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AN AMERICAN NATIONAL STANDARD

ENGINEERING DRAWINGS AND RELATED DOCUMENTATION PRACTICES

OPTICAL PARTS

ASME/ANSI Y14.18M-1986

SPONSORED AND PUBLISHED BY

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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FOREWORD

(This Foreword is not part of ASME/ANSI Y14.18M-1986.)

This Standard establishes drawing and related documentation practices for optical parts in order to provide for uniformity of drawing interpretation. The terms and dimensioning requirements peculiar to lens elements, optical testing, optical materials, etc., used in optical systems require that drawings include delineation, dimensions, notes, and material definition different from that of mechanically machined and formed material.

This Standard utilizes other American National Standards and U.S. Military Standards and Specifications as necessary. The ISO Standard on this subject is in process and is not yet released. Due to substantial differences in symbology and notation between European and American optical drafting practices, no attempt has been made to make the release of this Standard compatible with ISO practice.

This is the first release of ASME/ANSI Y14.18M, Optical Parts. Previously, the Military Standard MIL-STD-34, General Requirements for Preparation of Drawings for Optical Elements and Optical Systems, was the only national standard on optical drawing practice.

The first draft of this Standard was prepared in May 1979. It was an extension of MIL-STD-34 but with a revised format, more detail, and an appendix that addressed some of the differing methods of testing optical performance. This draft was repeatedly revised by the subcommittee, with the final draft going to Y14 Committee vote in August 1981.

Throughout the development of this Standard, the subcommittee grappled with the conflicts between conventional optical drawing practice and American National Standard practices. Theoretically, all of the optical components could be described by standard drafting practice using Y14.5M for tolerance of form, Y14.36 for surface roughness, and the PH3 series for supplementary testing procedures. However, this would have differed from most of the current practices and test procedures, the result being that Y14.18M would simply not have been used by the industry. This Standard is then written to include the most current practice either as a preferred or an alternate method.

The ISO standards under development face similar problems; however, ISO/TC 172, Optics and Optical Instruments, is the subcommittee which is developing an extensive interlocking set of definitions, test procedures, and drawing standards to create a total documentation set. Future revisions of Y14.18M will take advantage of the ISO developments as well as American National Standards developed between this release and the 5 year review.

Suggestions for improvement of this Standard will be welcomed. They should be sent to the Secretary, Y14 Committee, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N. Y. 10017.

This standard was approved by the American National Standards Institute on July 14, 1986.

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Standards for Engineering Drawings and Related Documentation Practices

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ENGINEERING DRAWINGS AND RELATED DOCUMENTATION PRACTICES

OPTICAL PARTS

1 GENERAL

1.1 Scope

This Standard establishes practices for pictorial representation and specification definitions on drawings for optical parts.

1.2 Application

Because of the unique nature of optical components and their manufacturing techniques, standard drawing practices do not always apply. In the event of a conflict with such standards, the requirements stated in this document shall take precedence.

1.3 Applicable Documents

1.3.1 References in Text

When the following American National Standards referred to in this Standard are superseded by a revision approved by the American National Standards Institute, Inc., the revision shall apply.

American National Standards

ANSI PH3.617-1980, Definitions, Methods of Testing, and Specifications for Appearance Imperfections of Optical Elements and Assemblies

ANSI Y14.1-1980, Drawing Sheet Size and Format

ANSI Y14.2M-1979, Line Conventions and Lettering

ANSI Y14.5M-1982, Engineering Drawing and Related Documentation Practices, Dimensioning and Tolerancing

ANSI Y14.36-1978, Engineering Drawing and Related Documentation Practices, Surface Texture Symbols

U. S. Military Standards and Specifications

MIL-STD-1241, Optical Terms and Definitions

MIL-G-174, Optical Glass

1.3.2 Other Applicable References. Appendix A provides a list of additional references related to optical parts.

1.4 Measurement and Production Methods

This Standard does not define measurement or production methods for producing optical parts. When special processing is necessary to meet design requirements, this is specified in an advisory note on the drawing. Such notes are used in some figures for example only.

1.5 Units

The International System of Units (SI) is featured in this Standard. It should be understood that U. S. customary units could equally have been used without prejudice to the principles established.

1.6 Definitions

Unless otherwise specified, definitions for terminology used in this standard are in accordance with MIL-STD-1241.

1.7 Advisory Notes

An advisory note is reference information.

2 PICTORIAL REPRESENTATION

2.1 Introduction

The mechanical view of an optical element typically follows standard drawing practice except as noted below. Individual optical elements shall be presented in the orientation that they maintain in their optical system drawing (see para. 2.8.3).

2.2 Single Lens Elements

2.2.1 Views. A single lens is depicted by a single sectional view (see Fig. 1). Hidden lines (backedges) are omitted. Glass hatching in accordance with ANSI Y14.2M is optional. Lenses of unusual configuration are depicted using as many views as are required.

2.2.2 Dimensions. Sufficient dimensions and associated tolerances shall be given in accordance with ANSI Y14.5M to physically describe the item with respect to perimeter and thickness. Surface radii should be labeled and the information tabulated.

2.2.3 Surface Information. All surface information shall be given either specifically or by default to title block information (see ANSI Y14.1). The surfaces shall be labeled and the information tabulated.

2.3 Prisms

2.3.1 Views. As many views as required to depict the necessary details shall be used to represent a prism. A sample prism drawing is shown in Fig. 2.

2.3.2 Dimensions. Sufficient dimensions and associated tolerances shall be given in accordance with ANSI Y14.5M to describe the shape and volume of the prism. Additional tolerancing is discussed in Section 3.

2.3.3 Surface Information. All surface information shall be given either specifically or by default to title block information (see ANSI Y14.1). The surfaces shall be labeled and the information tabulated.

2.4 Cemented Elements

2.4.1 Views. Two or more elements cemented together shall be shown as a detailed assembly. A sample drawing is shown in Fig. 3.

2.4.2 Dimensions. Sufficient dimensions and associated tolerances, as required to control the finished assembly, shall be used. Unless otherwise specified, the assembled elements shall meet their individual element tolerances.

2.5 Plano-Plano Elements

2.5.1 General. This type of element, a special case of para. 2.2, may be a window, filter, reticle, or other element depending upon its specification.

2.5.2 Wedges. The wedge shall be drawn with its maximum thickness given, and the optical deviation of the wedge given and toleranced at a specified wavelength of light. The mechanical angle of the wedge may be given alternatively, but the drawing should clearly differentiate between the two. A sample wedge drawing is shown in Fig. 4.

2.5.3 Reticles. Reticle markings shall be shown in the drawing and shall be fully portrayed and dimensioned. It is usually necessary to specify certain processes such as etching for manufacturing control of the item. A sample reticle drawing is shown in Fig. 5.

2.5.4 Windows and Filters. These items are drawn similarly to para. 2.2 and differ primarily in the types of coatings used as noted in para. 6.5. A sample filter drawing is shown in Fig. 6.

2.5.5 Flat Mirrors. These items are drawn similarly to para. 2.2 and differ from the above primarily in the materials and coatings used.

2.6 Aspheric Elements

2.6.1 General. This type of element, a special case of para. 2.2, has one or more nonspherical surfaces.

2.6.2 Dimensions. Aspheric optical surfaces shall be dimensioned by indicating the equation of the curve of the surface, as a defined deviation from a spherical surface, or as a tabulation of surface coordinates. Tolerances shall be specified and the axis of the aspheric contour clearly defined.

2.7 Precision Machined Optics

2.7.1 General. This type of element is directly machined and is quite often an aspheric element.

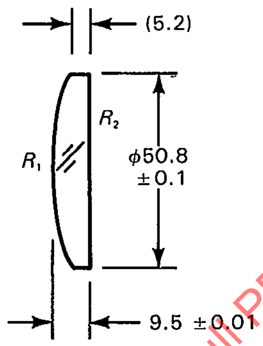
2.7.2 Dimensions. Precision machined optical surfaces shall be dimensioned by basic contour as noted in para. 2.6.2, by irregularity as noted in para. 3.4.3, and by surface roughness as noted in para. 3.6.2.

2.8 Systems and Assemblies

2.8.1 Optical System Drawing. The optical system drawing shall fully describe the system from a mathematical point of view. All spacings, materials, and other information necessary for evaluation of the system shall either be contained on the drawing or referenced on the drawing. A sample system drawing is shown in Fig. 7.

2.8.2 Assembly Drawing. Optical assemblies shall be drawn to conventional drawing practice.

2.8.3 Orientation. Optical system and assembly drawings should be oriented so that the source of illumination comes from the left side of the drawing. An alternate orientation for lens assemblies is that the long conjugate is on the left side of the drawing.



GENERAL NOTES:

(a) Dimensions in mm.

(b) All edges shall have a protective chamfer 0.5 maximum face width.

(c) Edge chips shall not exceed 10% of the total perimeter or be larger than 0.5 maximum width.

(d) Both surfaces shall have surface quality 80–50, per MIL-O-13830.

(e) Testing wavelength = 633 nm.

(f) Grind unspecified surfaces using 330 grit.

(g) Material shall be:

Type	Ohara SF2 optical grade flint glass
η_d	(1.648)
ν_d	(33.8)
η_{633}	1.644 ±0.001
Homogeneity	Grade A20 ($\Delta n \pm 20 \times 10^{-6}$)
Birefringence	10 nm/cm
Grade	A (no visible striae)

(h) Polish indicated surfaces as:

Surface	R_1	R_2
Clear aperture	48	46
Radius	76.9 cx	∞
Tolerance	±0.4 mm	±14 fr
Irregularity	2 fr pv	2 fr pv

(i) Centering error 0 deg. 2 min deviation referenced to R_2.

(j) Coat polished surfaces over clear aperture for minimum reflectance, 0.5% maximum, 450–650 nm, 0 deg. angle of incidence, 30 deg. total cone, to withstand eraser test of MIL-C-675.

FIG. 1 SINGLE LENS ELEMENT

GENERAL NOTES:

(a) Dimensions in mm.

(b) All edges shall have a protective chamfer 0.5 maximum face width unless otherwise specified.

(c) Appearance imperfections per ANSI PH3.617 shall be:

L	3 × 80 × 10
R	5 × 80
E	10 × 1
A	N

(d) Testing wavelength = 633 nm.

(e) Grind unspecified surfaces using 330 grit.

(f) Material shall be optical quality fused silica, birefringence less than 10 nm/cm, no internal defects greater than 0.05.

(g) Pyramid error less than 0 deg. 5 min with respect to 90 deg. edge.

(h) Coat all polished surfaces for minimum reflectance 0.5%, 450–650 nm, 0 deg. angle of incidence, to withstand eraser test of MIL-C-675.

NOTES:

(1) Two 45 deg. angles shall be equal within 0 deg. 5 min.

(2) Polish indicated surfaces as:

Surface	R_1	R_2	R_3
Clear aper diam.	10	10 × 15	10
Radius	∞	∞	∞
Tolerance	±12 fr	±6 fr	±12 fr
Irregularity	2 fr pv	1 fr pv	2 fr pv

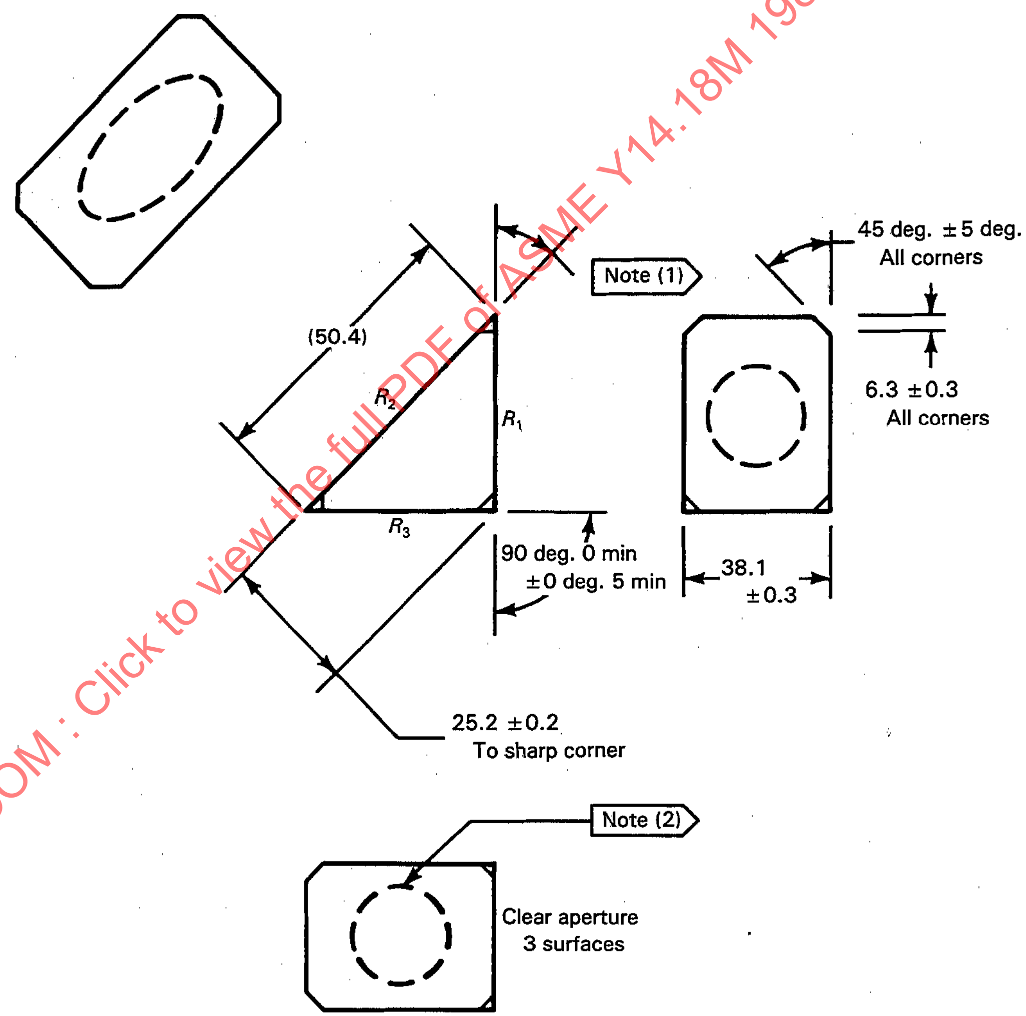
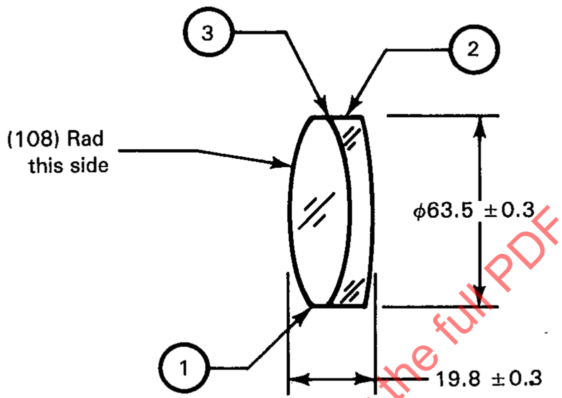


FIG. 2 PRISM ELEMENT

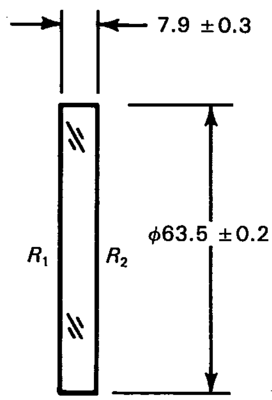


3	AR	Optical cement	AAAA-BBBB
2	1	Element no. 2	XXXX-YYYY
1	1	Element no. 1	XXXX-ZZZZ
Item	Qty.	Description	Part Number

Parts List

GENERAL NOTES:
(a) Dimensions in mm.
(b) Centering error 0 deg. 1 min deviation with ray normal to element no. 1 in white light.
(c) Bond elements together using optical cement per specification CCCC.
(d) Assembly shall exhibit less than 0.01 diameter blur circle at best focus in collimated white light.
(e) Advisory note: elements may be rotated and fixtured to control centering wedge.

FIG. 3 CEMENTED ELEMENT



GENERAL NOTES:

(a) Dimensions in mm.

(b) All edges shall have a protective chamfer 0.5 maximum face width unless otherwise specified.

(c) Appearance imperfections per ANSI PH3.617 shall be:

L	3 × 80 × 10
R	5 × 80
E	10 × 2
A	N

(d) Testing wavelength = 633 nm.

(e) Grind unspecified surfaces using 330 grit.

(f) Material shall be optical grade crown glass with:

η_{633}	1.52 ±0.02
Homogeneity	±20 × 10^{-6}
Grade	B (light striae)
Birefringence	10 nm/cm

(g) Polish indicated surfaces as:

Surface	R_1	R_2
Clear aper	25	25
Mount aper	30	30
Radius	∞	∞
Tolerance	±12 fr	±12 fr
Irregularity	1 fr pv	1 fr pv

(h) Coat polished surfaces for minimum reflectance, 0.3% maximum, 633 nm, 0 deg. angle of incidence, to withstand normal cleaning with cheesecloth.

(i) Optical deviation of wedge shall be 0 deg. 15 min ±0 deg. 1 min at 633 nm, with incident ray normal to R_1.

(j) Advisory note: mechanical wedge angle is 0 deg. 29 min ref.

FIG. 4 WEDGE ELEMENT

GENERAL NOTES:

(a) Dimensions in mm.

(b) All edges shall have a protective chamfer 0.5 maximum face width unless otherwise specified.

(c) Appearance imperfections per ANSI PH3.617 shall be:

L	3.6 2 × 11 × 2	+	3 × MC × 10		
R	3.6 1 × 1	+	10 × 50		
E	10 × 1				
A	3.6 N	+	G–M	S–M	O–M

(d) Testing wavelength = 633 nm.

(e) Grind unspecified surfaces using 330 grit.

(f) Material shall be optical quality crown glass, birefringence less than 6 nm/cm, selected to meet the requirements of (c) above.

(g) Polish indicated surfaces as:

Surface	R_1	R_2
Clear aper diam.	3.6	3.6
Mount aper diam.	20	20
Radius	∞	∞
Tolerance	±12 fr	±12 fr
Irregularity	2 fr pv	2 fr pv

(h) Optical deviation to be less than 0 deg. 5 min.

(i) Coat polished surfaces for minimum reflectance per MIL-C-675.

(j) Pattern to be vacuum deposited inconel.

(k) Reticle tolerance ±0.005 non cuml.

NOTES:

(1) Outer cross to be centered on element within 0.05.

(2) 27 places, 13 each side of the center line, horizontal and vertical.

(3) Inner cross to be central to outer cross within 0.01.

(4) Line width 0.025.

(5) Line width 0.015.

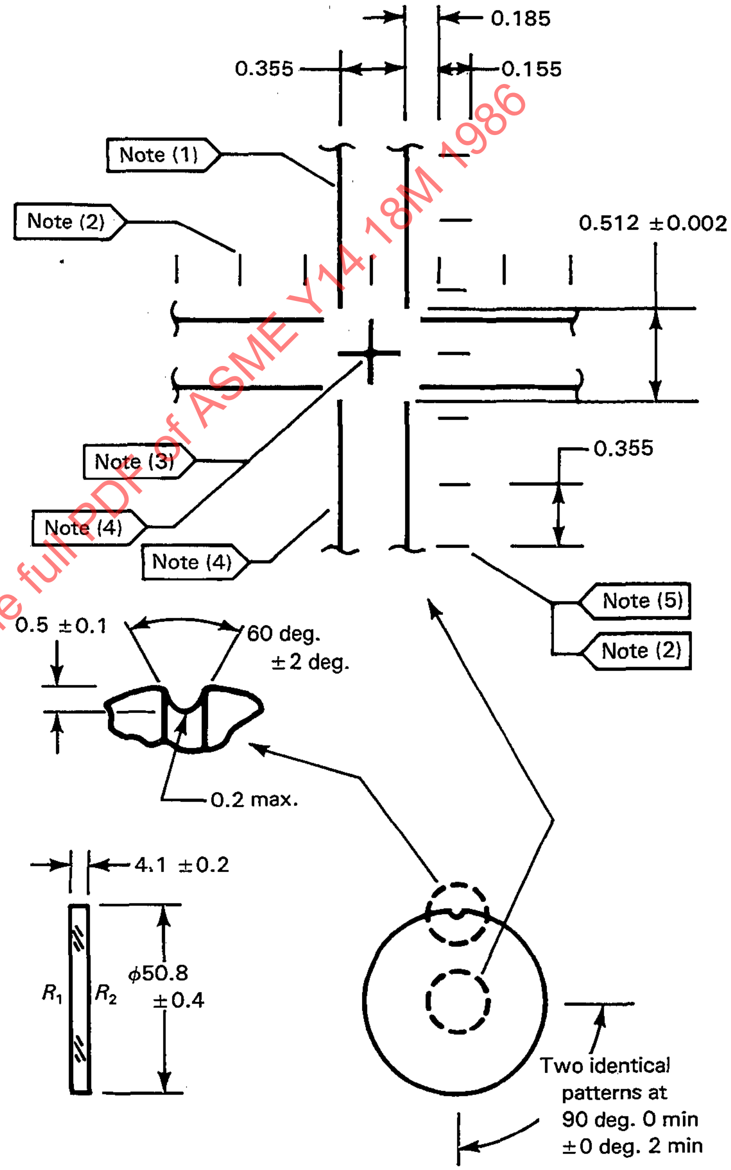
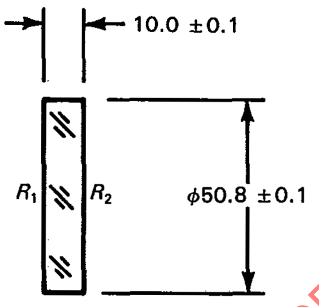


FIG. 5 RETICLE ELEMENT



GENERAL NOTES:
(a) Dimensions in mm.
(b) All edges shall have a protective chamfer 0.5 maximum face width unless otherwise specified.
(c) Edge chips shall not exceed 10% of the total perimeter or be larger than 1.0 maximum width.
(d) Both surfaces shall have surface quality of 80–50 per MIL-O-13830.
(e) Testing wavelength ≈ 633 nm.
(f) Grind unspecified surfaces using 330 grit.
(g) Material shall be optical quality crown glass, birefringence less than 10 nm/cm, homogeneity $\pm 20 \times 10^{-6}$, no visible striae.
(h) Polish indicated surfaces as:

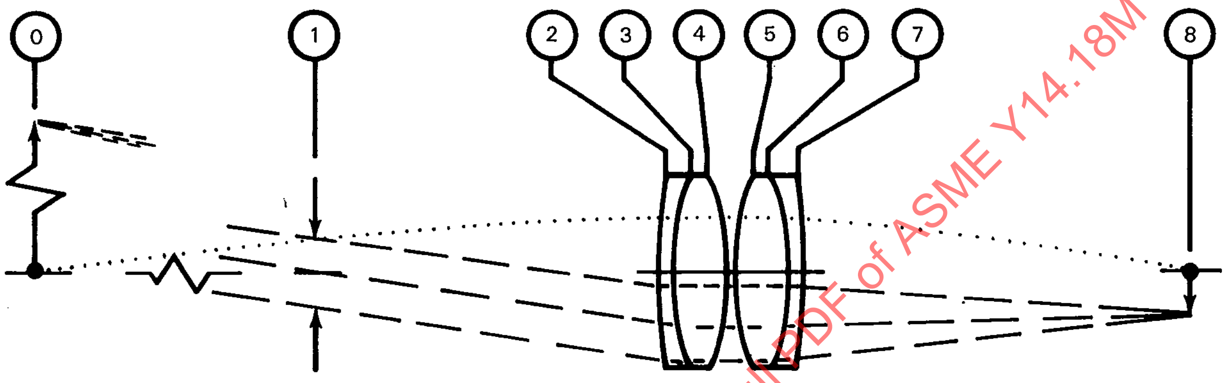
Surface	R_1	R_2
Clear aper diam.	20	20
Radius	∞	∞

(i) Angular deviation to be less than 0 deg. 5 min.
(j) Coat R_1 to yield a finished piece as:

Wavelength (nm)	*Min. Trans*	*Max. Trans*
350 – 395	. . .	0.1%
400 – 420	1.0%	15.0%
425 – 460	45.0%	50.0%
465 – 520	. . .	1.0%
520 – 1000	. . .	0.1%

(k) Coat R_2 for minimum reflectance per MIL-C-675.
(l) Transmitted wavefront to be 4 fr pv irregularity.

FIG. 6 FILTER ELEMENT



Surf. No.	Rad of Curv.	Properties to Next Surface: Spacing	η_d	ν_d	Glass	Remarks
0	∞	266.70	1.000	. . .	. . .	Object ϕ77.6
1	∞	35.01	1.000	. . .	. . .	Stop ϕ8
2	69.84	1.27	1.648	33.8	SF12	
3	28.32	3.81	1.517	64.2	BK7	
4	−55.20	3.66	1.000	. . .	. . .	Adjusted to meet system performance
5	55.20	3.81	1.517	64.2	BK7	
6	−28.32	1.27	1.648	33.8	SF12	
7	−69.84	37.53	1.000	. . .	. . .	
8	∞	. . .	. . .	. . .	. . .	Image ϕ10.8

GENERAL NOTES:
(a) Dimensions in mm.
(b) Magnification: 0.139
(c) Clear aperture of lenses ϕ16.5
(d) System to resolve 4.2 lpm in the object plane (surface 0) in white light at an object to image distance of 353.06 ±0.25.

FIG. 7 OPTICAL SYSTEM DRAWING

3 OPTICAL–MECHANICAL TOLERANCING

3.1 Introduction

Specific methods of tolerancing and workmanship are inherent in optical manufacturing. This section lists and describes those items; however, it lists them for illustration and not as a design guide.

3.2 Apertures

3.2.1 Clear Aperture. The clear aperture is the portion of element surface filled with the image forming beam.

3.2.2 Mount Aperture. The mount aperture is the mechanically toleranced portion of the element surface. If not otherwise stated, the mount aperture is the same as the clear aperture.

3.2.3 Coating Aperture. As elements may have to be supported by their edges in a vacuum chamber when being coated (see para. 6.1), the coating aperture needs to be specified. If not otherwise stated, the coating aperture is the same as the mount aperture.

3.2.4 Surface Sags. When desired, the sagitta depth (SAG) from a surface may be dimensioned. Surface sags shall be dimensioned as a reference dimension unless a control tolerance is required.

3.3 Edges

3.3.1 Protective Chamfer. In order to reduce chipping and to eliminate unnecessarily sharp edges, all edges with an included angle less than some value (typically 135 deg.) usually have a small chamfer (typically 0.5 maximum face width at approximate symmetry). A default condition is often applied as a standard drawing note as shown in Fig. 1. The interpretation of the chamfer dimensions is per Fig. 8.

3.3.2 Roof Edges. When the application requires it, an edge or edges may be left sharp, i.e., with no protective chamfer. This shall be called out in the field of the drawing with a maximum chamfer tolerance.

3.3.3 Design Chamfers. All chamfers applied for a design purpose shall be called out on the field of the drawing as noted in Fig. 2.

3.3.4 Edge Chips. Glass elements can chip at the edges with handling. The size and distribution of chips shall be specified, typically by a default condition as noted in Fig. 1.

3.3.5 Edge Thickness. Edge thickness shall be dimensioned as a reference dimension unless a control tolerance is required.

3.4 Spherical Radius Surface

3.4.1 Surface Curvature Tolerance (Mechanical). Each spherical radius shall be given a tolerance reflecting the limits, but not the geometric form, of the surface. This tolerance shall be given in the same units as the radius, except for plano surfaces which are treated in para. 3.4.2. The radius shall be specified concave or convex.

3.4.2 Surface Curvature Tolerance (Power). Plano surfaces shall be toleranced as the difference in sagitta between a perfect surface and the spherical surface of the smallest radius allowable. The measurement shall be given in the number of fringes of light at a specified wavelength. The fringe spacing shall correspond to a sagitta difference of one-half of the wavelength of the light per fringe. Plano–plano elements may have their individual surfaces exempted from this tolerance when the element is toleranced per para. 4.3.

3.4.3 Irregularity Tolerance. The nonspherical deviation of a surface from its specified shape shall be given in the number of fringes of light at a specified wavelength. The fringe spacing shall correspond to a sagitta difference of one-half of the wavelength of the light per fringe. The error is preferably given as an absolute limit (peak-to-valley — PV), but may be specified as an average error (RMS) or as a gradient error (wavelengths/cm).

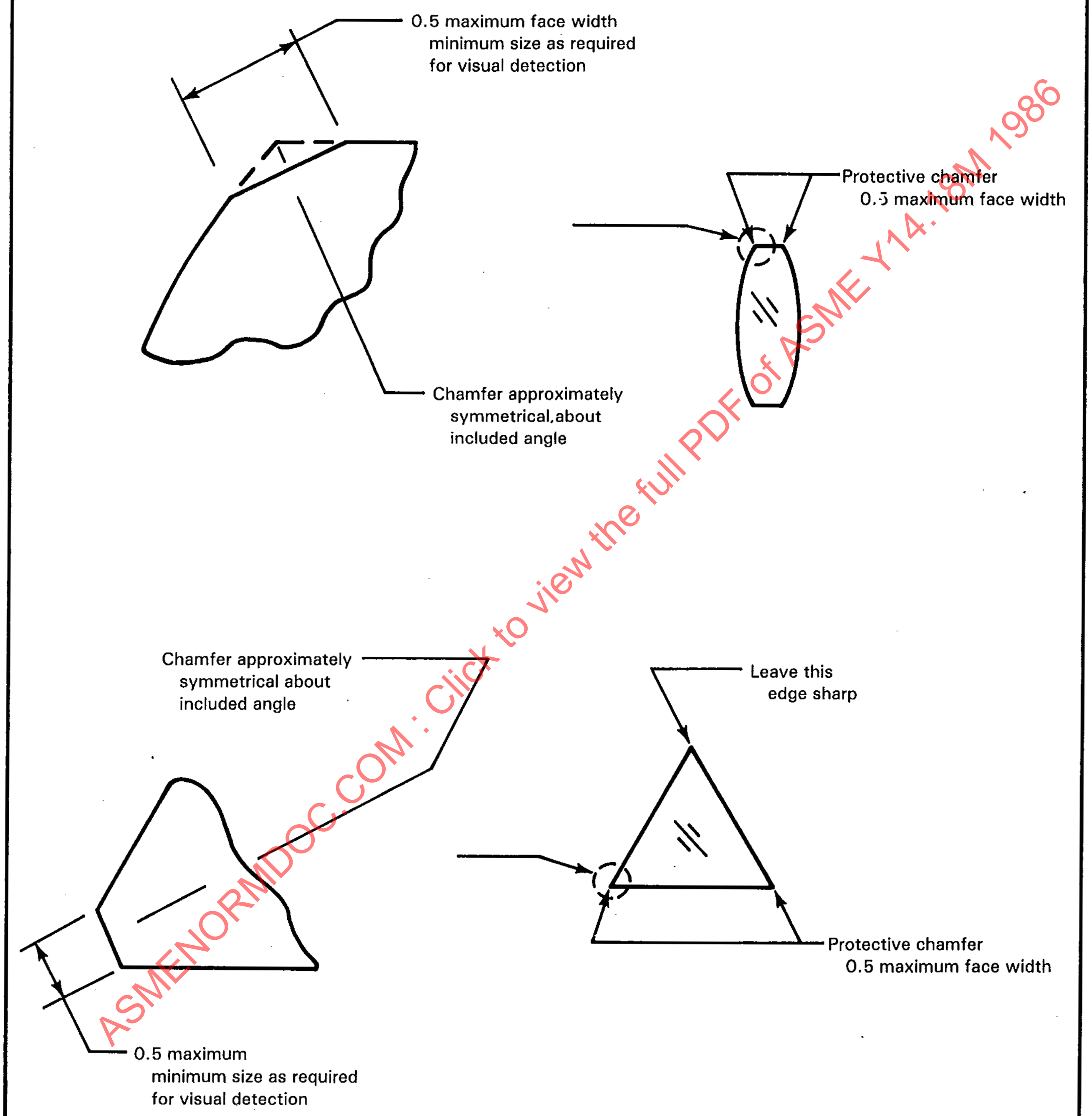


FIG. 8 CHAMFER DESCRIPTION

3.5 Wedge Tolerances

3.5.1 Lens Centering. The centering of a lens refers to the alignment between the mechanical lens diameter and the optical axis of the lens, which is the line between the centers of curvature of the surface radii for spherical surfaces. This is preferably toleranced as the angular deviation of a ray along the mechanical axis of the element, although it may be toleranced otherwise if clearly specified on the drawing. The centering should be specified relative to a particular side and diameter of the element rather than just to the diameter alone. Equivalent methods of callout are noted in Appendix B.

3.5.2 Prism Pyramidal Error. Pyramid error exists in a prism when the line of intersection between any two adjacent surfaces is not parallel to the plane of a third face. Pyramid error is preferably toleranced as a mechanical angle, although it may be toleranced otherwise if clearly specified on the print.

3.5.3 Cemented Elements. The wedge tolerance on cemented elements shall be given in units per para. 3.5.1. If the assembly tolerance is less than that obtained by random assembly of the elements, an advisory note on the assembly process (e.g., orient elements, fixture elements, edge after assembly) to control wedge shall be placed on the field of the drawing.

3.5.4 Plano–Plano Elements. The wedge tolerance shall be given per para. 3.5.1.

3.5.5 Wedges. The wedge tolerance shall be given in the same units as the wedge itself.

3.6 Surface Imperfections

3.6.1 Appearance Imperfections. The tabulation for each surface shall indicate size and extent of surface blemishes, scratches, and other imperfections as applicable. Unless otherwise specified, the appearance imperfections shall refer to ANSI PH3.617.

3.6.2 Surface Roughness. The tabulation for each surface shall indicate RMS or other description of surface roughness where applicable. This type of tolerance typically applies only to directly machined optical surfaces (e.g., diamond turned elements) and shall use the notation of ANSI Y14.36, as applicable.

3.7 Testing Wavelength

3.7.1 Single Wavelength Testing. Dimensions and tolerances affected by wavelength (paras. 2.5.2, 3.4.2, 3.4.3, and 3.5.1) shall have the testing wavelength specified when monochromatic light is to be used.

3.7.2 Spectrum Testing. Dimensions and tolerances affected by wavelength (paras. 3.4.2, 3.4.3, and 3.5.1) shall have the testing spectrum (wavelengths and relative intensities) specified. White light refers to the spectrum of light corresponding to human vision.

4 ELEMENT AND SYSTEM TOLERANCES

4.1 Introduction

Elements, assemblies, and systems are referred to interchangeably in the following.

4.2 Focal Lengths

The following focal lengths may be specified where applicable:

(a) effective focal length (EFL)
(b) back focal length (BFL)
(c) front focal length (FFL)

4.3 Wavefront Tolerance

The transmitted or reflected wavefront of an element may be given where applicable. If given, the wavefront may be specified with both a power and irregularity tolerance as noted in para. 3.4, or its power equivalent per Appendix C.

4.4 Aberration Tolerance

The element or system drawing may specify an aberration tolerance (spherical aberration, chromatic aberration, etc.) where applicable. The test conditions for any aberration tolerance shall be specified and may include the method (i.e., process) of testing.

4.5 Modulation Transfer Function (MTF) Tolerance

The element or system drawing may specify a tolerable minimum MTF or tolerable target/image contrast degradation at one or more spatial frequencies and one or more wavelengths as applicable.

4.6 Visual Resolution

Performance may be specified in terms of visual resolution through the element or system as applicable.

5 MATERIAL AND TOLERANCING

5.1 Optical Glass

The material shall be called out by either a specification or description (generic or trade name) as applicable.

5.1.1 Type. The specification or description (generic or trade name) of the glass.

5.1.2 Index of Refraction. The index of refraction at a specified wavelength shall be given. The index of refraction shall be toleranced as applicable. Unless otherwise specified, the index of refraction shall refer to a wavelength of 587.6 nm (Helium d line); however, care should be taken to note whether the drawing refers to 589.3 nm (center of Sodium D lines) or some other wavelength.

5.1.3 Dispersion. The variation of index of refraction with wavelength (dispersion) of the material over some spectrum of wavelengths may be given and toleranced as applicable. Unless otherwise specified, the dispersion shall refer to the Abbe V-number.

$$\nu_d = (\eta_d - 1)/(\eta_F - \eta_C)$$

5.1.4 Quality. The quality of glass refers to the allowable material defects or inclusions present in the material. This may be specified by the amount of defects seen or measured in transmission. These defects include striae.

5.1.5 Homogeneity. Variation of the index of refraction within an element is called optical homogeneity and is typically toleranced as a plus and minus variation of the index, although some glass manufacturers use total variation.

5.1.6 Birefringence. An optical element, even though annealed, retains small residual strains. This is observed as optical birefringence and is toleranced in optical path difference per thickness with the units of nm/cm.

5.1.7 Striae. Striae are threadlike veins seen in the glass which are caused by abrupt variations in the index of refraction. Striae grades shall refer to MIL-G-174, unless otherwise specified. Other uses of the term *grade* refer to manufacturer's classification of quality and homogeneity.

5.1.8 Bubbles and Inclusions. The size, number, and distribution of bubbles and inclusions is usually specified by a bubble group classification of a manufacturer or standard. Often this is specified by default in the glass quality given per para. 5.1.4. Alternatively, the bubbles and inclusions may be specified per ANSI PH3.617.

5.1.9 Other Properties. Additional required properties may be specified and toleranced as applicable.

5.2 Absorption Filters

Absorption filters shall be specified for their internal or external transmission as a function of wavelength and thickness. Trade names or generic descriptions may also be used. Other optical materials requirements may be specified per para. 5.1, as required.

5.3 Metals

Materials shall be called out by either a specification, generic or chemical, or trade name description, as applicable.

5.4 Plastics

Materials shall be called out in a manner similar to that in para. 5.1.

6 COATINGS

6.1 Introduction

Optical components often have vacuum coatings on the order of a wavelength of light in thickness deposited on their surface to act as an anti-reflection, mirror, or beamsplitter coating.

6.2 Coating Aperture

See para. 3.2.3.

6.3 Common Specifications

6.3.1 Angle of Incidence. The angle of incidence of the incoming rays of light shall be given in degrees relative to the normal to the surface.

6.3.2 Cone of Incidence. The total included angle of the incoming rays symmetrical about the angle of incidence shall be given. If none is given, collimated light shall be assumed.

6.3.3 Spectrum. The spectrum and polarization of wavelengths over which the coating is to operate shall be specified.

6.3.4 Durability and Environment. The durability and environmental requirements of the coating shall be specified.

6.3.5 Element Material. The type of material being coated shall be specified.

6.4 Anti-Reflection Coating

This coating reduces the amount of light reflected from a surface by matching the indices of refraction at the interface. The reflection at each surface in percent shall be given and toleranced. A tabulation of reflectance versus wavelength may be used.

6.5 Filter Coating

This coating transmits a particular spectrum of wavelengths at a specified transmittance. The transmitted light in percent shall be specified and toleranced. A tabulation of transmittance versus wavelength may be used.

6.6 Mirror Coating

This coating reflects a particular spectrum of wavelengths. The reflectance in percent shall be given and toleranced. A tabulation of reflectance versus wavelength may be used.

6.7 Beamsplitter Coating

This coating transmits a percentage and reflects a percentage of a particular spectrum of wavelengths. The coating shall be specified for the transmitted and reflected portions in percent. In addition, the polarization of the incident light shall be specified as applicable.

APPENDIX A
REFERENCES

(This Appendix is not part of ASME/ANSI Y14.18M-1986, and is included for information purposes only.)

American National Standards

ANSI PH 3.13	Focal Length Marking of Lenses
ANSI PH 3.16	Method for Determining Resolving Power of Lenses for Projectors for 35 mm Filmstrips and Slides in 2 × 2-Inch Mounts
ANSI PH 3.17	Specification for Photographic Optical Filter Sizes
ANSI PH 3.22	Method of Determining the Distribution of Illuminance Over the Field of a Photographic Objective
ANSI PH 3.29	Methods for Designating and Measuring Apertures and Related Quantities Pertaining to Photographic Objectives and Projection Lenses
ANSI PH 3.35	Methods of Designating and Measuring Focal Lengths and Focal Distances of Photographic Lenses
ANSI PH 3.63	Method for Determining the Photographic Resolving Power of Photographic Lenses
ANSI PH 3.604	Test Methods for the Selective Transmission of Photographic Lenses
ANSI PH 3.609	Dimensions for Resolution Test Target for Photographic Optics
ANSI PH 3.57	Guide to Optical Transfer Function Measurement and Reporting
ANSI PH 3.74	Method of Testing Image Distortion of Photographic Lenses
ANSI PH 3.615	Method for Testing Veiling Glare of Still-Picture Camera Objectives
Available from	American National Standards Institute 1430 Broadway New York, NY 10018

American Society for Testing and Materials

C 162-71	Standard Definitions of Terms Relating to Glass and Glass Products
F 529-77T	Interpretation of Interferograms of Nominally Plane Wavefronts
F 532-77T	Width of Defects in Optical Surfaces
STP-666	Optical Interferograms — Reduction and Interpretation
Available from	American Society for Testing and Materials 1916 Race Street Philadelphia, PA 19103

German Industry Norms

DIN 3140 (October 1958)	Optical Components, Particulars of Drawings, Illustration, Materials, Surfaces
DIN 3140, Sheet 2	Optical Components, Blisters
DIN 3140, Sheet 5	Optical Components, Form Errors
DIN 3140, Sheet 7	Optical Components, Surface Imperfections
Available from	American National Standards Institute 1430 Broadway New York, NY 10018

U. S. Federal Specifications

MMM-A-131	Glass to Metal Adhesives
Available from	Naval Publications and Forms Center 5801 Tabor Avenue Philadelphia, PA 19120

U. S. Military Specifications, Standards, and Handbooks

MIL-HDBK-25	Glossary of Photographic Terms Including Document Reproduction
MIL-HDBK-141	Optical Design
MIL-STD-34	General Requirements for Preparation of Drawings for Optical Elements and Optical Systems
MIL-STD-150	Photographic Lenses
MIL-A-3920	Thermosetting Optical Adhesive
MIL-A-48611	Adhesive System, Epoxy, Elastomeric, Glass to Metal
MIL-B-48612	Bonding With Epoxy, Elastomeric, Adhesive System, Glass to Metal
MIL-C-675	Coating of Glass Optical Elements (Anti-Reflection)
MIL-C-14806	Reflection Reducing Coating for Instrument Cover Glasses and Lighting Wedges
MIL-C-48497	Durability Requirements for Single or Multilayer Interference Coatings
MIL-F-48616	General Specification for Infrared Interference Filter Coatings
MIL-G-1366	Aerial Photographic Window Glass
MIL-M-13508	Front Surface Aluminized Mirror Coating Process for Optical Elements
MIL-O-13830	General Specification Governing the Manufacture, Assembly, and Inspection of Optical Components for Fire Control Instruments
MIL-O-16898	Packaging of Optical Elements
MIL-W-1366	Optical Sensor Window
Available from	Naval Publications and Forms Center 5801 Tabor Avenue Philadelphia, PA 19120

APPENDIX B
CENTERING OF OPTICAL ELEMENTS

(This Appendix is not part of ASME/ANSI Y14.18M-1986, and is included for information purposes only.)

Single Element

The *optical axis of a rotationally symmetrical optical lens element* is defined as the straight line from the center of curvature of one optical surface normal to the other surface. (If the second surface has curvature, the line goes through that surface's center of curvature.) The mechanical axis is defined by the geometric center of the lens diameter. The misalignment of these two axes is referred to as centering error. A decentered element is presented in Fig. B1.

This definition holds rigorously only for thin lenses with spherical surfaces. Aspherics may require special drawing definition of their optical axis.

The effect of decentration is to cause a light ray entering the element coincident to the mechanical axis to exit the element not parallel to the mechanical axis as shown in Fig. B2.

The relationship between variables is:

$$\delta = \frac{\Delta}{EFL} = (\eta - 1)\,\frac{ET_{max.} - ET_{min.}}{D}$$

While the angle of deviation δ is specified in para. 3.5.1, quite often the decentration is specified in process, i.e., shop measurement, terms. Some of these are specified as follows.

Method of Measurement — Image Runout

The element is rotated in a holding fixture as shown in Fig. B3, and the image runout is measured directly with a microscope and reticle or other means.

Method of Measurement — Edge Runout

The element is rotated about its optical axis on a mechanical clamping machine as shown in Fig. B4, and the edge runout is measured directly as shown.

Method of Measurement — Wedge Runout

The element is rotated in a holding fixture as shown in Fig. B5, and the wedge runout is measured directly.

ANSI/DIN Style Tolerances

An alternate callout to centering, using totally mechanical tolerance of form according to ANSI Y14.5M, is as shown in Fig. B6 and is measured as noted for wedge runout. This type of dimensioning is not common in the U.S., but the interpretation should be straightforward. A similar approach is taken in the current German DIN 3140 standard, except that the centering error is called out in arc minutes of angular deviation δ instead of second surface wedge runout.

Other Elements and Assemblies

Elements which are not round or have specially fabricated mounting surfaces and assemblies of elements also have centering requirements. These items should be specified as required using the above nomenclature as suitable. For example, a lens assembly may specify image runout referenced against the barrel diameter and a mounting flange as shown in Fig. B7.

Bibliography

[1] Smith, W., *Modern Optical Engineering,* McGraw-Hill, New York, 1966.

[2] Hartman, R., *Centering of Optical Elements,* Martin Marietta, unpublished paper, June 1976.

[3] Fischer, R. E., Lens Element Drawing 260089, Hughes Aircraft Co., January 1980.

[4] DIN 3140, Sheet 6, *Inscription of Dimensions and Tolerances for Optical Components, Centering Error,* October 1978.

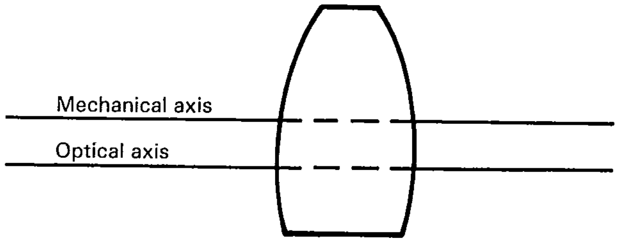
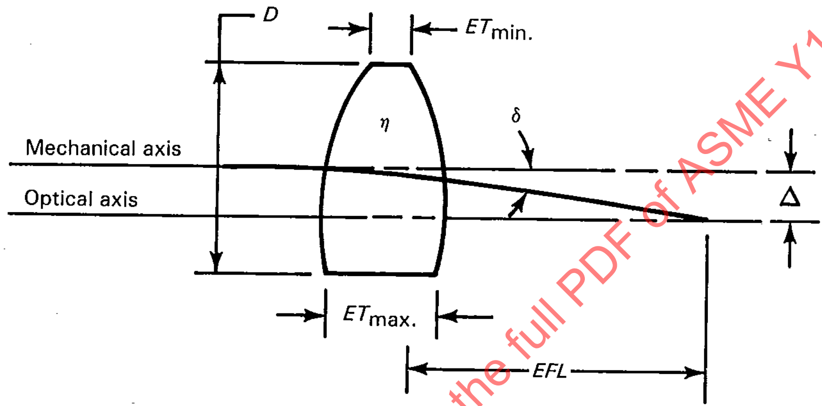


FIG. B1 SINGLE ELEMENT



D = the element diameter
δ = the angle of deviation
$ET_{min.}$ = the minimum edge thickness
$ET_{max.}$ = the maximum edge thickness
EFL = the effective focal length of the element
Δ = the lateral displacement
η = the index of refraction of the glass

FIG. B2 EFFECT OF DECENTRATION

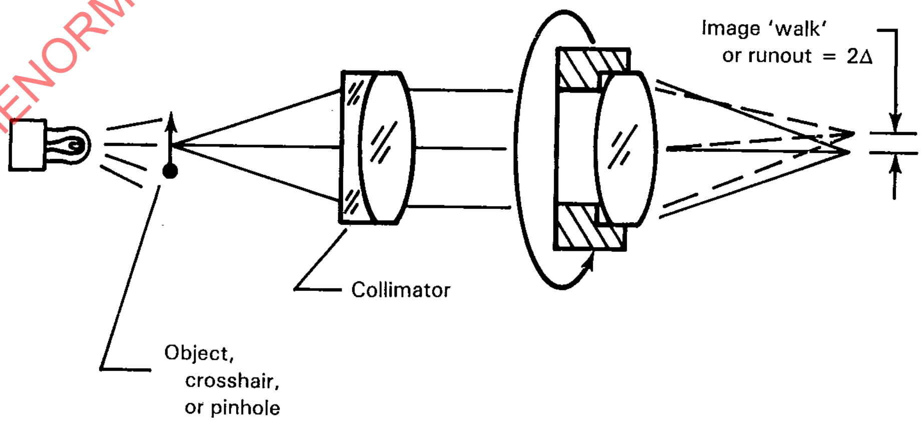


FIG. B3 IMAGE RUNOUT

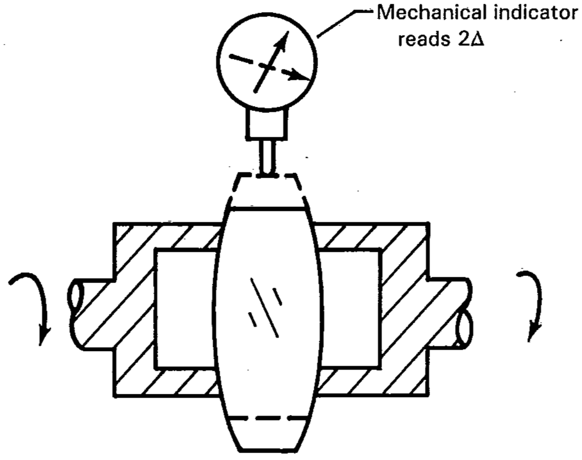


FIG. B4 EDGE RUNOUT

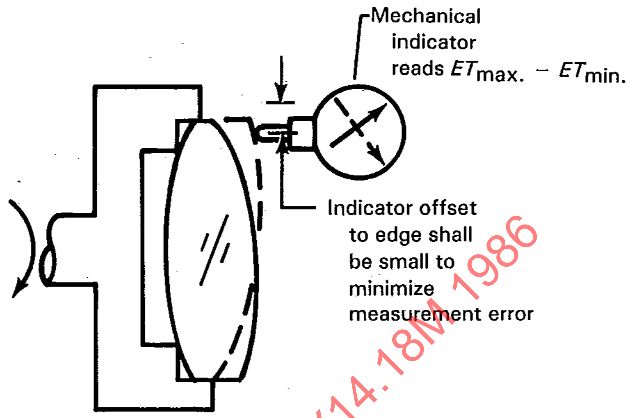


FIG. B5 WEDGE RUNOUT

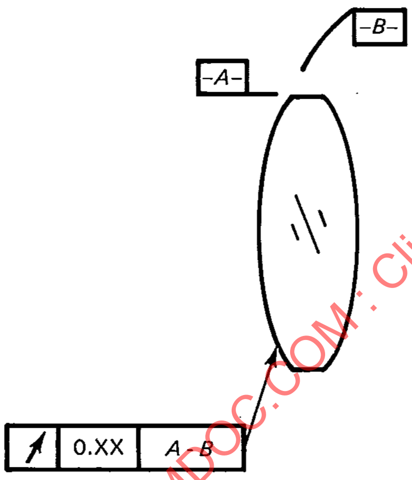


FIG. B6 ALTERNATE CALLOUT

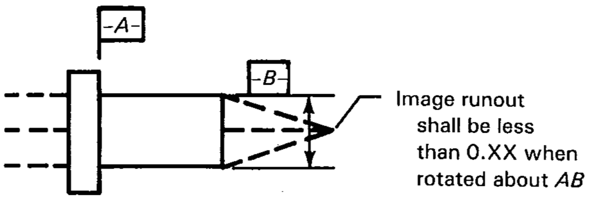


FIG. B7

APPENDIX C
SPHERICAL POWER CONVERSIONS

(This Appendix is not part of ASME/ANSI Y14.18M-1986, and is included for information purposes only.)

The power of a transmissive plano–plano element may be expressed in terms of:

$$\text{Power (millidiopters)} = \frac{1}{\text{focal length (km)}}$$

or alternately

$$\text{Power (millidiopters)} = \frac{2 \bullet 10^6 \alpha}{D}$$

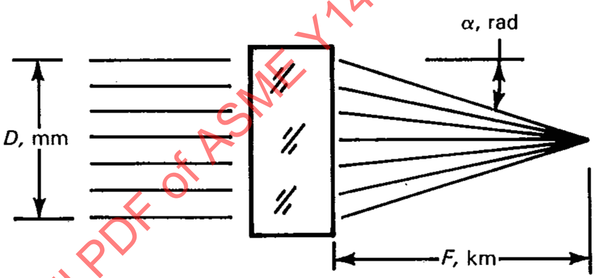


FIG. C1

where α and D are defined in Fig. C1 and the △ approximation $\tan \alpha \cong \alpha$ is used.

Different powers in different directions (typically 90 deg. apart) is astigmatism and is measured as shown in Fig. C2.

The actual measurement may be made with a millidioptometer (see Ref. [2]) which is a calibrated telescope with reticle as shown in Fig. C3.

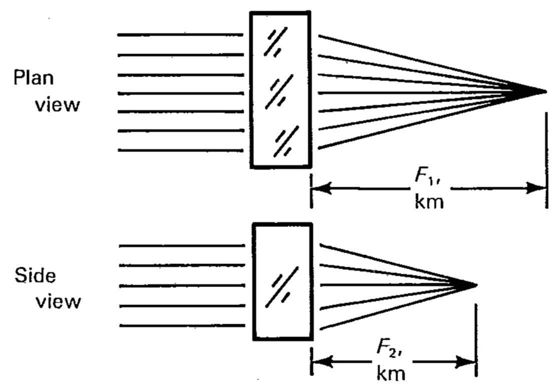
The transmissive element to be tested is placed in the field as shown in Fig. C4, and the telescope refocused for best image (or images in the case of astigmatism). The amount of movement z necessary to restore the image is related to the power introduced by the element in test as:

$$z = \frac{2F_t^{\ 2} \alpha}{D}$$

$$\alpha = \frac{zD}{2F_t^{\ 2}}$$

or

$$\text{Power (millidiopters)} \cong \frac{10^6 z}{F_t^{\ 2}}$$



$$\text{astig} = \frac{1}{F_2} - \frac{1}{F_1}$$

$$\begin{aligned} \text{power} &= |1/F_2| \quad \text{if } F_2 < F_1 \\ &= |1/F_1| \quad \text{if } F_2 > F_1 \end{aligned}$$

for standard practice or

$$= 1/2 \left[\, |1/F_2| + |1/F_1| \,\right]$$

for strict compliance to Ref. [2]

FIG. C2