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SUPERSEDING
MIL-O-13830 (Ord)
7 DECEMBER 1954

MILITARY SPECIFICATION

OPTICAL COMPONENTS FOR FIRE CONTROL INSTRUMENTS; GENERAL SPECIFICATION GOVERNING THE MANUFACTURE, ASSEMBLY, AND INSPECTION OF

This specification has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

1. SCOPE

1.1 This specification covers the manufacture, assembly, and inspection of finished optical components such as lenses, prisms, mirrors, reticles, windows and wedges for fire control instruments.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

SPECIFICATIONS

MILITARY

MIL-G-174 —Glass, Optical
MIL-C-675 —Coating of Glass Optical Elements
MIL-A-3920 —Adhesive; Optical, Thermosetting
MIL-S-11030 —Sealing Compounds, Non-Curing, Polysulfide Base
MIL-M-13508 —Mirrors, Glass, Front Surface Aluminized, for Optical Elements
MIL-A-14443 —Adhesives, Glass to Metal for Bonding of Lenses
MIL-O-16898 —Optical Elements, Packaging of

DRAWINGS

U. S. ARMY MUNITIONS COMMAND

F7560085 —Vibration Tester
C7641866 —Surface Quality Standards for Optical Elements

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

3. REQUIREMENTS

3.1 **General.** All optical elements, components and systems shall comply with the requirements of this specification, except as further defined in the detailed instrument specification or on applicable drawings forming a part of the contract.

3.2 **Materials.** Materials shall be in accordance with applicable specifications or component or instrument drawings.

3.2.1 *Glass, optical.* Optical glass shall be of type and grade specified on the drawings and conform to Specification MIL-G-174, unless otherwise authorized by the contracting officer On authorization to use glass other than that specified, complete information regarding the optical characteristics of the glass and design data shall be furnished the contracting officer

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3.2.2 *Adhesive.* Unless specified by the contract or order, optical cement shall be in accordance with Sp ification MIL-A-3920.

3.2.3 *Bonding compound.* Bonding compound for glass to metal bonding shall be in accordance with Specification MIL-A-14443.

3.2.4 *Sealing compound.* Sealing compound shall be in accordance with Specification MIL-S-11030.

3.2.5 *Reflection reducing film.* Reflection reducing film required for coating of specified optical surfaces shall be in accordance with Specification MIL-C-675.

3.2.5.1 *Reflecting surfaces.* Reflecting surfaces aluminized shall be in accordance with Specification MIL-M-13508.

3.3 **Mechanical dimensions.** Optical elements shall conform to the mechanical dimensions and optical data specified on the drawings or in the contract.

3.3.1 *Rim edges.* Rim edges of all optical parts shall have a chamfer of 0.020 inch—0.005 at 45° ± 15° as measured along the face width unless otherwise specified by the drawing. Edges meeting at angles of 135° and larger need not be beveled unless specified by the drawings.

3.4 **Finish and defects.** Finish and defects of the optical glass shall conform with requirements of this specification or as indicated on applicable drawings or optical diagrams.

3.4.1 *Glass defects.* Striae, cords, ream, bubbles, seeds, strain, laps, or folds in pressings, or any other defect permitted in Specification MIL-G-174, located in such a point, plane, or position as to impair the performance of the element shall be cause for rejection of that element.

3.5 **Optical glass surface quality.**

3.5.1 *Optical drawings and diagrams.* Component optical drawings shall indicate surface quality, and optical system diagrams shall indicate the diameter of an axial beam of rays

3.5.1.1 *Designation of defect size.* Limiting sizes of surface defects shall be designated on the drawings by two numbers which refer to two graded sets of surface quality standards Drawing C7641866. The first number shall refer to scratches and the second number shall refer to digs (see 6.3).

3.5.2 *Scratches.*

3.5.2.1 *Circular element.* The combined length of maximum size scratches located on each surface of an optical element shall not exceed one quarter the diameter of that element.

3.5.2.1.1 *Maximum combined lengths of scratches.* When a maximum size scratch is present, the sum of the products of the scratch numbers times the ratio of their length to the diameter of the element or appropriate zone shall not exceed one half the maximum scratch number. When a maximum size scratch is not present, the sum of the products of the scratch numbers times the ratio of their length to the diameter of the element or appropriate zone shall not exceed the maximum scratch number.

3.5.2.2 *Noncircular shaped element.* The computing diameter of element shapes other than circular shall be that of a circle of equal area. Scratches beyond the free aperture of any element as given on the optical system drawings or detail drawings shall not be considered when applying the appropriate formula specified in 3.5.2.1.1.

3.5.2.2.1 *True roof surfaces on prisms* True roof surfaces on prisms shall be considered equivalent to a single surface of an equal to the sum of the individual roof areas for purposes of scratch and dig computation, except that the roof edge shall not be considered in the summation of the length of the allowable scratches Scratch and dig tolerances for roof prisms are set on the basis that the equivalent surface above is viewed from the air side (3 7 10 1)

3.5.2.2.2 *Surface quality, central zone* Areas of surfaces whose specified scratch qualities are 20 or better shall have no conglomeration of scratches such that in any

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¼-inch diameter circular area there are more than four separate scratches. This requirement does not apply for scratches smaller than number 10. Small reticle surfaces equal to or less than 20mm (0.787 inch) diameter shall be handled separately on the drawings with elimination of zones, particularly for cemented reticles.

3.5.2.3 *Surface quality, outer zone.* Surface quality outside the free aperture of any element shall be considered 80–50, unless otherwise required.

3.5.2.4 *Coating scratches.* Coating scratches, scratches which do not penetrate the glass surface, shall be within the same limits which are specified in 3.5.2. Coating scratches shall not count in determination of the normal surface quality but shall be counted in addition to the surface quality—once to evaluate the glass scratches and one to evaluate the coating scratches.

3.5.3 *Digs.*

3.5.3.1 *Dig designation.* Dig numbers are the actual diameters of defects allowed, specified in units of 1/100mm. In the case of irregular shaped digs the diameter shall be taken as the average of the maximum length and maximum width.

3.5.3.2 *Maximum size digs.* The permissible number of maximum size digs shall be one per each 20mm of diameter or fraction thereof on any single optical surface. The sum of the diameters of all digs as estimated by the inspector shall not exceed twice the diameter of the maximum size specified per 20mm diameter. Digs less than 2.5 microns shall be ignored.

3.5.3.3 *Surface quality.* All digs on each surface whose dig quality is number 10 or smaller shall be separated edge to edge by at least 1mm. The measurement of scattering shall not be required for surfaces where digs larger than number 10 are allowed.

3.5.4 *Bubbles and inclusions.* Bubbles shall be classed as surface digs Any inclusion in the glass shall be treated as a bubble. The size of irregular shaped inclusions shall be considered as one half the sum of the maximum length and the maximum width. Bubble size tolerances are identical in all respects to digs; but the identical bubble tolerances, while identical, are in addition to the digs.

3.5.4.1 *Maximum size bubbles.* The permissible number of maximum size bubbles shall be one per each 20mm of light path, or fraction thereof, of any single element. The sum of the diameters of all bubbles as estimated by the inspector shall not exceed twice the diameter of the maximum size specified per 20mm diameter for each 20mm of light path. When surface dig quality is 10 or better, bubbles shall follow requirements for digs as specified in 3.5.3.1.

3.5.5 *Limiting size of surface defects.* If not specified on drawings, the limiting size of scratches or digs shall be determined from Table I and is based on the beam diameter of magnification

3.5.5.1 *Beam diameter of magnification.* The beam diameter shall be obtained from the optical date. It is the diameter at the surface of the optic in question, of a bundle of axial rays proceeding to the observer's eye. The diameter of the bundle at the eye shall be taken as 3.5mm, (0.1378 inch) if the exit pupil is over 3.5mm. If the exit pupil is smaller than 3.5mm, that diameter of the bundle at the eye shall be the same as the exit pupil.

3.5.5.2 *Beam size less than in table I.* When the beam size is less than that specified for focal planes and near local planes of any surface, the size of defect is determined by the magnification of the eyepiece or of the eyepiece multiplied by magnification of the erecting system

3.5.5.3 *Zone.* The surface on which the beam diameter of an axial bundle is 25 percent or less of the free aperture shall be divided into a central and outer zone. The central zone shall be half the free aperture in width Zone size for reticles shall be as specified in 3 7 11 1.

3.6 **Cement defects.** Cement bubbles, voids, undissolved particles, dry spots, blisters, dirt (lint or dust) within the free aperture of the cemented lens shall not exceed the limits of

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TABLE I

Focal planes and near focal planes			Central zone ½ diameter of surface		Outer zone	
Beam diameter (mm)	Magnifying power	Focal length (mm)	Scratch	Dig	Scratch	Dig
Over 5			80	50	80	50
4–5			60	40	60	40
3 2–4			60	30	60	40
2 5–3 2			40	20	60	40
2 1–2 5			40	15	60	30
1 6–2 1			30	10	40	20
1 0–1 6			20	5	40	15
0 6–1 0			15	3	30	10
0 4–0 6			10	2	20	5
0 2–0 4			10	1	15	3
0 2	20–10	12 5–25	10	1	15	3
0 4	10–5	25–50	10	2	20	5
0 6	5–3 3	50–75	15	3	30	10
1 0	3 3–2	75–125	20	5	40	15
1 6	2–1	125–250	30	10	40	20

defects for digs and bubbles specified in 3.5.3.1 thru 3.5.4.1 inclusive.

3.6.1 *Surface quality of cemented face.* Cement defects inside the free aperture shall be considered on the basis that the cement interface is a single surface of the specified surface quality. When not specified, the surface quality for a cement face shall be intermediate between that of adjacent faces.

3.6.2 *Edge separations.* Edge separation and edge cement defects in optical components shall not extend beyond the edge chamfer of the cemented surface of the lens or prism by a distance greater than ½ the distance between the cemented surface chamfer of the component and the radius of the clear aperture. The maximum dimension of any edge separation or cement defect shall not extend into the cemented surface of the component by more than 1mm The sum of the edge separations or cement defects larger than ½mm as measured at the surface chamfer of the lens or prism, shall not exceed 10 percent of the perimeter

3.6.3 *Bonding defects (glass to metal).* Bonded optical assemblies shall have a continuous bead of the curved adhesive along the edge of the bonded surface

3.6.3.1 *Voids and separations* Subsequent to meeting the requirements of 3.7.2 and 3.8.2 5.2, there shall be no voids or separations that exceed 10 percent of the bonded area

3.7 **Optical component details.**

3.7.1 *Temperature operation.* Cemented components as a result of exposure to ambient air temperatures of minus 80° and plus 160° F shall not develop "feathering," show evidence of separation or softening of cement or other defect, except as specified in 3.6, with the provision that the increase or development of edge separation or edge cement defects shall be cause for rejection.

3.7.2 *Relative humidity—temperature operation* Cemented components as a result of exposure to an ambient atmosphere of plus 130° F temperature, and at least 95 percent minimum relative humidity, and subsequent exposure to ambient air temperature of minus 80° and plus 160° F., shall not develop "feathering," show evidence of separation or softening of cement or other defects, except as specified in 3.6.

3.7.3 *Reflection reducing films.* Optical surfaces specified on drawings as "surfaces to be coated" shall be coated with a reflection reducing film (see 3.2.5).

3.7.4 *Optical blackening* When specified,

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ground surfaces of optical elements shall be blackened with a finish approved by the responsible technical activity.

3.7.5 *Resolution.* Resolution tests shall be performed on each objective, collective, erector, eyepiece, mirror, wedge, window, filter, prism and prism assembly (optical) as specified in 4.2.5

3.7.6 *Parallelism, filters.* Parallelism of filters shall be within the tolerance specified on the drawings. When no tolerance is specified, filters located internally or in front of a telescope shall not exceed 1 minute of arc light deviation. Filters located between the eyelens and the exit pupil shall have a light deviation not exceeding 5 minutes of arc.

3.7.7 *Reticle scale spacing.* Reticle scale spacing shall be tested in accordance with 4.2.10.5.

3.7.8 *Polished surfaces.* Polished surfaces shall show no evidence of grayness or stain when inspected in accordance with 4.2.2.

3.7.9 *Lenses.*

3.7.9.1 *Surface quality* Surface quality of each lens shall be in accordance with applicable drawings or instrument specifications. When not specified, the surface quality shall be as follows: Objectives, erectors, windows and other elements which lie at least fifteen diopters out of the focal plane, shall have a surface quality of 80–50 or better. Field and collective lenses shall have a surface quality of 20–5 in the central zone and 40–15 in the outer zone. Center lenses of oculars shall have a surface quality of 40–15 in the central zone and 40–20 in the outer zone. Eyelenses, excepting those in symmetrical eyepieces, shall have a surface quality of 40–20 in the central zone and 60–30 in the outer zone. When the field and eyelens are identical, the surface quality for both shall be 20–5 in the central zone and 40–15 in the outer zone. Filters which lie between the eyelens and the exit pupil shall have a surface quality of 40–20 in the central zone and 60–30 in the outer zone. Filters which lie internally shall have the same requirements as specified for prisms in 3.7.10.1. Filters located in front of the objective shall have a surface quality of 80–50 or better.

3.7.9.2 *Edge chips.* Edge chips which do not encroach on the free aperture of the lens shall be allowable, providing the chip does not interfere with the sealing of the lens in the mount. The surface of all chips larger than ½mm, as measured at the largest extremities, shall be "stoned" to roughen it and lessen the possibility of annoying reflections and additional chipping. The sum of the chip widths of chips larger than ½mm, as measured at the edge of the lens, shall not exceed 10 percent of the perimeter. Fractures in excess of ½mm depth in any face or edge shall be ground out. Ground out areas shall remain within the applicable stoned chip limits of this paragraph. Fractures in excess of these limits shall be cause for rejection. Stoned chips and fractures in ground faces whose total summed up areas are in excess of 2 percent of the area of the ground face or which are in excess of 2mm depth shall be cause for rejection. Such stoned chips and fractures shall be cause for rejection when they interfere with the optical path or mounting or sealing methods regardless of their size.

3.7.9.3 *Concentricity.* Edges of all elements shall be trued to diameter about the optical axis as a center by grinding. Lenses composed of two or more elements shall be cemented and centered in such a manner that the axis of each element coincides with the axis or axes of the other element or elements. Ocular lenses shall be concentric within 6 minutes of arc, and all other lenses shall be concentric within 3 minutes of arc unless otherwise specified on the drawing or in detail specifications. After centering and cementing, mechanical eccentric glass overhang in excess of 50 percent diameter tolerance shall be removed. Optical eccentricity is defined as the angular deviation, after refraction of an incident ray which is coincident with the geometric axis of the lens.

3.7.10 *Prisms and mirrors.*

3.7.10.1 *Surface quality.* Surface quality of each prism shall be in accordance with appli-

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cable drawings or instrument specifications. For surfaces which lie at least 15 diopters out of the focal plane, quality shall be 80–50 or better. For surfaces which lie within 5 to 15 diopters of the focal plane the surface quality shall be 20–5 for the central zone and 40–15 for the outer zone. For surfaces which lie within 5 diopters of the focal plane surface quality shall be the same as for reticles.

3.7.10.2 *Edge chips.* Edge chips which do not encroach on the free aperture of the prism shall be allowable within the following limitations: The sum of the chip widths shall not exceed 10 percent of the length of edge on which the chips occur. Chips shall be measured from the bevelled edge, not from sharp edge; i.e. after bevelling and not before. Chips less than ½mm shall not be counted and not stoned; chips larger than ½mm shall be stoned. Encroachment of chips shall be measured on the faces of the prism from the bevelled edges. If the nominal length (measured to sharp corner before bevelling) of the shortest edge of the prism which is adjacent to any polished face is an inch or less, chips may encroach the faces 1mm; if said length exceeds 25.4mm chips may encroach 2mm. This shall be permissible provided that there are no edge chips which interfere with mounting methods or sealing and the chips do not encroach upon the free aperture.

3.7.10.3 *Drawing requirements.* The deviation of angle errors, pyramidal error or error due to pyramid, spherical power, astigmatism, resolution, and image tilt shall be as specified on the drawings.

3.7.10.4 *Erecting prisms.* Erecting prisms shall be inspected as specified in 4.2.5.2.

3.7.10.5 *Reflecting surfaces—silvered or aluminized.*

3.7.10.5.1 *Edges.* The edges of partially silvered surfaces of ocular prisms shall be sharp and shall show freedom from irregularities when inspected with the aid of a magnifier of at least the power of the eyepiece of the instrument to which the prism pertains.

3.7.10.5.2 *Defects.* Defects on reflecting surfaces appear the same as defects on other optional surfaces and shall be treated in the same manner as specified in 3.7.10.1.

3.7.10.5.3 *Aperture surfaces.* Aperture surfaces of prisms through which light is to be transmitted shall be free from particles of silver or aluminum remaining from processing of other surfaces.

3.7.11 *Reticles.*

3.7.11.1 *Surface quality.* The surface quality shall be as specified on the drawings. When not so specified the surface quality shall be as specified for focal planes in 3.5.5.3, except for zone sizes. The central zone shall be the central area, one half the free aperture in width, for reticles having reticle graduation extremities within this area, and those reticles having horizontal and vertical lines without graduations outside the area. Reticles having graduations outside the central area, one half the free aperture in width, the central zone shall be the central area, three-fourths the free aperture in width. Imperfections beyond the free aperture shall be permitted providing their characteristics do not impair performance of the instrument.

3.7.11.2 *Edge chips.* Edge chip limitations shall be evaluated in accordance with 3.7.9.2.

3.7.11.3 *Parallelism of flat surfaces.* Parallelism of reticle flat surfaces shall be within the tolerances specified by the drawings. Where no tolerance is given on the drawing, the tolerance shall be 6 minutes of arc deviation of light path.

3.7.11.4 *Markings.* Reticle markings shall be viewed through an eyepiece of essentially the same power under which the reticle will be viewed in the finished instrument. Letters and numerals (whether in part number or adjacent to graduations) shall be inspected primarily for legibility. Defects in numbers or letters shall be acceptable provided each letter or figure is legible beyond doubt. Stencil type letters and numbers shall be permissible. Line breaks one half the width of the line shall be permitted For reticles containing more than 15 lines, 1 break per 5 lines or fraction thereof shall be permitted. All lines shall appear to be of uniform width and depth and the intersections of lines shall ap-

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pear to be sharp. Smooth or abrupt variations in line width along the entire line shall not be in excess of 20 percent of the line width. In addition, bowed lines shall be within dimensional requirements and in no case shall reticle lines be bowed in excess of ½ the reticle line width. The fillet radius at the intersection of reticle lines shall not exceed the line width. Acid burns shall be cause for rejection, if visible when reticle is viewed with appropriate eyepiece.

3.7.11.5 *Illuminated reticles.* If the brightness of a defect is greater than the brightness of a reticle line when illuminated by the associated instrument light or light of equal intensity, the defect shall be cause for rejection.

3.7.12 *Wedge and window.* Wedge and window surface quality shall be in accordance with 3.7.9.1.

3.8 **Optical systems.**

3.8.1 *Unassembled.* Optical systems of specified design procured unassembled shall be grouped into systems in accordance with the optical diagram pertaining to the system, and shall be inspected as specified in 4.2.9.

3.8.2 *Assembled.* Optical systems of specified design procured assembled in their respective instruments shall be assembled in accordance with the drawing and specification for the instrument, and shall be inspected as specified in 4.2.10

3.8.2.1 *Defect criteria.* Defects not otherwise covered in this specification, which will not impair the performance of the finished instrument, shall be permissible. Whether a particular defect shall be permitted will depend on the location of the element in the finished optical system. Defects in elements not near a focal plane are not as important as in elements which lie in or near a focal plane. In all instances primary emphasis shall be placed on the performance of the lens or prism rather than its appearance unless the latter definitely indicates poor workmanship. The order of importance is as follows:

(a) Most critical surfaces,
Etched surface of reticle
Surface of collective lenses in a focal plane

(b) Less critical surfaces,
Surface of ocular field lens nearest the reticle,
Collective lens, center lens or prism surfaces near a focal plane

(c) Least critical surfaces,
All other surfaces of windows, objectives, prisms, erector, and eyelenses

3.8.2.2 *Alinement.* The optical elements of all optical systems procured assembled in their instruments shall be alined so that the exit pupil viewed on the optical axis shall have a minor diameter not less than 90 percent of its major diameter. The exit pupil shall be concentric with the exit free aperture within 10 percent of the exit free aperture when viewed from a point on the optical axis at a distance of approximately two feet from the eyelens.

3.8.2.3 *Sealed joints.* When specified, moisture preventive sealing compound (see 3.2.4) shall be evenly applied to the optical component to form an unbroken bead. When injection sealing is utilized, 24 hours shall elapse before collimation of the instrument.

3.8.2.4 *Padding.* The use of pads, shims, wedges, or opening under or around optical elements is prohibited and shall be cause for rejection of the instrument unless specified by the drawings.

3.8.2.5 *Performance characteristics.*

3.8.2.5.1 *Vibration.* After being subjected to the vibration test specified in 4.2.10.7 the optical instrument shall show no dirt (dust or lint) in excess of that allowed by the detail specification. In the absence of detail requirements, dirt in any confined space shall not be in size or amounts larger than the allowable dig specification for the adjacent surface requiring the best dig quality. The instrument shall show no evidence of loose or damaged parts subsequent to this test.

3.8.2.5.2 *Shock.* All completed subassemblies in which an optical element is physically

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supported from another part or parts by a glass to metal bond shall be subjected to the shock test.

3.8.2.5.3 *Cleanliness*. The optical surface of completed instruments shall be clean and free of condensates and volatile substances when examined by method specified in 4.2.10.9. Dust retention grease shall not be used except with specific authorization of the responsible technical activity.

3.8.2.5.4 *Parallax*. Parallax shall be removed where specified in 4.2.10.4.

3.8.2.5.5 *Fixed eyepiece focus*. Unless otherwise specified the reticle at the center of the field shall be in sharp focus when the eyepiece is set between minus 0.75 and minus 1.0 diopter. A calibrated dioptometer with a magnification of at least 3 power or an equivalent auxiliary telescope shall be used to make this setting.

3.9 **Workmanship.** Standards of workmanship shall be such that components will meet all requirements of this specification and any referenced specifications or drawings when inspected in accordance with section 4.

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, the supplier may utilize his own facilities or any commercial laboratory acceptable to 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 supplies and services conform to prescribed requirements

4.2 **Test methods.**

4.2.1 *Inspection, optical components* Optical components shall be inspected by approved optical methods and equipment in accordance with applicable detail specifications. In absence of approved test methods and equipment, the following procedures of the general specification shall apply. Appropriate sampling procedures may be used with prior approval of the responsible technical activity.

4.2.1.1 *Mechanical dimensions*. Each optical component shall be checked for compliance with the mechanical dimensions of the drawing and shall be inspected in accordance with the requirements and tests in this specification.

4.2.2 *Surface quality*. Each element shall be inspected by the following methods for compliance with 3.5.2, 3.5.5, 3.6 1, 3.7.9.1 and 3.7.10.1.

4.2.2.1 *Inspection method No. 1*. The element to be inspected shall be viewed against a ground glass or opal surface illuminated from behind by a forty watt lamp approximately 3 inches from the glass. Two or more opaque horizontal bars occupying approximately ½ the area of the glass shall be placed in front of and in contact with the glass.

4.2.2.2 *Inspection method No. 2*. The light through ground glass from a 40 watt bulb shall be passed through the element. Defects are observed by light scattered from the surface while viewing it at approximately 90° to the path of the beam against a dark background.

4.2.3 *Temperature test.*

4.2.3.1 Three out of the first 10 of each type of cemented or bonded component completed under each contract shall be tested at the high and low temperatures specified in 3.7.1 If there is reason to doubt quality, the right is reserved to test additional samples as the inspector deems necessary. Components subjected to these tests shall have passed all other required tests

4.2.3.2 The cemented or bonded components shall be subjected to an ambient temperature of minus 80° F for 5 hours When inspected visually at this temperature, and again after remaining five hours at room temperature, the optical assembly shall show no evidence of "feathering" or reticulation and there shall be no separation of the com-

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ponents. In performing this test the optical assemblies shall not be subjected to any undue thermal shocks while being cooled to minus 80° F., or while being warmed to room temperature.

4.2.3.3 The cemented optical assembly shall then be subjected to the following test at the high temperature. One of the components shall be held rigidly in such a manner that the cemented interface shall be approximately in a vertical plane. A weight of such magnitude as to induce in the optical assembly a unit shear stress of 5 ounces per square inch of area of the cemented or bonded surface shall be suspended from the other component. In no case shall the weight be less than one ounce. For lenses this area may be taken as the projected area, $\pi \times \frac{D2}{4}$ where D is the diameter of the lens in inches. The entire apparatus shall be allowed to soak at an ambient temperature of plus 160° F., or slightly higher, for 2 hours. The lens shall pass the requirements specified by 4.2.6 when tested at room temperature and the movement or slippage of one component with respect to the other shall not exceed .002 inch. In performing this test the optical assemblies shall not be subjected to any undue thermal shocks while being raised to 160° F. or while being cooled to room temperature.

4.2.3.4 Failure of one optical assembly shall be cause for stopping shipments pending an investigation of the cause. The contractor shall institute an immediate investigation in the presence of a representative of the contracting officer if the representative desires to be present to determine the cause of failure. If the investigation discloses a fault in cementing or bonding, acceptance of optical assemblies incorporating this fault shall be stopped pending correction. The contractor shall correct his cementing technique and shall correct all faulty optical assemblies previously produced Acceptance and shipments will be resumed when ten consecutive optical assemblies of the type rejected have successfully passed the temperature tests.

4.2.4 *Temperature—relative humidity*

4.2.4.1 Three out of the first 10 of each type of cemented or bonded components at the beginning of each contract, or upon change in method of cemeting or change in type cement, shall be tested at the temperature-humidity conditions specified herein. If there is reason to doubt quality, the right is reserved to test additional samples as the inspector deems necessary.

4.2.4.2 The cemented or bonded component shall be gradually heated in a dry atmosphere to plus 140° F., and then immediately placed in an ambient atmosphere of plus 130° F. at 95 percent relative humidity for 2 hours. The optical assemblies shall be removed from the humid atmosphere, immediately wiped dry, and allowed to cool to room temperature. After 8 hours at room temperature the component shall be subjected to the tests specified in 4.2.3.2 and 4.2.3.3. The test as specified in this paragraph shall be repeated in the same identical procedure whenever passable optical assemblies having edge separation or cement blisters at the start of the test increase, or additional cement defects develop not in excess of that specified in 3.6. Components failing the initial test, or a change in any cement defects, or the development of additional cement defects after the retest shall be cause for rejection including all optical assemblies having passable cement defects from the corresponding lots offered for inspection. All components subjected to the humidity test shall be recemented and recoated if required prior to acceptance.

4.2.4.3 Failure of one component to pass the tests specified in 4.2.4 shall be cause for the components to be treated in the same manner as specified in 4.2.3.4.

4.2.5 *Resolution test.* Resolution test shall be standard and shall be performed using one of the resolving power charts, see figure 1. Resolving power is a measure of the optical performance. The resolving power is the angular subtense (in seconds of arc) of a series of parallel bars that can just be resolved. Resolving power is measured by viewing charts containing parallel bars of appropriate equal spacings. An auxiliary telescope is used to obtain sufficient magnification A re-

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solving power chart shall consist of four sets of lines, all sets either entirely three or entirely four lines at 45° steps (horizontal, vertical, and two at 45°). The three line sets shall contain lines that are five times as long as they are wide. The four line sets shall contain lines that are seven times as long as they are wide. The widths of lines and spaces shall be equal. The lines may be either black on a white background, or white on a black background. There shall be an identifying numeral in the center of the four sets of lines. The contrast shall be as high as possible. The chart of appropriate dimensions may be located in a collimator, or it may be viewed directly. In the latter case, the chart shall be at least 2 M^2 feet from the telescope objective, where M is the power of the telescope under test. The angular subtense of a chart is measured in seconds and equals arc tangent 2W/X, where W is the width of a chart line and X is either collimator focal length or distance from chart to telescope under test. The telescope under test is aligned so the chart is in the center of the field. The auxiliary telescope is added and oriented to again center the chart. With the diopter scale of the auxiliary telescope at zero, the telescope under test shall be focused on the numeral in the resolving power target. In reading resolution, the auxiliary telescope may be focused plus or minus 1/8 diopter for each of the four meridians. All four meridians shall have the correct line count. The limit of resolution is reached when any of the lines start to degenerate.

4.2.5.1 *Objective and erector.* When an objective or erector is being inspected by means of the above chart, it shall be placed at the proper distance and the image formed by the objective or erector shall be viewed with a microscope at a given power as required by the detail specification or the contracting officer. It shall be possible to discern a line structure in the blocks equivalent to the resolution specified. The chart shall be so illuminated as to give a brightness of the image of 10 to 20 millilamberts.

4.2.5.2 *Lens.* When the effect of the lens on the definition of the complete instrument is being checked, the other optical component of the instrument having approved quality shall be arranged exactly as in the actual instrument. The lens to be tested shall then be inserted in position, and the chart shall be viewed through the complete setup by means of an auxiliary telescope giving a combined power of 40 to 60 magnifications per inch of aperture. It shall be possible to discern a line structure in the block representing the line structure required for the specified resolution. The chart shall be so illuminated as to give a brightness of the image of 10 to 20 millilamberts. Any optical elements needed for this test that are not being manufactured by the contractor will be furnished by the contracting officer.

4.2.5.3 *Plane components used extremely to a optical system.* The definition shall be tested by observing through the appropriate free aperture of the component, the image of a target of the form shown in figure 1. The image shall be observed with a telescope of at least 5-power greater than the power of the optical system between the component and the eye.

4.2.5.4 *Optical components or partial systems.* Optical components or partial systems procured as such and not as complete systems shall be tested in accordance with the detail specification or contractual document.

4.2.6 *Concentricity of lenses.* Cemented and single lenses shall be checked for conformance with the concentricity requirements of 3.7.9.3. The instrument specified in 4.2.8 with modifications, may be used for this test except that the reticle in the collimator shall be capable of being focused to permit placing it in the focal plane of the lens combination consisting of the collimator objective and the lens undergoing test for concentricity, and the stage shall be constructed to permit the lens to rotate about the geometric axis.

4.2.7 *Deviation of prisms.* The angle of deviation of prisms shall be tested by checking the deviation of light rays passing through the prisms, by standard or approved spectrometer practices.

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4.2.8 *Parallelism.* Windows, wedges, reticles or similar flat surfaced elements shall be tested for parallelism or taper of flat surfaces by checking the deviation of light rays passing through the element. An instrument suitable for this test is constructed as follows:

4.2.8.1 *Instrument.* The instrument is composed of a collimator, an observation telescope, and a revolving stage or table upon which the element is placed and revolved to determine the amount of light ray deviation, hence the deviation from parallelism of surfaces.

4.2.8.1.1 *Collimator.* The collimator consists of an objective and a reticle. The reticle is provided with a horizontal and vertical cross line. The reticle is illuminated from the rear by an electric light.

4.2.8.1.2 *Observation telescope.* The observation telescope consists of an objective, a reticle and an eyepiece. The reticle is graduated along the horizontal and vertical axes with short lines which are separated so as to subtend an angular distance of 30 seconds from the objective. The number of graduations necessary is determined by the range of deviations to be measured.

4.2.9 *Inspection of optical systems procured unassembled.*

4.2.9.1 *Optical elements* The optical elements of these systems shall be subjected to the inspection specified in 4.2.1 thru 4.2.8.

4.2.9.2 *Systems, grouped.* The elements shall be grouped into systems for inspection and shipments. They shall be spaced, in accordance with the optical diagram pertaining to the system, and assembled in a master instrument or tester and given a test for definition and quality of image. Elements causing unsatisfactory performance shall be replaced before acceptance of the system (see figure 1 for testing targets, and 4.2 10 2 and 4.2 10.3 for outline of inspection).

4.2.10 *Inspection of assembled optical systems.*

4.2.10.1 *Optical elements.* The optical elements of these systems shall be subject to the inspection specified in 4.2.

4.2.10.2 *Target.* Targets used in testing optical systems may be either actual size targets or miniature targets contained in collimators. The actual size targets can be made by printing black lines on a white background. The target in a collimator may be an etched or photographic reticle duplicating in miniature form, a full size target. The targets will vary, as required, by the detailed specification, from plain crosslines to targets containing a plumb line, level line, tolerance limit lines, and graduated scales (see figure 1 for resolution testing target).

4.2.10.2.1 *Collimator reticle.* The reticle cell of the collimator is adjustable so that the reticle may be moved toward or away from the objective to represent different outside distances at which an outside target would be placed. For example, suppose that the specification for a telescope requires that the instrument be free from parallax when viewing a target at a distance of 200 yards and a collimator target is to be used for testing. It is necessary to adjust the collimator reticle to represent this distance. This may be accomplished by removing parallax in a sample instrument when observing an outside target at 200 yards and then using this sample telescope to adjust the collimator reticle until there is no parallax observed when sighting through the sample telescope at the collimator reticle.

4.2.10.2.2 *Image quality.* When a collimator target is used to test the image quality of a telescope, due allowance shall be made for any aberrations of the collimator objective which will appear to be defects of the telescope being tested. Caution shall be exercised to eliminate the effect of these aberrations.

4.2.10.3 *Instrument, inspection.* Where necessary, the field may be observed by the use of a dioptometer or an equivalent auxiliary telescope to compensate for the individual inspector's eye accommodation.

4.2.10.4 *Parallax.* Parallax shall be re-

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moved at the center of the field unless otherwise specified in the detail specification.

4.2.10.5 *Reticle scale spacings.* Accuracy of angular subtense of reticle scale spacings of each reticle shall be tested by checking them against a target, which is an enlarged facsimile of the reticle; or a collimator reticle target. The enlarged target shall have black lines or marks against a white background and be placed at the proper distance with the face of the target perpendicular to the line of sight of the telescopes being tested

4.2.10.6 *Surface quality, reticle.* Each reticle shall be checked for compliance with 3.7.11.1 by viewing with a magnifier whose magnification is equal to or greater than the pertinent viewing lens of the telescope of which it is a component. The light and method shall be the same as specified in 4.2.2.

4.2.10.7 *Vibration test.* Each optical instrument shall be mounted singly or in groups on an approved vibration machine, similar to that shown on Drawing F7560085, and vibrated at an amplitude of not less than 1/16 inch (1/8 inch total movement at the center of the mounting face of the fixture) at a frequency of 30 cycles per second for 2 to 2½ minutes.

4.2.10.8 *Shock testing of bonded and cement-supported assemblies.* In absence of specific requirements each assembly shall be subjected to shock acceleration in a direction parallel to the plane of the joint in test for poor adherence or incomplete curing in the bonded or cemented joint. The time variation of the acceleration shall be roughly that of a half cycle of a sine function in which the time for increase of the acceleration from zero to maximum is 0.7 to 2.0 milliseconds. The amplitude of high frequency components in the time vs acceleration curve shall not exceed 30 percent of the fundamental amplitude. Unless otherwise specified by the detail specification, each assembly shall be subjected to six shocks of 150 G peak acceleration.

4.2.10.9 *Cleanliness.* Each optical system shall be examined through the objective and eyepiece ends with the unaided eye. Inspection for moisture shall be made by the technique of shadowing. Inspection for dust particles shall be made by viewing a uniformly illuminated field having a brightness of approximately 300 apparent foot candles

5. PREPARATION FOR DELIVERY

5.1 Packaging, packing, and marking. Packaging, packing, and marking of components weighing less than a pound shall be in accordance with Specification MIL-O-16898. Assembled optical components that exceed this weight shall be packaged in accordance with a specific detail specification or contract covering that assembly.

6. NOTES

6.1 Intended use. The finished optical components are to be used for fire control instruments such as sights, telescopes, periscopes and range finders either as individual elements, partial or complete systems, and assembled or unassembled, as required by contract.

6.2 Ordering data. Procurement documents should specify the following

(a) Title, number and date of this specification.

(b) Selection of an applicable level of preservation, packaging and packing.

6.3 Definitions.

6.3.1 *Scratch* Any marking or tearing of the surface. Scratch types are identified as the following:

(a) Block reek—chain like scratch produced in polishing.

(b) Runner-cut—curved scratch caused by grinding

(c) Sleek—hairline scratch

(d) Crush or rub—surface scratch or a series of small scratches generally caused by mishandling

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6.3.2 *Dig*. A small rough spot on the polished surface similar to pits in appearance, generally caused by mishandling.

6.3.3 *Feathering*. The physical change in cement causing the cement to lose its adhesion and develop into a feather like pattern.

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Navy—SHIPS
Air Force—MAAMA

Preparing activity:
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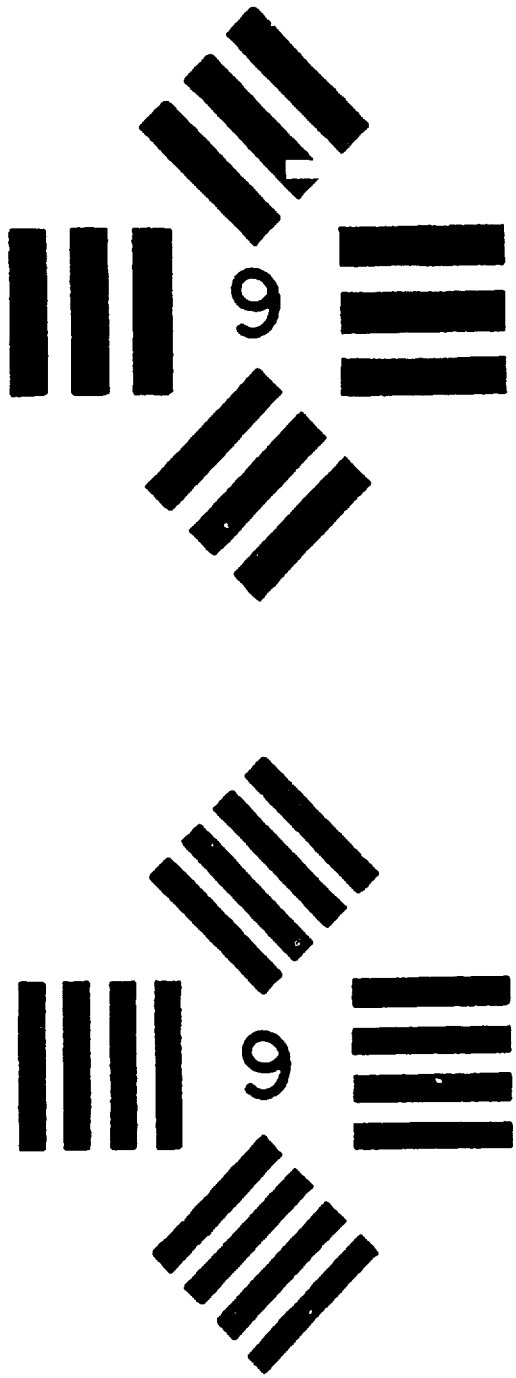

FIGURE 1

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☐ YES ☐ NO *(If "Yes", in what way?)*

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