 Strain. The stress birefringence of glass and window assembly shall conform to MIL-G-174, unless otherwise specified.

3.1.6 Size and thickness. The size and thickness of the glass shall be as specified by the procuring activity. The procuring activity will specify adequate thickness consistent with aircraft design considerations and optical fabrication requirements. Nominal thicknesses, tolerance on nominal thickness, and tolerances on width and length shall be as specified in table II.

Table II. Nominal Thickness and Tolerances

Nominal Thickness (inches)	Tolerance on Thickness (Inches)	Tolerance on Length and Width (Inches)
1/4, 3/8, 1/2	± 1/32	± 1/32
5/8, 3/4	± 3/64	± 1/32
7/8, 1	+ 1/16	± 1/32

3.1.7 Surface finish. The surface of all windows shall be equivalent to that typical of high-grade plate glass for the thickness required. Grayness or stain shall not be visible when observed as specified herein. Occasional faint hairlines, pits, and sleeks are admissible when well scattered. Unless otherwise specified, a surface quality of 80-50 shall be required for scratches and digs.

3.1.8 Transmittance. The glass shall have external transmittance, over the spectral range of 400 to 600 nm, of not less than 87 percent for a 1/4 inch thickness when tested at normal incidence using a light source approximating sunlight. For glass other than 1/4 inch thick, the minimum shall be 87 percent plus or minus the difference due to absorption.

3.1.9 Surface flatness. The departure from flatness within the usable section of each surface shall not exceed that specified by the procuring activity, and category 1, group M glass shall not exceed one wavelength per 6-inch diameter area of surface.

3.1.10 Parallelism. The glass specified according to category 1 and type shall have allowable wedge not exceeding that specified in table III. The glass specified according to category 1 and group shall have allowable wedge not exceeding that specified in table IV. The wedge tolerance applies only over the usable section of the glass as specified by the procuring activity.

Table III. Wedge Requirements for Types 1 through 5.

Type	Obliquity Angle (degrees)	Maximum Wedge Angle (min - sec)
1	10	06 - 00
2	20	06 - 00
3	30	04 - 00
4	40	04 - 00
5	50	04 - 00

Table IV. Wedge Requirements for Groups A, B, C, and M

Group	Maximum Fringe Differential	Maximum Wedge	Testing Length (inches)
A	0.5 fr/in.	15 sec (10/fr/in.)	5
B	1.25 fr/in.	30 sec (20/fr/in.)	5
C	2.5 fr/in.	30 sec (20/fr/in.)	3
M	1.25 fr/in	4 sec (2.5/fr/in.)	2.5

3.1.10.1 Wedge. In cases where window assemblies are composed of two or more glazings side-by-side(segmented windows), the direction of wedge shall be such that all wedge angles are in the same orientation (all thick ends in the same direction). For segmented windows specified to Group C wedge requirements, the fringe differential across adjacent edges between segments shall be permitted up to 3.5 fringes per inch. If significant differences in pressure or temperature exist between inside and outside air volumes, special corrections must be applied for high performance sensors.

3.1.11 Transmitted image quality. Category 1 windows when tested in accordance with 4.3.7 and angle of obliquity designated in table III, shall have no longitudinal shift of the target image.

3.2 Category 2 windows

3.2.1 Materials. The material shall be clear glass of adequate quality to meet the requirements of the procuring activity. Optical glass shall conform to MIL-G-174 for color and absorption. The requirements for the limits on the coefficient of thermal expansion and the change in refractive index with temperature (dn/dT) shall be as specified if transmitted wavefront thermal testing is not specified. A certificate of compliance of the required values may be obtained from the glass supplier.

3.2.2 Indentation hardness. The glass shall be of maximum possible hardness consistent with the other requirements specified in 4.2.2. The indentation hardness number shall be provided upon request of the procuring activity.

3.2.3 Striae. Striae shall not be visible to the unaided eye or corrected vision when observed as specified in 3.1.3 and 4.3.1.

3.2.4 Foreign particles and bubbles. If optical glass is used, the glass shall fulfill the bubble and seed requirement of the paragraph 3.3 class I-standard, of MIL-G-174, with the exception that six bubbles, between 0.020 inch and 0.039 inch mean diameter per square foot will be permissible and the sum of the diameter shall not exceed 0.150 inch.

3.2.5 Strain. The stress-birefringence of the glass and the window assembly shall conform to MIL-G-174 unless otherwise specified.

3.2.6 Surface finish. The surface finish shall be specified in accordance with the requirements of MIL-O-13830 for scratches and digs. Unless otherwise specified, a surface quality of 80-50 shall be required.

3.2.7 Transmittance. The glass shall have external transmittance, over the spectral range of 400 to 700 nm, of not less than 90 percent for a 1/4 inch thickness, when tested at normal incidence using a light source approximating sunlight. For glass other than 1/4 inch thick, the minimum shall be 90 percent plus or minus the difference due to absorption.

3.2.8 Surface flatness. The departure from flatness shall not exceed that specified by the procuring activity.

3.2.9 Parallelism. The finished window shall meet the parallelism requirements specified by the procuring activity.

3.2.9.1 Wedge. For segmented windows made up from two or more pieces of glass, the wedge directions shall all have the same orientation and all the thick ends shall be in the same direction provided there are no pressure or temperature differences between inside and outside air volumes. If such differences exist, then wedge angles determined by the procuring activity must be factored into the glazings in specific orientations, especially if there are to be instances when the optical system looks through two adjacent glazings at same time, as in panoramic camera systems.

3.2.10 Transmitted wavefront error. Windows intended for use with optical systems of high acuity, shall be tested for transmission wavefront error. Windows of category 2 and 3 are frequently designed in conjunction with the lens system and must be tested to the level of a high quality lens. The maximum wavefront deformation shall be specified for the clear aperture of the window and a maximum wavefront deformation specified for any x-inch diameter within the window aperture.

3.3 Category 3 windows. Category 3 windows shall meet the requirements of category 1 or category 2, as specified, and shall meet additional requirements such as heating rates for electro-conductive windows or specific emissivity values for thermal control coatings. These special requirements and the testing procedures required to ensure achieving these requirements shall be specified by the procuring activity.

3.4 Window assembly. The window assembly shall be subjected to the tests and measurements stated herein to ensure optical performance is not degraded by distortion introduced by the mounting frame. The requirements of 3.1.5, 3.1.11, 3.2.5, and 3.2.10 shall be verified for the assembled window. Additional measurements may be specified by the procuring activity.

3.5 Environmental endurance. All windows or window assemblies shall be capable of meeting the environmental conditions of 4.4.2 for high temperature, altitude, low temperature, temperature shock, humidity and vibration.

3.6 Identification of product

3.6.1 Glass. The glass shall be marked for identification in accordance with MIL-STD-130. The following designation, etched or sandblasted, occupying a space not greater than one inch square, shall appear in one corner of each piece of glass in a position to be legible when the glass is fitted as a window. For round glass, the inscription shall appear on an arc near the edge of the glass.

WINDOW, OPTICAL SENSOR
Category_____Type/Group_____Max. Wedge_____
Specification MIL-W-1366F
Manufacturer's name or code identification

A value of maximum wedge in minutes or seconds of arc shall be inscribed only on glass of the type category. When applicable, the wedge direction shall be marked with an arrow or suitable symbol pointing in direction normal to the line of intersection of the window surfaces. The arrow shall be placed at the thickest portion of glass.

3.6.2 Protective covering. After the glass has satisfactorily passed the inspection for optical quality at the manufacturer's plant, a protective sheet of suitable paper coated with a pressure-sensitive adhesive shall be applied to both sides. The adhesive used shall not require moisture, heat, or any special manner of preparation before applying the paper to the glass. Category 2 and 3 windows may require alternate protective covering if the pressure-sensitive adhesive will degrade or contaminate the finished optical surfaces. The information below shall be imprinted either on the protective covering or on a gummed paper label which shall be attached to the protective covering on each piece of glass.

WINDOW, OPTICAL SENSOR
Category_____Type/Group_____Max. Wedge_____
Specification MIL-W-1366F
Manufacturer's name or code identification
Part Number
Size

3.7 Workmanship. All details of workmanship shall be in accordance with high-grade manufacturing practice for this type of material.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein unless disapproved by the government. The government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to the prescribed requirements.

4.2 Materials verification tests. The following tests shall be performed for each batch of glass.

4.2.1 Material. Examination of the glass for color and absorption characteristics shall be in accordance with MIL-G-174. (See 3.1.1, and 3.2.1.)

4.2.2 Indentation hardness. Verification of material hardness shall be obtained from an established micro indentation hardness test performed on a sample specimen of the material. (See 3.1.2 and 3.2.2.)

4.2.3 Transmittance. The glass shall be measured with a spectrophotometer or similar method using selective filtering and a photometer. Certification from the glass supplier is acceptable in lieu of these tests.

4.3 Window and window assembly. Each window shall be inspected to determine compliance with the requirements as specified.

4.3.1 Striae. All glass shall be inspected for striae by the following method:

A shadowgraph, consisting of an incandescent zirconium concentrated arc lamp (similar to Sylvania Type C) whose glass shall have no striae or radial changes in thickness, the glass sample and a 20 inch by 20 inch ground glass project on screen (medium grind) shall be used. The center of the ground glass shall be normal to the axis of the test set-up and shall be 80 inches from the arc lamp. The glass sample shall be parallel to the ground glass and between the screen and the arc lamp at the distance specified in table IV. The shadowgraph shall be used in a darkened room such that the only illumination falling on the screen is from the arc lamp and through the glass sample. (see 3.1.4 and 3.2.4.)

4.3.2 Foreign particles and bubbles. The glass shall be examined for inclusions by the following method (see MIL-G-174). The sample is to be illuminated by a beam of light from the side and viewed normally against a dark background. Inclusions will appear as bright specks on a dark field.

4.3.3 Strain. The window glazing shall be examined for stress before and after installation in the mounting frame. A comparison can then be made to detect deleterious effects from the frame. The presence of birefringence can be detected with crossed polarizers illuminated by a uniform light source. The birefringence can be determined more accurately using a polarimeter. (See 3.1.5 and 3.2.5.)

4.3.4 Surface finish. The glass shall be inspected with the unaided eye, or corrected vision, using normal room illumination or the methods of MIL-O-13830. (See 3.1.7 and 3.2.6.)

4.3.5 Surface flatness. The glass shall be tested on both surfaces for surface flatness by the following methods:

4.3.5.1 Method 1 (preferred method). The window, or the window and frame assembly, shall be tested with an interferometer. The reference surface of the interferometer shall be certified flat to 1/5 of the specified window flatness over the required aperture. A photographic recording of the fringe pattern shall be made for category 2 and 3 windows. The interferogram shall be examined for indication of surface irregularity and analyzed for determination of surface flatness.

4.3.5.2 Method 2. The window or window and frame assembly shall be tested with a 6-inch diameter test flat, certified to 1/5 of the specified window flatness, with an extended source of monochromatic light. To avoid the up-to-20 percent uncertainty in flatness due to the test flat errors, the test flat shall be removed, rotated 90°, and replaced several times in each area to determine if the errors follow the flat or not. If the errors are in the test flat, they are to be subtracted from the total irregularity or power.

4.3.6 Parallelism and wedge. For windows having known surface flatness and moderate wedge requirements, precision micrometer readings of the edge thicknesses are acceptable. In general, the windows shall be tested interferometrically such that interference is obtained from the light reflected from the two surfaces (see appendix). Photographic recording of the fringe pattern is mandatory for category 2 and category 3 windows. The aperture over which the fringes are required shall be specified by the procuring activity. A fiducial arrangement should be provided on the window for scale and orientation. The following technique shall be used in the determination of fringe differential:

Two test circles, each one inch in diameter, shall be so located that the difference between the number of fringes within the circles shall be the maximum which can be observed, when the circles are within the usable area and have their centers separated by not more than the specified testing length. When the positions of maximum fringe difference have been thus located, the number of fringes is determined for each circle,and the difference between these two values calculated to give the fringe differential. The resulting value for fringe differential shall not exceed that specified in table IV for the group requirement designated by the procuring activity. In counting fringes, the diameter of the test circle is selected which crosses the maximum number of fringes, and each intersection along this line shall be counted as one fringe, regardless of whether the same fringe is intersected more than once by this diameter. No fringe or group of fringes within the usable area of the glass shall form a closed curve of minimum diameter equal to or less than one inch. Glass exhibiting closed fringe systems in which the centers of the systems are separated by less than twice the specified testing length shall be rejected. In all cases, fringes shall form smooth curves or lines. Windows exhibiting fringes with sharp changes in direction shall not be acceptable.

4.3.7 Transmitted image. A resolving power test may be used for inspecting category 1 type windows. The test apparatus shall consist of a collimator with suitable resolving power test chart and a high quality apochromatic objective lens. The effective aperture of the objective and the collimator lenses shall be equal to or larger than the largest aperture lens to be used with the window, but shall be not less than 2.5 inches diameter. The glass or window to be inspected shall be placed between the collimator and the lens, immediately in front of the lens. The angle of obliquity between the optical axis and the normal to the plane of the window shall conform to the requirements of table III. The window shall be examined in two positions obtained by rotating it through an angle of 90 degrees about an axis normal to the surface of the glass when it is in the test position for which the angle of obliquity is specified in table I. The target image formed by the testing objective and selected for the window analysis shall subtend an angle no greater than 10 seconds (bar and adjacent space). The image pattern shall be observed with a standard positive orthoscopic ocular or microscope of not less than 10-power magnification. The ocular shall include a fixation scale or reticle properly located for coincidence with the target image when no glass is in front of the objective. Longitudinal shift of the target image with respect to the reticle shall be cause for rejection of the glass or window. Significant loss of contrast in the region of the observed images such as flare, color, or overall haze, shall be cause for rejection of the glass. The tested area shall be that specified by the procuring activity. Pieces of glass, the tested areas of which fail to permit the formation of distinct, undistorted images under the foregoing conditions, shall be rejected.

4.3.8 Transmitted wavefront error. The windows, or window assembly, shall be tested in transmission in an interferometer. The interferometer shall have an aperture diameter as large as the aperture over which the wavefront error is specified; e.g., if the maximum wavefront deformation is (1/x) λ over any 10-inch diameter area, the minimum interferometer aperture shall be 10 inches diameter. The root-mean-square (rms) wavefront error (see appendix) of the empty interferometer shall not exceed 1/5 of that specified for the window for the same aperture. The fringe pattern of the empty interferometer and of the interferometer-plus-window shall be recorded photographically. The interferogram of the empty interferometer shall be properly subtracted from the interferogram of the window and interferometer before the rms of the window (assembly) is determined.

4.4 Window assembly tests

4.4.1 Prototype testing. Prototype window assemblies shall be tested as specified by the procuring activity. The prototype testing may include testing (transmitted wavefront, etc.) under environmental conditions of vibratory, pressure, or thermal loading. It is recommended that the prototype windows be subjected to the testing specified below, as well as additional thermal testing for both survival and operating performance.

4.4.2 Environmental tests. Unless othewise specified by the procuring activity, two window assemblies out of each lot shall be subjected to the environmental tests specified herein in accordance with MIL-STD-810. A lot shall not exceed 50 window assemblies.

4.4.2.1 High temperature. In accordance with method 501, procedure II, and maximum temperature of 160°F.

4.4.2.2 Altitude. In accordance with method 500, procedure II.

4.4.2.3 Low temperature. In accordance with method 502, procedure I.

4.4.2.4 Temperature shock. In accordance with method 503, procedure I.

4.4.2.5 Humidity. In accordance with method 507, procedure I.

4.4.2.6 Vibration. In accordance with method 514, procedure I, figure 514-1 (curve Z), time table 514-II (schedule II).

4.4.2.7 Rejection. Failure of any glass or window assembly to pass any of the above tests shall be cause for rejection of the lot.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging. Preservation and packaging shall be level A or C as specified. (see 6.2)

5.1.1 Level A. Each unit package shall consist of a single plate of glass, wrapped and cushioned as specified herein.

5.1.1.1 Wrapping. Each plate of glass not protected by adhesive paper shall be initially wrapped in a double thicknes of wrapping tissue conforming to UU-P-553.

5.1.1.2 Cushioning. The glass shall be overwrapped with a 1 inch thickness of cushioning material conforming to PPP-C-843, type III.

5.1.1.3 Bookfolder. The cushioned glass shall be further protected by enclosing it in a one-piece bookfolder made of a minimum 275 pound Mullen test, A or C flute, corrugated material. If the inner flaps do not meet, they shall be not less than 3 inches in length, and the void between the flaps shall be covered by an inserted filler of the same material. The outside flaps shall be sealed by a gummed paper tape at least 2 inches wide conforming to PPP-T-45, or pressure sensitive tape conforming to PPP-T-60. The tape shall extend the full length of the seams, down the sides and at least 2 inches on the opposite side of the container. Projections or irregular surfaces shall be cushioned or padded to provide support and allow for a minimum of movement or friction between the part and the folder.

5.1.2 Level C. Glass shall be packaged in accordance with manufacturer's commercial practice.

5.2 Packing. Packing shall be level A or C as specified.

5.2.1 Level A. When level A is specified in the procuring document (see 6.2), glass packaged as specified in 5.1 shall be overpacked in exterior shipping containers conforming to PPP-B-601 (overseas type) or PPP-B-621. The container shall be lined with a minimum 1 inch thickness of cushioning conforming to PPP-C-1120 on all six faces. In lieu of cushioning material, a minimum 1 inch air space shall be provided around all faces. This shall be accomplished by means of a series of slotted or corner-cut corrugated trays or inverted lids, constructed of a minimum 275 pound Mullen test, A or C flute, corrugated material. Insofar as practical, shipping containers shall contain the same number of unit packages and shall be uniform in size. The gross weight of the fully packed exterior shipping container shall not exceed 100 pounds. Containers shall be closed and reinforced in accordance with the appendix of the applicable container specification.

5.2.2 Level C. When level C is specified in the procurement document (see 6.2), glass packaged as specified in 5.1 shall be overpacked in exterior shipping containers which will assure safe arrival at the point of delivery at the lowest rate. The containers shall conform to Uniform Freight Classification Rules in effect at the time of shipment.

5.3 Marking of shipments. Interior packages and exterior shipping containers shall be marked in accordance with MIL-STD-129. The identification shall be composed of the following information listed in the order shown:

* Stock number or other identification number as specified in the purchase document.

WINDOW, OPTICAL SENSOR
Wedge angle
Type or group
Part number
Size
Specification MIL-W-1366F
- Contract number

*NOTE: The contractor shall enter the Federal Stock Number specified in the purchase document or as furnished by the procuring activity. When the Federal Stock Number is not provided or available from the procuring activity, leave space therefor and enter the stock number or other identification when provided by the procuring activity.

6. NOTES

6.1 Intended use. This glass is intended for use as an optical sensor window in aircraft window assemblies where optical imagery is to be obtained.

6.2 Ordering data. Procurement documents should state the following:

a. Title, number, and date of this specification

b. The size, shape, and thickness of glass required

c. The category, type or group of glass required

d. The usable portion of the glass

e. Packing level required

6.3 Terminology. Words, definitions, terms, and expressions peculiar to the general field of optics as used in this specification are defined in MIL-STD-1241, Optical Terms and Definitions.

6.4 Float glass. The manufacture of float glass has been developed as a replacement for plate glass. If carefully selected, or with moderate rework, float glass may be used for most category 1 window applications.

6.5 Refractive index and glass quality. A specific value of refractive index in the glass is not required. However, the index must be sufficiently uniform throughout the glass to permit compliance with all the tests enumerated herein. Windows in category 1, groups A and M, may require glass of higher optical quality with respect to homogeneity of index than is sometimes available in commercial plate glass, but if plate glass fulfills the test requirements, it is acceptable. Category 2 windows require glass with excellent uniformity of refractive index.

Custodian:
Navy - AS
Air Force - 11

Preparing activity:
Air Force - 11

Project number 9340-0045

Review activity:
Air Force - 84

APPENDIX

10. SCOPE

10.1 Scope. This appendix provides information regarding test apparatus and procedures as well as clarification of terminology used in the specification.

20. REFERENCED DOCUMENTS

20.1 The following documents of the issue in effect on date of invitation for bids or requests for proposal form a part of this standard to the extent specified herein.

MILITARY HANDBOOKS:

MIL-HDBK-722 Glass

(Copies of specifications, standards, drawings and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

30. TEST APPARATUS

30.1 Interferometry

30.1.1 Interferoscope. A suggested schematic diagram of the interferoscope is shown in figure 1. As small a source of light as possible shall be used, and the light source shall be monochromatic such as a mercury-vapor type or a laser. A suggested source for the thicker glass is the Hg-198 lamp of the National Bureau of Standards. The front surface reflecting mirror may be spherical or paraboloidal. If spherical, it should be not faster than f/3.3. The maximum diameter of the mirror determines the maximum possible testing diameter. The glass under inspection may be placed anywhere in the space AB of figure 1. The distance from the apparent source to the beam splitter, plus the distance from the beam splitter to the mirror, is the focal length of the mirror. When inspecting windows of different thickness, the position of the source should be adjusted to accommodate the change in focal position owing to the change in intervening glass thickness.

Interference fringes will be seen at the eyepoint, one for each half wavelength difference in the optical path distance. One fringe, therefore, gives a region of equal optical thickness, and several fringes determine the thickness change in any given region. Fringe differential is defined as the numerical difference in fringes per inch, between the fringe count in a region of maximum number of fringes per inch and another region of minimum number of fringes per inch.

30.1.2 Wedge. In glass having a constant wedge in one direction, the fringes will be straight and evenly spaced. The wedge may be determined using the following expression (for wavelength = 546nm, and index 1.5):

Number of seconds' wedge = 1.5 x number of fringes per inch

30.1.3 Interferometer. Three types of interferometers which may be used for measuring the surface flatness or transmitted wavefront through a window are shown schematically in figures 3 and 4. The interferogram may be analyzed by visual and manual methods or data reduction may be done with a computer. The wavefront error analysis should be presented for the clear aperture of the window.

30.1.4 Analysis of interferogram. A suggested procedure for hand analysis of an interferogram is illustrated in figure 5. First, obtain an interferogram with fringes as straight as possible. Three reference points are then chosen, two on one fringe near one side of the interferogram and a third on a different fringe near the opposite side. A series of straight, parallel reference lines with equal spacing are then drawn on the interferogram, representing the fringes that would be obtained from a perfect tilted wavefront. Deviations of the actual fringes from the lines are then measured at as many points as desired. Contours may be sketched in using the measured points as guides. If S is the separation between the equally spaced lines and Δ is the deviation of a particular fringe point from the nearest line, then the optical path difference (OPD) at that point is Δ/S, expressed in wavelengths.

30.1.5 RMS wavefront error. The root-mean-square (rms) wavefront error is calculated from the square root of the average of the squares of the OPD across the wavefront.

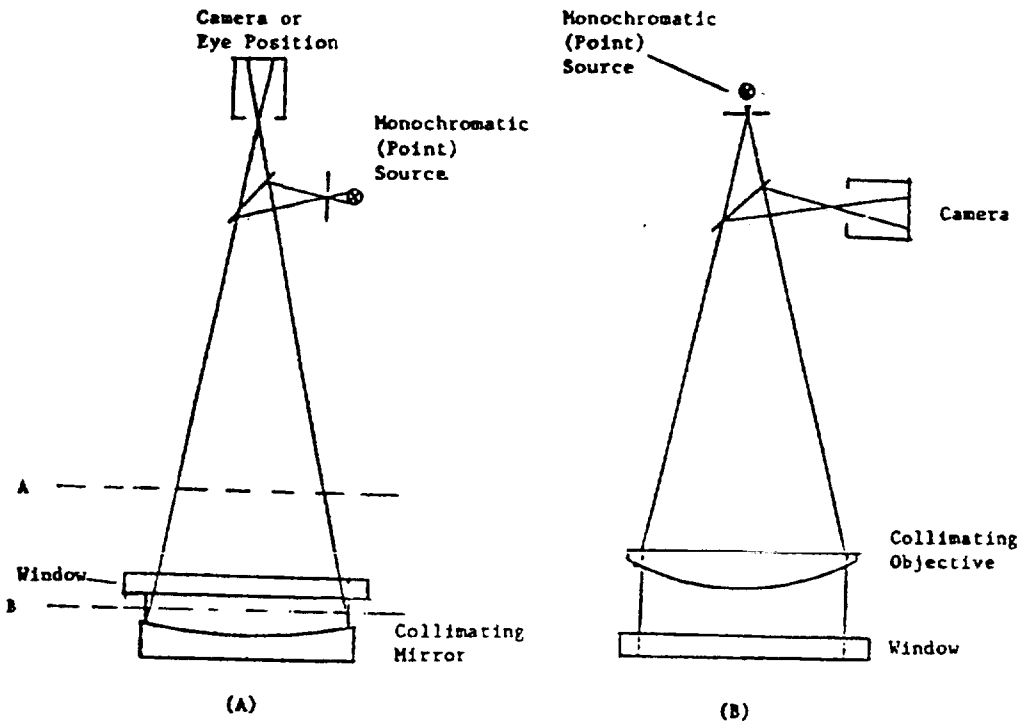


FIGURE 1. Interferoscope Schematic

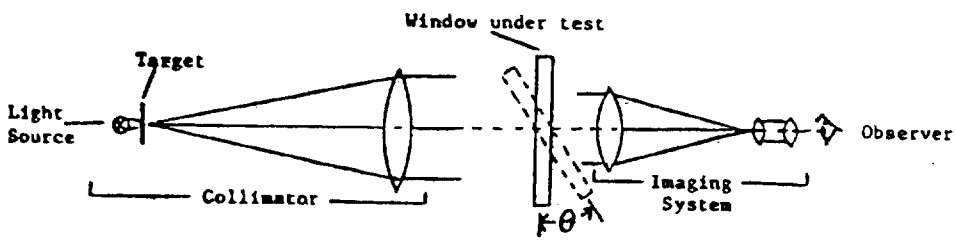


FIGURE 2. Arrangement for
Transmitted Image Test

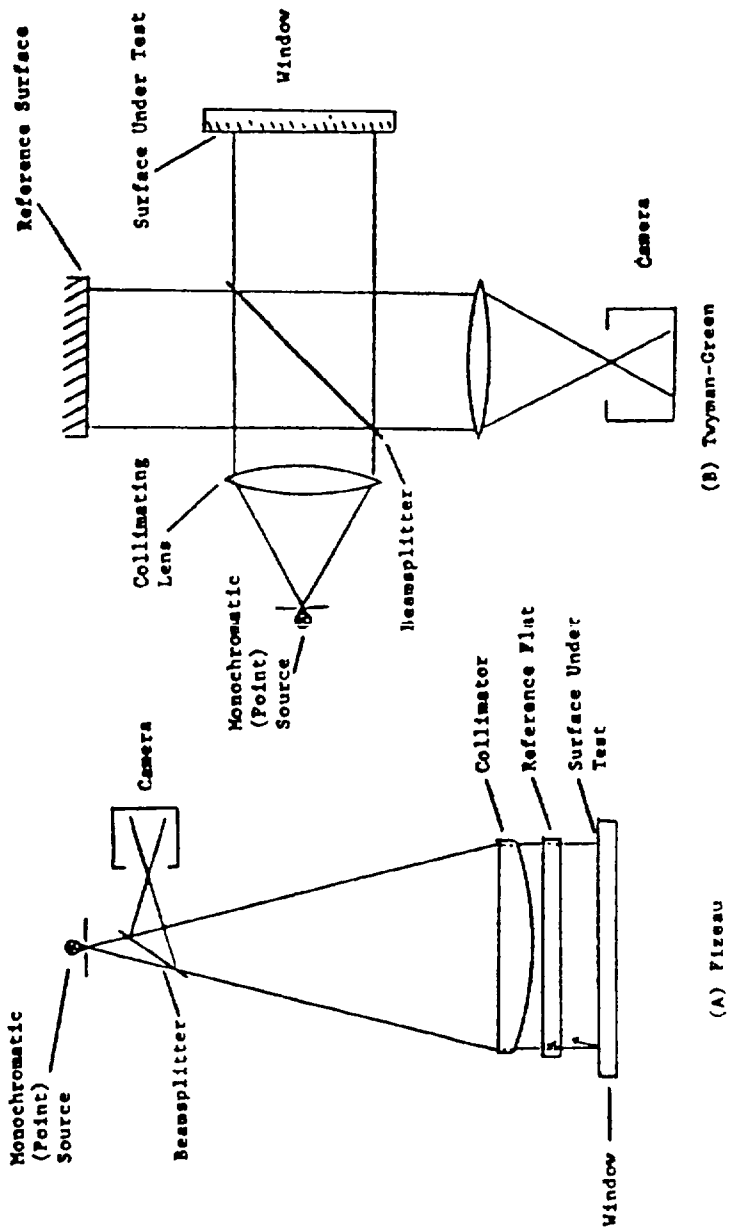


FIGURE 3. Surface interferometers

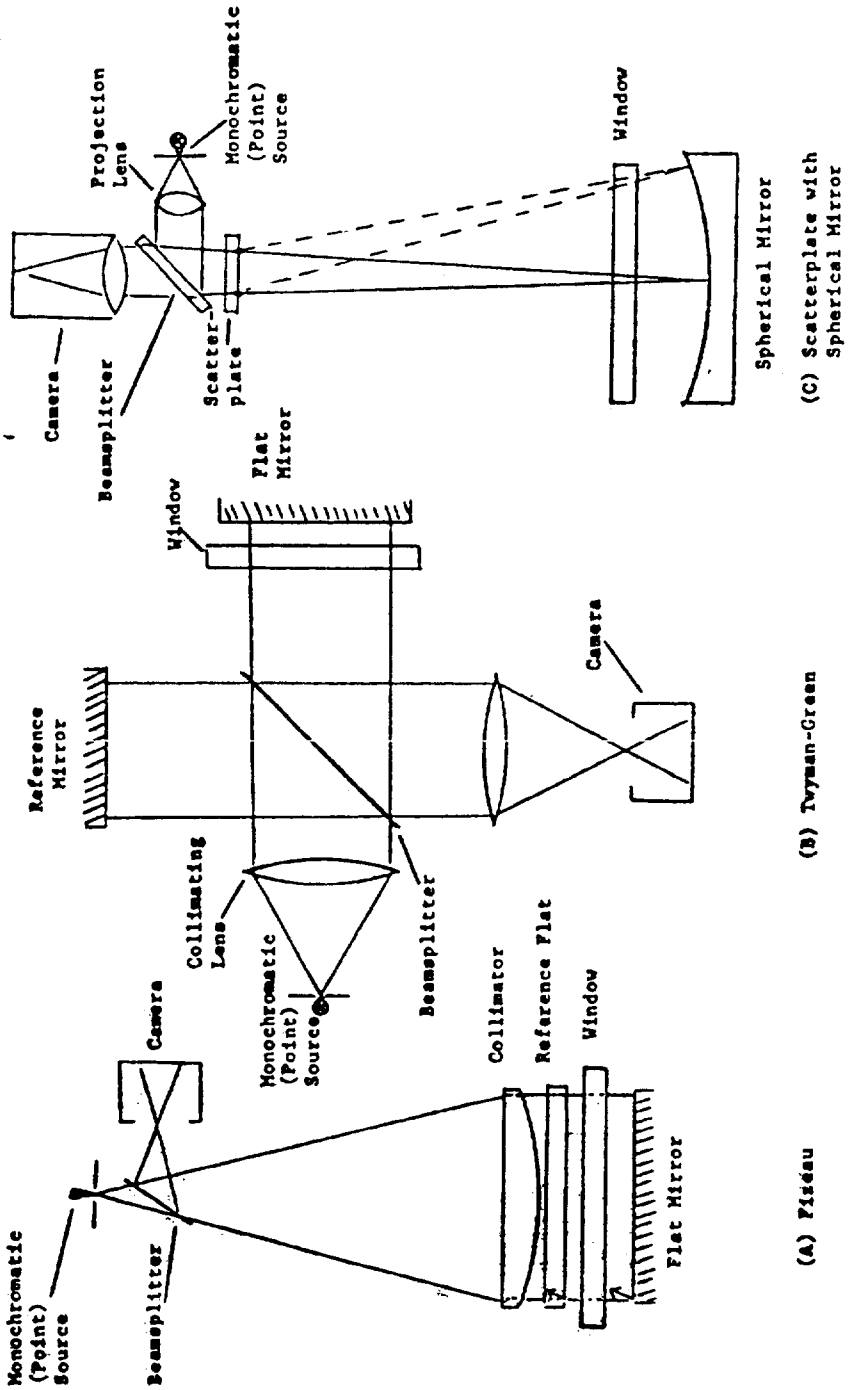
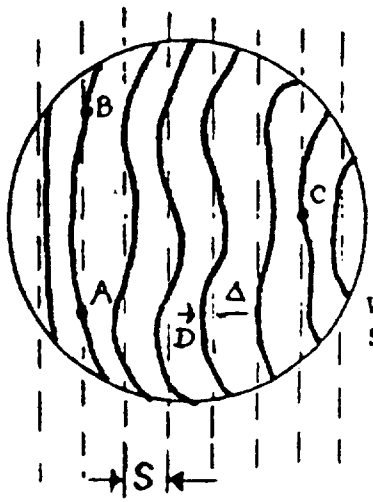


FIGURE 4. Interferometers for Measuring Transmitted Wavefront



Δ/S = wavelengths of OPD at point D

Where
S = 1 wavelength OPD

Figure 5. Hand analysis of an interferogram. Points A, B and C are selected to form a reference surface. Equally spaced lines drawn parallel to AB and through C provide the basis for measuring OPD at any point D.

30.2 Indentation hardness. Indentation hardness tests have been made successfully on glasses, using a pointed diamond indenter. These hardness values are expressed in terms of the load in kilograms divided by the area of the impression in square millimeters. Data obtained by different investigations and techniques are not entirely consistent, but representative values are listed in table VIII, MIL-HDBK-722.

30.3 Stress birefringence. Glass, even after special annealing, may retain small residual strains. Internal stresses or compressive stresses caused by external pressure will influence the density characteristics of the glass with the effect of changing the refractive index. If the stresses acting in two geometrical axes differ, then the refractive indexes in these axes for a light passing through the glass in the third axis will differ. Under such conditions, the glass is said to have become doubly-refracting or birefringent. The birefringence is measured by optical path differences and specified in nm/cm. Normal quality is considered $\leq$10 nm/cm, however, special annealing for optical glass can produce $\leq$4 nm/cm as required for high performance optical systems.

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