U. S. ARMY TEST AND EVALUATION COMMAND
COMMODITY ENGINEERING TEST PROCEDURE

TELESCOPES

1. OBJECTIVE

This document provides test methods and techniques necessary to determine the technical performance and safety characteristics of telescopes and their associated tools and equipment, as described in Qualitative Materiel Requirements (QMR's), Small Development Requirements (SDR's), Military and/or Technical Characteristics (MC's or TC's), and to determine the item's suitability for service tests.

2. BACKGROUND

Requirements exist for optical instruments for viewing distant objects by means of the refraction of light rays through a lens system. Specifically, Army requirements for these instruments are allocated in two major categories, as follows:

Fire Control and/or Range-Finder Telescopes: Requirements exist for optical instruments capable of providing accurate angular information and range data to be used in computing or deriving fire control solutions. Since operation of these instruments is based on the rectilinear propagation property of light, a high degree of mechanical precision and a well corrected optical system are basic requirements of design and construction. Other implicit requirements for instruments of this type include the capability to provide erect, bright, and clear images of near or distant objects. Telescope designs responding to these requirements are further characterized by high resolution, narrow fields of view, low light losses, and low linear distortion.

Observation Telescopes: Other requirements exist for telescopes which assist an observer by rendering distant objects more visible and/or provide a magnified wide-angle view of an area of interest. Mechanical accuracy and precision of construction requirements for these types are somewhat relaxed in respect to fire control telescopes; however, wide angle provisions usually require highly corrected optical components to avoid image distortion. Also, observation telescopes are required to provide erect, bright, and clear images of near or distant objects.

3. REQUIRED EQUIPMENT

a. Measuring Tape
b. Ruler
c. Caliper
d. Suitable Scale for weighing
e. Still Camera and Film
f. Vibration Test Fixture as follows:

1) Physically suitable for mounting the test item in a normal

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position.

2) Capable of operating at a constant 30 cycle per second frequency with an amplitude of 1/16th inch.

g. Environmental Test Chambers

1) Rain Test Chamber with the following characteristics:

a) Physically suitable for mounting the test item in a normal operating position.
b) Capable of producing simulated rainfall as follows:

(1) Rate: 4 inches per hour, +1, -0, inches per hour.
(2) Rainfall type: small droplets.
(3) Rainfall temperature: between 52 degrees F. and 68 degrees F.
(4) Rainfall dispersion: uniform over the test item.
(5) Rainfall direction: variable between the vertical to 45 degrees from the vertical in any direction.

2) Temperature Test Chamber with the following characteristics:

a) Physically suitable for mounting the test item in a normal operating position.
b) Containing a view port or window through which the telescope objective lens or eyepiece lens may be clearly viewed during testing.
c) Capable of reaching and maintaining a temperature at least 10 degrees F. below test item specified internal gas dew point temperature.

3) Cold Test Chamber capable of the following:

a) Physically suitable for containing the test item and performing adjustment operability tests (paragraph 6.2.1.5)on the test item with the temperature stabilized at the specified low temperature.
b) Capable of descending to a temperature of -80 degrees F.

4) Oven type test chamber capable of the following:

a) Physically suitable for containing the test item and performing adjustment operability tests (paragraph 6.2.1.5)on the test item with the temperature stabilized at the specified high temperature.
b) Capable of being elevated to a temperature of +160 degrees F.

h. Pressurizing Gas and Associated Fixtures consisting of the following:

1) Nitrogen gas, dry, contained in a cylinder.
2) Suitable hoses, pressure regulator, and attachments/fixtures required for use with nitrogen gas cylinder and test item pressure connections.
3) Pressure gage, 0 psig to 10 psig, calibrated in tenths of a pound (psig).
4) "Tee" connectors and valves.

i. Thermocoupler capable of measuring from -80°F. to +160°F.
j. Test Targets

1) Test target consisting of symmetrical line pairs spaced such that the test item horizontal crosshair and vertical crosshair may be accurately and repeatedly positioned between corresponding test target vertical and horizontal line pairs.
2) Test target consisting of a single vertical line and a single horizontal line perpendicular to the vertical line within a tolerance of ±5 minutes.
3) Test target which is an enlarged facsimile of the test item reticle suitable for wall mounting. In addition, reproduce calibration points on the test target representing the specified test item reticle accuracy tolerance limits.
4) Test target as required in 2) with an additional set of calibration limit marks representing test item parallax limits.
5) National Bureau of Standards (NBS) resolution chart, part of NBS Circular 533, dated May 1953 (currently effective) or resolution chart as specified by and included as part of MIL-O-13830A.
6) Test target consisting of a rectangular wood or metal strip similar to a yard or meter stick with a scale calibrated in convenient units.
7) Linear distortion test target consisting of three vertical, equally spaced lines. The equal-distant line will be centered on the target surface and the lines to the right and left are to be spaced to represent the angular displacement from optical axis for which the test item linear distortion is specified.
8) Test target consisting of two vertical lines spaced to represent the angular subtense of arc at which the test item field of view is specified and the distance at which the target will be observed.

k. Auxiliary Telescopes, Collimators, and Diffraction Slits.

1) Low power auxiliary telescope or collimator with crosshairs and an angular displacement scale.
2) Auxiliary telescope of 1 to 2-power with provisions for measuring angular displacement in the horizontal and vertical planes. Crosshairs are required.
3) Collimator with built-in diffusion screen and light source

capable of operating at an approximate color temperature of 2500 degrees K.

4) Auxiliary telescope or pick-up lens system capable of focusing images onto the plane of the single slit specified by 3.k.5.
5) Single vertical slit of the following approximate dimensions: 1.5mm wide and 5mm high and is otherwise suitable for projecting a diffracted image onto the plane of the photomultiplier or phototube cathode.
6) Calibrated dioptometer, 3-power (3x) with focusing reticle.
7) Auxiliary telescope having a minimum of 3 power (3x) scaled in diopter.

l. Electronic Components

1) Photomultiplier or phototube with a RETMA spectral response of S-3.
2) Photomultiplier amplifier or signal processor for connecting with the output of the photomultiplier or phototube of item 1.1.
3) Output meter suitable for photomultiplier or phototube calibrated in percent, 0-100%.

m. Running Torque Test Equipment

1) Inch-pound torque wrench capable of measuring running torque values specified for the test item.
2) Adapters suitable for connecting torque wrench to test item adjustment knobs.

n. Special Test Equipment or Fixtures

1) United States Weather Bureau type rain gage.
2) Dew point test set, capable of measuring dew point temperatures to -25 degrees F.
3) Lens bench, suitable for mounting the test item, electronic equipment, collimator, pick-up lens system, and diffraction slit.
4) Tripod or other suitable foundation (i.e. lens type bench) for mounting the test item.

4. REFERENCES

A. USATECOM Regulation 385-6 Safety Release.
B. USATECOM Regulation 705-4 Equipment Performance Report.
C. USATECOM Regulation 700-1 Value Engineering.
D. MIL-F-13926A(MU) Fire Control Materiel: General Specification Governing the Manufacture and Inspection of.
E. MIL-O-13830A Optical Components for Fire Control Instruments; General Specification Governing the Manufacture, Assembly, and Inspection of.

F. MIL-STD-1241A Optical Terms and Definitions.
G. National Bureau of Standards Circular 533 Method for Determining Resolving Power of Photographic Lenses, 20 May 1953.
H. MIL-STD-150A Photographic Lenses.
I. Kissam, Philip, Optical Tooling for Precise Manufacture and Alignment, McGraw-Hill Book Company, Inc., 1962.
J. MTP 10-2-500 Physical Characteristics.
K. MTP 10-2-501 Operator Training and Familiarization.
L. MTP 10-2-503 Surface Transportability (General Supplies and Equipment).
M. MTP 10-2-505 Human Factors Evaluation.
N. MTP 10-2-507 Maintenance Evaluation.
O. MTP 10-2-508 Safety.

5. SCOPE

5.1 SUMMARY

This procedure describes the preparation for and methods of evaluating the technical characteristics of telescopes and their suitability for service testing. The required tests are summarized as follows:

a. Preparation for Test - A determination of the condition and physical characteristics of the test item upon arrival and the requirements for operator training and familiarization.

b. Mechanical Evaluation - A study, at ambient temperatures, to determine test item quality of construction, internal cleanliness, sealing integrity, internal dew-point temperature, adjustment control operability, and the degree of azimuth and elevation gear-train backlash.

c. Reticle Accuracy - A study, at ambient temperatures, to determine test item reticle parallelism, scale calibration accuracy, and the degree of observed parallax.

d. Eyepiece Focus - A determination of test item capability to deliver diverging rays within a specified diopter range.

e. Resolution - A determination of test item capability to record fine detail in the object as limited by diffraction, optical system aberrations, and the precision employed in preparing and centering optical components.

f. Angular Magnification - A determination of test item capability to produce on an observer's retina an image expanded by a specified number of diameters when the object is being viewed at a specified distance.

g. Linear Distortion - A determination of test item image deformation as caused by possible variations in the magnification of the optical system.

h. Field of View - A determination of the maximum angle at which the test item will admit object field rays as limited by allowable image distortion.

i. Relative Light Efficiency - A determination of the relative loss of image brightness as a result of test item objective lens light reflection and additional light losses of optical components within the test item.

j. Extreme Temperature Effects - Determinations of test item adjustment operability while thermally stabilized at extreme temperatures and the

capability of the test item to meet all specified performance criteria while thermally stabilized at standard ambient temperatures following exposure and thermal stabilization at extreme hot and cold temperatures.

k. Transportability - An evaluation to determine test item and spedified shipping container capability to withstand shocks, extraneous forces, and impacts encountered during normal handling incident to shipment and while being transported.

l. Maintainability and Reliability Evaluation - That portion of the test which is concerned with the following: verification and appraisal of failures· determination and appraisal of maintenance characteristics and requirements; appraisal of design-for maintainability; appraisal of the maintenance test package· and, calculation of indicators which express the effects of the preceding aspects.

m. Safety - An evaluation to determine test item compliance with safety requirements and to confirm safety features of the test item.

n. Human Factors Evaluation - An evaluation of the man-item relationship during test item operation and maintenance.

o. Value Analysis - An evaluation to determine any unnecessary, costly or nice-to-have test item features which coul be eliminated without reducing test item performance or safety.

5.2 LIMITATIONS

The test procedures contained in this MTP are applicable to all types of telescopes except as specified by the following:

a. Observation telescope applicability:

1) Mechanical evaluation tests and reticle accuracy tests are applicable to observation telescopes only as specified by test item Technical Characteristics or other governing documents.
2) Image assessment engineering tests provided herein are applicable to observation telescopes to the extent specified by test item Technical Characteristics or other governing documents.

b. Transportability, maintenance, safety, human factors, and value analysis evaluations prescribed by this document are applicable to all types of telescopes selected for testing.

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 Initial Inspection

Perform the initial inspection according to MTP 10-2-500, and visually inspect the test item and record evidence of in:

a. Manufacturing

b. Material
c. Workmanship

NOTE: The visual inspection shall include, but not be limited to the following considerations:

a. Optical Glass, Physical Quality: Glass defects including striae, cords, ream, bubbles, seeds, strain, laps, or folds in pressing should not be evident. Scratches present on optical surfaces should not exceed one quarter the diameter of the element containing a scratch, or as otherwise specified. The permissible number of maximum size digs should not be more than one per each 20mm of diameter or fraction thereof on any optical surface. In the absence of specific test item scratch and dig requirements, consult MIL-O-13830A, Table I. (This table is reproduced as part of this document as Appendix A.)
b. Reticle Quality: Reticle markings should be inspected primarily for legibility, unless otherwise specified. Normally, defects in reticle numbers or letters will be acceptable provided each letter or figure is legible beyond doubt. All reticle lines should appear uniform in width and depth and intersections of lines should appear to be sharp.
c. Construction: Unless otherwise specified, the use of pads, shims, wedges, or openings under or around optical elements is not acceptable. All test item metal surfaces should be free from burrs and sharp edges. Material should be sound, of uniform quality and condition, and be free of seams, cracks, and other defects which may adversely affect the strength, endurance, or wear resistance of the test item.
d. Workmanship: Workmanship should be of a quality consistent with the highest existing instrument production standards and practices.

6.1.2 Physical Characteristics

a. Determine the physical characteristics of the test item in accordance with the applicable procedures of MTP 10-2-500 and the following:
b. Weigh and measure the test item, as applicable, and record the following:

1) Weight
2) Overall length
3) Diameter of lens barrel
4) Effective objective lens diameter
5) Effective eyepiece lens diameter
6) Azimuth setting circle calibration
7) Elevation setting circle calibration
8) Reticle calibration
9) Rated angular magnification

10) Rated resolution
11) Rated field of view
12) Eyepiece focus range
13) Rated parallax
14) Filter(s) description and type

6.1.3 Operator Training and Familiarization

Test personnel shall receive training and familiarization in accordance with applicable procedures of MTP 10-2-501 and the following:

NOTE: Personnel operating the test item should never attempt to observe the sun or any other intense light source.

a. Familiarize the test team concerning the purpose and methods of conducting telescope engineering tests. The following topics should be stressed during these familiarization sessions:

1) Tests: Fire control type telescopes are used to measure or establish certain geometric relationships, which to be accomplished successfully must be based on the maintenance of certain geometric relationships within the instruments themselves. These geometric relationships must be tested to determine the extent of errors involved and under what conditions these errors are minimum and maximum.
2) Order of Test Item and Test Equipment Adjustment: Stress the fact that certain tests are meaningless unless certain relationships have been previously established. Therfore, tests and adjustments should be carried out in the specified order so that factors affecting each test will have been established and re-testing and re-adjustment will be reduced or eliminated.
3) Test Equipment: Ensure that each team member understands the requirement for each specified test equipment and test fixture. Orient the team jointly and by example illustrate methods of establishing a line of sight, adjusting telescopes to minimize reticle parallax, leveling, and establishing planes parallel to local vertical.
4) Terminology: Familiarize team members with trade terms and unique or state-of-the-art optical terminology not otherwise defined in the supplied instructional matter.

b. Record test personnel data as required by MTP 10-2-501.

6.2 TEST CONDUCT

NOTE: All equipment failures shall be reported in accordance with USATECOM Regulation 705-4.

6.2.1 Mechanical Evaluation

6.2.1.1 Vibration

Determine the test item quality of construction and internal cleanliness by performing the following:

a. Rigidly mount the test item in a normal operating position on the vibration test fixture. (See item f. of Paragraph 3.)

b. Set the vibration test fixture operating controls to obtain a vibration frequency of 30 cycles per second and a vibration amplitude of 1/16th inch.

c. Activate the vibration test fixture and vibrate the test item for 5 minutes ±15 seconds at the specified frequency and amplitude. Record the frequency and amplitude of vibration used.

d. Following conduct of the vibration test, inspect the test item and record evidence of defects, including the following:

1) Loose parts
2) Damaged components
3) Internal dirt or lint particles

a) Number of particles grouped by dig size.
b) Location of particles in respect to optical axis.
c) Extent to which particles interfere with test item observation or adversely affect image quality.

4) Overall soundness of test item construction and degree of internal cleanliness.

6.2.1.2 Leakage (for Non-Pressurized Telescopes)

Determine test item capability of preventing the entrance of water or water vapor into telescope internal spaces or optical cavities, by performing the following:

a. Set up the rain test chamber (see item g.1 of Paragraph 3) to produce the following:

1) Rate: 4 inches per hour, +1, -0, inches per hour.
2) Rainfall type: small droplets.
3) Rainfall temperature: between 52 degrees F. to 68 degrees F.
4) Rainfall dispersion: uniform over the test item.
5) Rainfall direction: variable between the vertical to 45 degrees from the vertical in any direction.

b. Mount the test item in a normal operating position in the rain test chamber.

NOTE: The test should be conducted with a rain chamber temperature between 68 degrees F. and 86 degrees F.

c. Activate the rain test chamber and conduct the test for 2 hours, directing simulated rainfall on all test item surfaces which are normally subjected to rain.

d. Measure and record the following for each phase of the test (change in the direction of the rain):

1) Rainfall direction.
2) Test chamber temperature.
3) Length of exposure.
4) Rainfall type.
5) Rainfall dispersion.
6) Rate of rainfall as measured by a U. S. Weather Bureau type rain gage.

e. At the completion of the 2 hour test period, remove the test item and conduct an examination recording evidence of the following:

1) Water penetration into telescope internal spaces or optical cavities.
2) Internal damage to the test item.
3) External damage to the test item.

6.2.1.3 Optical Cavity Dew Point

Determine, where applicable, the dew point of the gas or gaseous mixture sealed within test item optical cavities by performing the following:

a. Mount the test item within the temperature test chamber described in paragraph 3.g.2.

b. Set temperature controls to obtain a chamber temperature of approximately 15 degrees F. above test item specified internal gas dew point temperature.

c. As the internal test chamber temperature is descending to the value specified in step b and subsequent to test item temperature stability at that value, observe telescope lenses for visible evidence of condensation on external or internal lens surfaces.

NOTE: 1. Condensation visible on external lens surfaces indicates excessive water vapor within the test chamber and an improper atmosphere for conducting the test.
2. Condensation visible on internal lens surfaces indicates failure of the test item to meet the specified internal gas dew point requirement. In the event of this occurrence, the test director would void the dew point test and proceed with the Pressurization Test, 6.2.1.4. Upon successful demonstration of test item sealing capabilities during the pressurization test, the test director should require that the test item be re-cycled through the dew point test.

d. Reduce test chamber temperature by 5 degrees F. Allow time for test item temperature stability at the new value, and observe lens surfaces for visible evidence of condensation. The notes of step c shall apply. Record the temperature value and evidence of external or internal lens condensation.

e. Repeat step d with the test chamber temperature reduced to within 5 degrees of the specified internal gas dew point temperature value.

f. Reduce test chamber temperature in 1 degree F. increments until condensation on test item internal lens surfaces is observed or a temperature of approximately 7 degrees F. below the specified gas dew point is reached. Record the due point temperature or the fact that the test item exceeded the due point requirement by approximately 7 degrees F.

6.2.1.4 Pressurization

Determine the capability of test item seals and construction to withstand and retain internal gas or gaseous mixtures under pressure for a specified period of time, by performing the following:

a. Assemble the pressure test equipment (see item h of Paragraph 3) as indicated in Figure 1 and connect the apparatus to the test item.

b. Pressurize the test item to 5 pounds per square inch, gage. Retain the specified pressure for 5 minutes ±15 seconds. Record test item initial internal pressure and the internal pressure at the completion of the test period. Record the actual pressurization period.

NOTE: Typically, any drop in pressure will constitute unsatisfactory test item performance.

c. Slowly bleed gas from the test item optical cavity into the dew point tester. Measure the resulting dew point temperature. Continue to purge the test item optical cavity until the resulting dew point is equal to the specified value.

d. Pressurize the test item internally to the specified value. Record the final dew point and pressure values.

e. Re-seal the test item, as required.

6.2.1.5 Running Torque

Determine the running torque required to rotate test item adjustment knobs at standard ambient temperatures, by performing the following:

a. Prepare the inch-pound torque wrench and appropriate adapters of item m of Paragraph 3, to accommodate the following test item adjustment knobs, as applicable:

1) Reticle knob.
2) Diopter adjustment.
3) Azimuth worm knob.
4) Elevation worm knob.
5) Any test item adjustment knob which requires rotation during the courses of normal use.

b. Rigidly mount the test item in a normal operating position or as convenient for attaching the inch-pound torque wrench to the applicable test item adjustment knob.

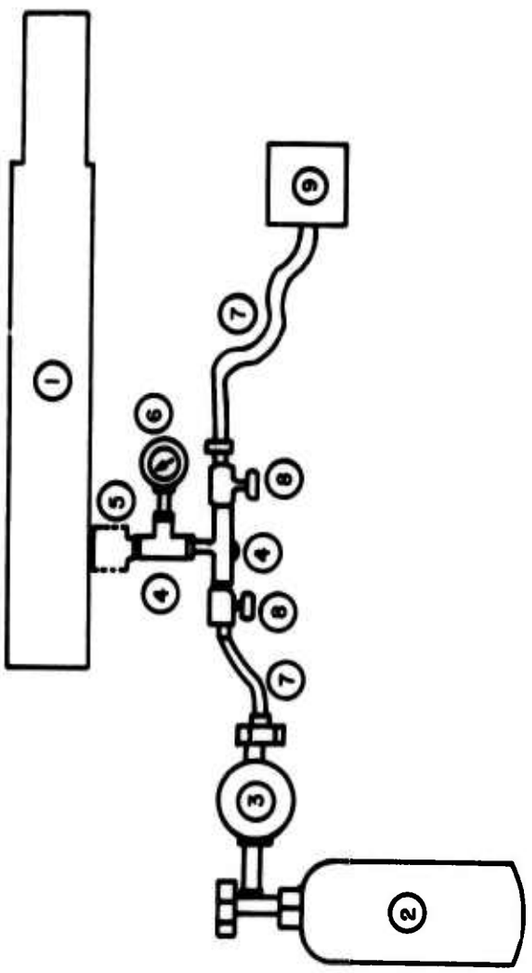


Figure 1. Typical Telescope Pressurization Test Setup.

c. Thermally stabilize the test item at an ambient temperature between 70 degrees F. and 80 degrees F. Record the temperature value.

NOTE: Thermal stabilization has been reached when the temperature of the largest internal centrally located test item mass does not vary more than 1 degree C. from the ambient temperature.

d. Attach the inch-pound torque wrench, with appropriate adapter, to each test item adjustment knob and perform the following:

1) Rotate the torque wrench/adapter/knob clockwise and while the knob is in motion, read the running torque required to rotate the knob.
2) Record the following:

a) Adjustment knob name
b) Running torque value
c) Direction of travel

3) Repeat steps d.1 and d.2 with the torque wrench/adapter/knob rotated in a counterclockwise direction.

6.2.1.6 Backlash

Determine the degree of accuracy to which the test item may be re-aimed or directed to a given set of coordinates as limited by the precision of azimuth and elevation setting mechanisms, by performing the following:

a. Rigidly mount the test item in a normal operating position.
b. Thermally stabilize the test item at an ambient temperature between 70 degrees F. and 80 degrees F. Record the stabilized temperature value.
c. Level the test item mount to local vertical such that azimuth rotation of the telescope lens barrel is in a horizontal plane.
d. Prepare a high contrast test target to serve as the test item pointing reference. Typically, the target will consist of symmetrical line pairs spaced such that the test item horizontal crosshair and vertical crosshair may be accurately and repeatedly positioned between corresponding test target vertical and horizontal line pairs. See Figure 2b for an illustration of a typical test target with dimensions based on a telescope crosshair angular width in the field of 2.5 to 3 seconds of arc.
e. With the test item elevation-depression mechanism indicator set to zero, level the test item such that the telescope line of sight is perpendicular to local vertical. Swing the telescope line of sight to several azimuth settings and verify that the line of sight, for each, is perpendicular to local vertical. Re-adjust overall test item leveling, as required.
f. Point the telescope to an arbitrary or convenient azimuth.
g. Extend the telescope line of sight along the azimuth of step f through test target center. The test target is positioned at a range of approximately 200 inches and mounted such that the target front surface is perpendicular to the line of sight. Record the test target range.

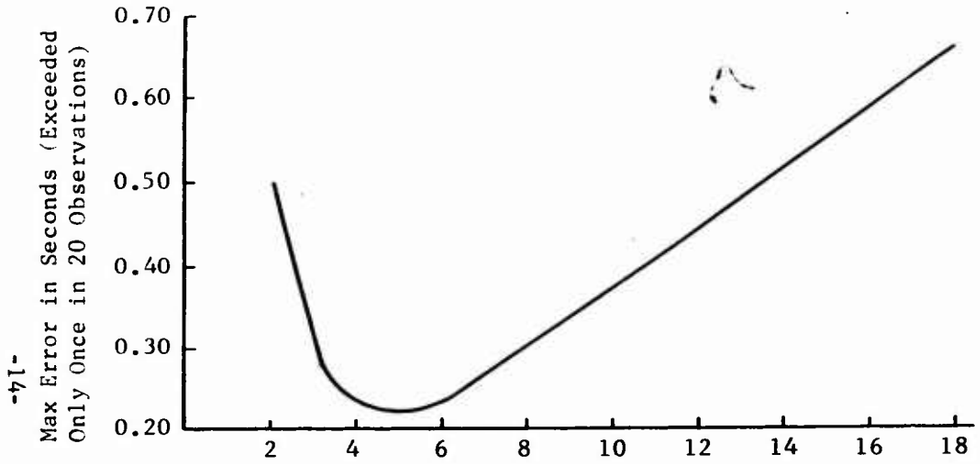
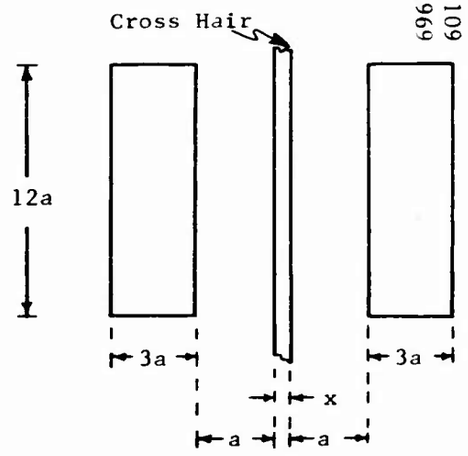


Figure 2a



NOTE: 1) "x", the width of cross hair in field of view can be taken as 2.5 to 3.0 sec of arc.
2) "a" dimension refers to desired or specified telescope crosshair positioning error.

Figure 2b

Figure 2. Precision Test Target Design Considerations Relating to Backlash Test

NOTE: If the dimensions provided by Figure 2a and 2b are used to construct the 200 inch-range test target and the telescope under test has a crosshair angular width of 2.5 to 3.0 seconds, the contribution of error due to positioning test item crosshairs on the test target will exceed 0.4 seconds only once in twenty different observations. Therefore, this error source may be considered, for practical purposes, to be a constant bias.

h. With the test item-target positional relationship established by step g, rotate the line of sight in azimuth 15 to 20 degrees counterclockwise. Slowly rotating the azimuth control clockwise, bring the test item vertical crosshair into the space between the test target vertical lines without overtravel. With the greatest accuracy possible, read from the azimuth indicator test item line of sight bearing. Record this azimuth value.

i. Rotate the test item azimuth control 15 to 20 degrees clockwise from the position established in step h. Reverse direction and without observing the test target, re-position the azimuth indicator to exactly the same reading as obtained in step h. Overtravel while performing this step will void the test.

j. Observe the test target through the test item. Note the deviation in mils of the test item vertical crosshair from the position of desired alignment between the test target vertical lines. Record the value of horizontal adjustment backlash.

k. Realign the test item vertical crosshair between the test target vertical lines.

l. Elevate the test item line of sight 15 to 20 degrees. Slowly depressing the line of sight, bring the telescope horizontal crosshair into the space between the test target horizontal lines without overtravel. With the greatest accuracy possible, read from the elevation indicator test item line of sight elevation. Record this elevation value.

m. Depress the test item line of sight 15 to 20 degrees, or as practical. Reverse direction and without observing the test target, reposition the elevation indicator to exactly the same reading as obtained in step l. Overtravel during this step will void test.

n. Observe the test target through the test item. Note the deviation in mils of the horizontal crosshair from the central position between the target horizontal lines. Record the value of vertical adjustment backlash.

6.2.2 Reticle Accuracy

6.2.2.1 Reticle-Image Parallelism and Image Tilt

Determine the degree of accuracy with which the test item vertical reticle line can be made parallel to local vertical and the horizontal reticle line can be made parallel to a plane perpendicular to local vertical, and determine the degree of test item image rotation from the vertical when the test item reticle is in coincidence with local vertical by performing the following:

a. Mount the test item on a lens type bench or other suitable

foundation.

b. Mount a high contrast test target consisting of a single vertical line and a single horizontal line (see item j.2 of Paragraph 3) on a vertical surface and plumb the test target vertical line to a local vertical within a tolerance of 5 minutes.

c. Position the test item at a convenient distance from the test target so that the extended line of sight passes perpendicularly through the intersection of the test target vertical and horizontal lines. Record the test target-test item distance.

d. Mount auxiliary telescope (see item k.2 of Paragraph 3) along the test item's line of sight.

e. Sighting through the auxiliary telescope, bring the auxiliary telescope crosshairs into coincidence with the test target vertical and horizontal lines.

f. Sighting through the test item, position one extremity of the test item's vertical crosshair coincident to the test target vertical plumb line.

g. Sighting through the auxiliary telescope, observe the opposite test item vertical crosshair extremity and record the angular deviation of the test item's vertical crosshair from local vertical. In a similar manner, observe and record angular deviation of the test item's horizontal crosshair from the test target horizontal line.

h. Remove the test item from the established line of sight.

i. Observe the test target through the auxiliary telescope. Perform adjustments as required to cause the resulting line of sight to be perpendicular to the intersection of the test target vertical and horizontal lines. Also, position auxiliary telescope crosshairs in coincidence with the test target vertical and horizontal lines.

j. Introduce the test item into the auxiliary telescope line of sight. Sight through the test item and position the vertical and horizontal crosshairs in coincidence with the test target.

k. Sight through the auxiliary telescope and the eyepiece of the test item to the target. Since the auxiliary telescope vertical crosshair represents local vertical (established in step i), image tilt due to the test item will appear as illustrated by Figure 3. Utilizing the auxiliary telescope angular displacement scale, measure test item image tilt and record the value.

6.2.2.2 Reticle Scale Spacing

Determine the accuracy to which test item reticle calibration has been accomplished, by performing the following:

a. Mount the test target, an enlarged facsimile of the test item reticle (see item j.3 of Paragraph 3) on a wall or other suitable vertical surface at the proper distance for target scale dimensions.

NOTE: 1. The dimensions of the test target will be scaled to suit individual reticle designs and the distance selected or specified for separating the test item from the target. If, for example, a distance of 400 inches is used, the

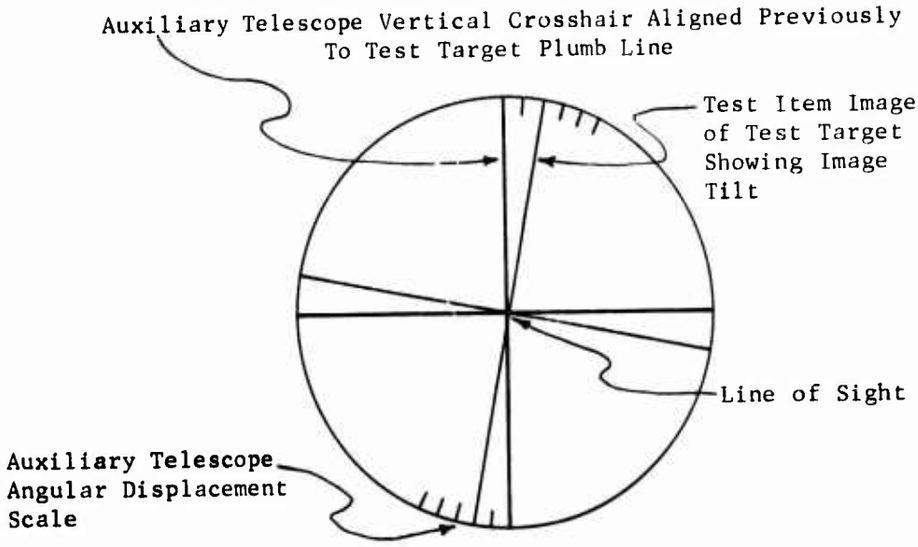


Figure 3. View Through Auxiliary Telescope Illustrating Image Tilt

spacing of angular scale calibration marks can be based on the fact that 0.002 inches is subtended for each second of arc at 400 inches.

2. For test item reticles which are calibrated with conventional or standard scales intended for measuring angles (in degrees, minutes, and seconds, or mils) or linear displacements, existing collimator targets may prove suitable for this test if accuracy permits comparisons within or exceeding specified test item tolerances.

b. Mount the test item on a tripod or other rigid foundation.

c. Adjust test item height and horizontal/vertical displacement to cause the line of sight to be perpendicular to the test target.

d. Precisely adjust the test item reticle boresight mark coincident with the appropriate test target reference point. Compare the reticle with the test target and record the cumulative scale error that exists at the reticle extremely opposite to the boresight reference point. Regardless of the cumulative scale error value, compare on a mark by mark basis and record the existence of any displaced scale mark and resulting incorrect scale interval.

6.2.2.3 Reticle Parallax

Determine the extent of apparent movement of the test item reticle line(s) in relation to the target image when the observer's head is moved from side to side or up and down, by performing the following:

a. Rigidly mount the test item in a normal operating position.

b. Mount the test target of item j.4 Paragraph 3, at the specified distance and at a height compatible with the test item mounting arrangement. Plumb the target front surface to local vertical.

NOTE: 1. The interval separating calibration marks is a function of the distance at which the parallax requirement is specified. This distance may typically range from 140 yards to 900 yards.

2. Generally, parallax requirements for precision instruments are severe and may be specified such that the maximum allowable parallax error is not to exceed the width of a reticle line at the specified range.

c. Establish the test item line of sight perpendicular to the test target. Position the test item's crosshair or reticle coincident with the test target vertical or horizontal line.

NOTE: When a telescope is carelessly focused, the image may be formed in front of or behind the plane of the crosshairs or reticle. Under these conditions, parallax will exist regardless of telescope assembly precision and excellence of optical correction. Therefore, prior to testing a given telescope to specified tolerances, it is necessary to obtain a high degree of accuracy in focusing both the eyepiece and

the image to the plane of the crosshairs or reticle. Steps d through j are specifically designed to reduce parallax errors to those of telescope design and/or defects existing in overall optical quality.

d. Adjust the position of the eyepiece until test item crosshair or reticle is seen with optimum definition and clarity.

e. Focus the objective lens until the target image is clearly defined.

f. Test for parallax by moving the eye to the left or right (or up and down). If the crosshair appears to move with respect to the object, change the focus of the objective lens until the apparent motion is reversed.

g. Continue focusing back and forth, reducing the apparent motion each time until a minimum is obtained.

NOTE: At this point it may be necessary to adjust the eyepiece lens slightly to bring the object image and the crosshair image into precise focus.

h. Measure the parallax at optical center as observed when moving the eye left and right (and/or up and down). Record the distance at which parallax was measured and the observed parallax values following several observations.

NOTE: Personnel making these observations should possess normal visual acuity.

6.2.3 Eyepiece Focus

Determine the capability of the test item to deliver diverging image rays within a specified diopter range, by performing the following:

NOTE: 1. The "diopter" is a measure of the power of a lens and is commonly used in measuring eyesight.
2. Telescopes are normally designed so that it is possible to move the eyepiece or optical parts of the eyepiece a short distance along the telescope tube and thereby accommodate the eye(s) of persons possessing normal vision (0 diopter), farsighted vision (- diopter), and nearsighted vision (+ diopter). Typically, a scale is provided by the telescope to indicate the divergence in diopters so that an observer can quickly set the eyepiece to a close approximation of the proper focus.

a. Sight through a dioptometer (see item k.6 of Paragraph 3) at a white background and adjust the eyepiece until the reticle is at a point of optimum definition and clarity. Position the barrel (objective) of the dioptometer to set the index to zero.

b. Rigidly mount the test item and orient such that the dioptometer may be introduced into the line of sight.

c. Position the dioptometer behind the test item eyepiece and along

test item line of sight.

d. Set the test item eyepiece diopter knob to indicate zero.

e. Sighting through the dioptometer to the telescope reticle assembly, adjust the dioptometer barrel (objective) to obtain best focus of the test item reticle.

f. Observe the dioptometer barrel scale and index. Record the error in test item diopter calibration.

g. Following an identical procedure, position the test item diopter knob to each scribed setting (+ diopter and - diopter) and establish best focus with the dioptometer barrel. Observe the dioptometer scale and index and record, for each, the error or inability to obtain any actual diopter value.

6.2.4 Resolution

Determine test item capability to record fine detail in the object as limited by diffraction, optical system aberrations, and the precision employed in preparing and centering optical components, by performing the following:

NOTE: The limit of resolution is defined as the smallest angle separating two points for which the two points are still distinguishable as separate points.

a. Ready an auxiliary telescope with 3-power (3X) scaled in diopter for use (see item k.7 of Paragraph 3).

NOTE: The use of the auxiliary telescope in this test is to ensure that the observer's eye is not the limiting factor in the determination of resolution.

b. Mount a copy of the high-contrast resolution wall test chart which is shown in the National Bureau of Standards (NBS) Circular No. 533, or a resolution chart specified for the test item on a flat vertical surface. Record the type resolution chart utilized.

NOTE: An alternate wall chart commonly employed for resolution testing is provided as part of MIL-O-13830A. Procedures and computation required for its use will be similar to those described herein.

c. Mount the test item oriented so that the auxiliary telescope may be conveniently introduced into the test item line of sight behind the eyepiece.

d. Determine the distance required between the test item objective lens and the resolution chart as follows:

1) Using the specified test item resolution value in seconds of arc, select from TableI the identical value (seconds column) and the applicable resolution pattern number. If, for example, the test item resolution value was specified to be 6 seconds of arc, according to Table I, the test chart

NBS PATTERN NUMBER	LINE WIDTH	ANGULAR SEPARATION FOR A TARGET DISTANCE OF:			
		25ft	35ft	50ft	100ft
	mm	seconds	seconds	seconds	seconds
80	0.31	8.5	6.0	4.2	2.1
56	.45	12.1	8.6	6.0	3.0
40	.62	16.9	12.1	8.5	4.2
28	.89	24.2	17.3	12.1	6.0
20	1.25	33.8	24.2	16.9	8.5
14	1.79	48.3	34.5	24.2	12.1
68	0.37	10.0	7.1	5.0	2.5
48	.52	14.1	10.1	7.0	3.5
34	.74	19.9	14.2	10.0	5.0
24	1.04	28.2	20.1	14.1	7.1
17	1.47	39.8	28.4	19.9	10.0
12	2.08	56.4	40.3	28.2	14.1

Table I. Angular Separation of Lines in the Various National Bureau of Standards (NBS) Circular No. 533 Resolution Chart Patterns at Different Viewing Distances

could either be placed 35 or 50 feet from the test item. Where 35 feet is convenient, test pattern No. 80 is used for the test. Otherwise, test pattern No. 56 is satisfactory and will provide identical results.

2) For specified resolution values not directly found in Table 1, locate in the "seconds" column the approximate resolution value and select a pattern number. Using the specified resolution value and the line width corresponding to the selected pattern, compute the exact distance required between test item objective lens and the chart, as follows:

a) ANGULAR SEPARATION IN SECONDS = ARC TAN X $\frac{\text{LINE WIDTH (mm)}}{\text{TGT DISTANCE (mm)}}$

b) Solve for TGT DISTANCE and convert to feet or meters and record the value.

e. Position the test item so that the test item line of sight passes perpendicularly through the chart pattern numeral of the chart selected in step d and so that the test item chart distance is equal to the distance selected. Record the number of the chart pattern used and the test item chart distance used.

f. Carefully focus the test item to obtain optimum definition and clarity at center field.

g. Introduce the auxiliary telescope into the line of sight behind the test item eyepiece. Focus the auxiliary telescope to obtain optimum definition and clarity at center field.

h. Observe the resolution chart through the auxiliary telescope through the test item and count the vertical lines near optical center. If the correct line count is obtained indicating that each line can be distinguished from the background, vertical resolution meets the specified resolution requirement at center field. Record the results of vertical resolution observations at center field.

i. Observe the vertical resolution pattern toward the extremity of the lines. At the point where an accurate line count is not possible and the lines are impossible to discern individually, re-focus the auxiliary telescope. If the line count can be correctly accomplished within a focus range of ±1/8 diopter, or as otherwise specified, the vertical resolution toward the edge of field meets typical resolution requirements. Record the results of vertical resolution observations toward edge of field.

j. Repeat steps h and i using the horizontal lines on the resolution chart.

k. For test item equipped with objective lens filters, repeat steps h through j for each filter installed or specified. Record the filter identification for each filter tested.

6.2.5 Angular Magnification

Determine test item capability to produce on an observer's retina an image expanded by a specified number of diameters when the object is being viewed at a specified distance, by performing the following:

a. Attach two movable markers, which can be seen by the naked eye at the distance at which the target image in the test item will be sharp when the test item is focused to infinity, to the test target described in item j.6 of Paragraph 3.

b. Mount the target along the vertical.

c. Rigidly mount the test item so that the test item line of sight is perpendicular to the target and at a distance from the target which will allow the test item to be focused to infinity, or at a distance specified for the test item magnification test. Record the test item-target distance.

d. Station a member of the test team at the target for the purpose of setting the moveable markers when required by the test item observer.

e. Sight through the test item and choose a certain section of the target scale for reference. (If, for example, a target scale calibrated in inches is used, select the 9 inch and 10 inch marks as illustrated by Figure 4.) Record the telescope viewed scale calibration interval selected.

f. While sighting through the telescope with one eye, as specified in step 3, look directly at the target scale with the other eye. Signal the assisting team member to adjust the two moveable markers on the scale as seen by the naked eye until they appear to be opposite the chosen marks as seen through the telescope. (Continuing with the example of step e: if, the markers were separated by 18 inches and the reference interval was 1 inch, the telescope magnification is 18 diameters.) Record the interval between the moveable target markers.

NOTE: MAGNIFICATION will change when the objective lens and eyepiece are moved in focusing. Therefore, telescope magnification is changed when focused on objects at different distances or when the eyepiece is adjusted for a different observer's eyesight.

6.2.6 Linear Distortion

Determine the degree of test item image deformation as caused by variations in the magnification of the optical system, by performing the following:

a. Mount the linear distortion test target of item j.7 of Paragraph 3 on a suitable vertical surface.

NOTE: Although line height and width are not critical, these dimensions should be considered in respect to the distance at which the target is to be viewed.

b. Rigidly mount the test item on a lens type bench or other suitable foundation.

c. Position the test item at the distance from the test target for which the target lines will represent the specified linear displacement and ensure that the test target is perpendicular to the test item line of sight at the target center line. Record the distance between the test item and the target.

d. Level the test item and obtain a clear focus of the test target.

e. Install the auxiliary telescope, described in item k.2 of Paragraph 3 along the line of sight behind the test item eyepiece and obtain a clear focus of the centerline image.

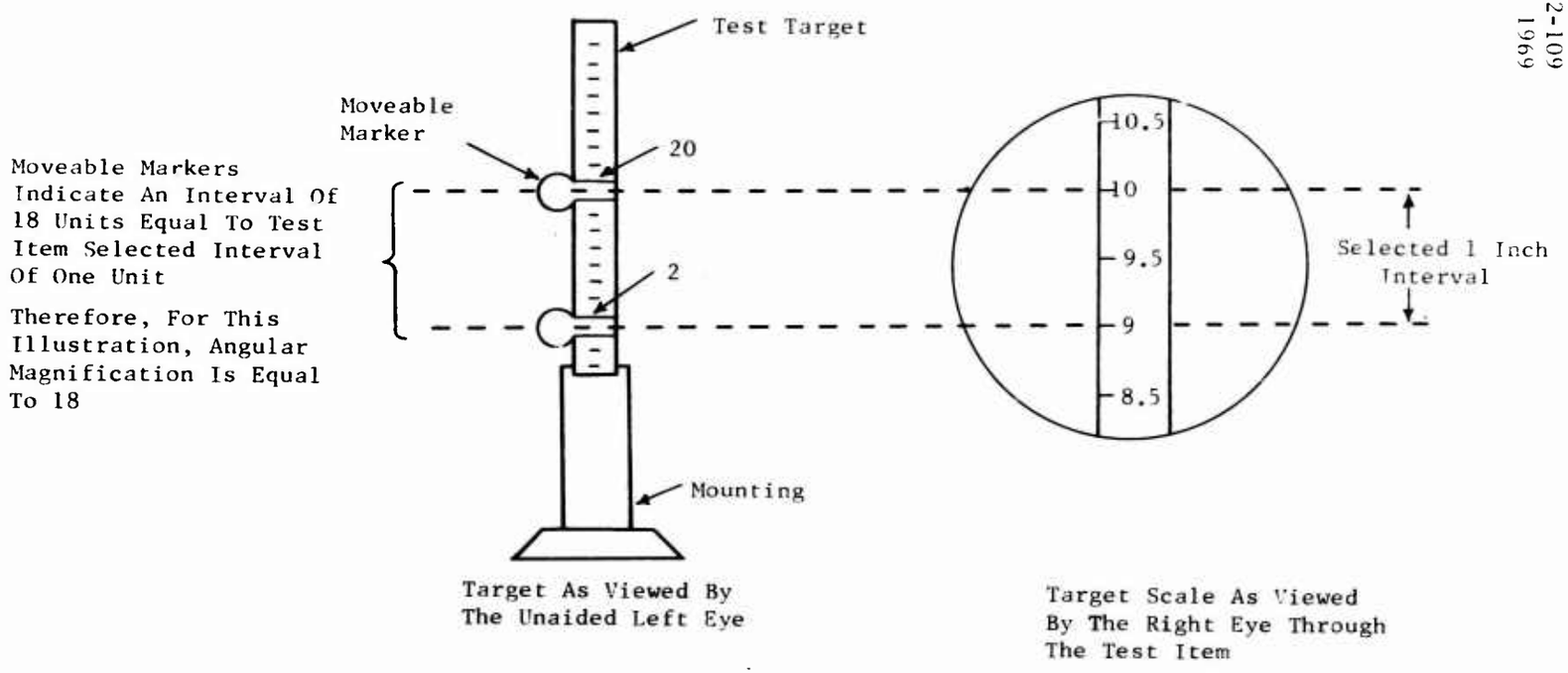


Figure 4. Illustration Of Angular Magnification Determination Method

f. Align the telescope vertical crosshair to the center line and with the telescope, measure and record the angular height of the test target center line.

g. Rotate the telescope around the entrance pupil to the right test target line. Align the line to the telescope vertical crosshair and measure. Record the angular height of the line.

h. Rotate the telescope around the entrance pupil to the left test target line. Align the line to the telescope vertical crosshair and measure and record the angular height.

6.2.7 Field of View

Determine the field of view of the test item by performing the following:

a. Mount the test item on a tripod or similar rigid base at the distance specified (approximately 15 feet) from a smooth vertical surface and record the distance.

b. Prepare a test target consisting of two vertical lines spaced to represent the angular subtense arc at which the test item field of view requirement is specified and the distance selected for placement of the test item from the test target.

NOTE: The test target would typically be of high contrast, i.e., 50/1 to 100/1. Line width would typically be as narrow as possible, but within the resolving capabilities of the test item.

c. Attach the test target to the vertical surface.

NOTE: The test setup is aligned such that the optical axis of the test item is perpendicular to the plane of the test target at a point equal distant between the test target vertical lines.

d. Install a light to illuminate the test target with visible light.

e. Observe the test target through the test item. Record the number of vertical lines visible.

f. If two test lines are visible, decrease the distance between the point of original observation and the test target in small increments. Continue until one or both lines disappear from the field-of-view. Record the distance value.

g. When fewer than two lines are observed in step g, increase the distance between the point of the original observation and the test target in small increments. Continue until both lines are visible. Record the distance value.

6.2.8 Relative Light Efficiency

Determine the relative loss of image brightness as a result of objective lens light reflection and light losses within the test item, by

performing the following:

a. Assemble the following components, described in Paragraph 3, as shown in Figure 5.

NOTE: Do not introduce the test item into the test setup optical path at this time.

1) Collimator as indicated in k.3.
2) Photomultiplier or phototube of item 1.1.

NOTE: The S-3 photo surface has a response closest to that of the human eye.

3) Pick-up lens system or auxiliary telescope of item k.4.
4) Single vertical slit of item k.5.
5) Lens type bench of item n.3.
6) Amplifier or signal processor of item 1.2.
7) Output meter of item 1.3.

b. Apply power to the collimator light source. Adjust the focus of the collimator, auxiliary telescope, and slit to obtain a clear well defined image on the surface of the photomultiplier cathode. Record the lamp operating voltage and current values.

c. Close-off the light source from the photomultiplier cathode, and apply high voltage to the tube. Adjust the high voltage in relation to ambient temperature to attain the minimum operating dark current. The output meter should read zero percent. Record the photomultiplier high voltage and current values.

d. Admit light source rays onto the photomultiplier cathode and adjust the output to obtain a reading of 100%, following optimization of focus and other adjustments of test set up.

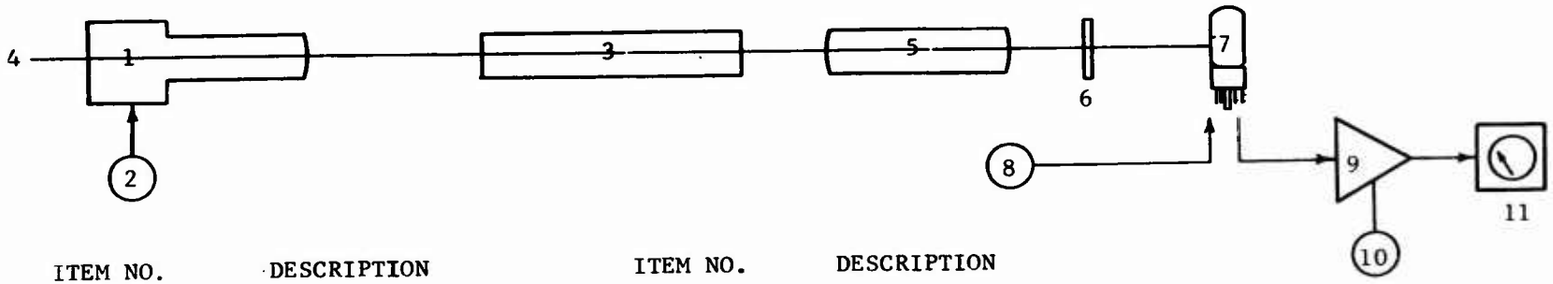
NOTE: 1. A change to any of the test apparatus adjustments following the establishment of the 100% point will void the test.
2. During this test, care should be exercised to prevent stray light from entering the test item, auxiliary telescope, slit, or photomultiplier cathode surface.

e. Introduce the test item into the optical axis of the test apparatus. Focus the test item objective lens barrel and eyepiece to obtain a maximum output as observed on the amplifier output meter. Record the relative loss of test item image brightness.

6.2.9 Extreme Temperature Effects

Determine the effects of extreme temperatures on the performance of the test item by performing the following:

6.2.9.1 Low Temperature Tests



ITEM NO.	DESCRIPTION	ITEM NO.	DESCRIPTION
1	Collimator and Lamp	6	Single Vertical Slit
2	Lamp Power Source	7	Photomultiplier Tube - S-3 Response
3	Test Item	8	Photomultiplier Power Supply
4	Optical Axis	9	Amplifier
5	Auxiliary Telescope	10	Amplifier Power Supply
		11	Output Meter

Figure 5. Schematic Layout Of A Typical Relative Light Efficiency Test Set-Up

a. Prepare the cold test chamber of item g.3 of Paragraph 3 for use.

b. Rigidly mount the test item in the cold chamber and attach a thermocouple to the largest centrally located test item mass.

c. Gradually reduce cold chamber temperature to -80 degrees F. and maintain this temperature until test item thermal equilibrium is attained.

NOTE: 1. Gradual temperature reduction is for protection of the test item and may vary as warranted within broad limits depending on how the particular telescope under test is expected to be affected by thermal shock.

2. Thermal stabilization has been reached when the temperature of the largest internal centrally located test item mass does not vary more than 1 degree C. from the ambient temperature.

d. Raise the chamber temperature to -40 degrees F. or to the value specified for testing running torque. Maintain this temperature until test item thermal equilibrium is attained. Record the stabilized temperature value.

e. Measure and record the running torque data values for each adjustment knob as directed in Paragraph 6.2.1.5.

f. Gradually increase cold chamber temperature to within the standard ambient test region of 60 F. to 90 degrees F.

g. Following attainment of test item thermal equilibrium, perform the following:

1) Inspect the test item for evidence of the following:

a) Lens cement separation
b) Glass breakage
c) Casting failure

2) Record a precise description of any defects found during this inspection and the stabilized temperature value.

h. Following the visual inspection of step g perform the tests listed below in their entirety recording data as required by the individual test.

1) 6.2.1 Mechanical Evaluation
2) 6.2.2 Reticle Accuracy
3) 6.2.3 Eyepiece Focus
4) 6.2.4 Resolution
5) 6.2.5 Angular Magnification
6) 6.2.6 Linear Distortion
7) 6.2.7 Field of View
8) 6.2.8 Relative Light Efficiency

6.2.9.2 High Temperature Tests

a. Prepare the oven type test chamber of item g.4 of Paragraph 3 for use.

b. Rigidly mount the test item with thermocouple attached in the oven

type chamber.

c. Gradually raise the oven chamber temperature to +160 degrees F. Retain this temperature until test item thermal equilibrium is attained.

d. Lower, gradually, the temperature to +150 degrees F. or to the temperature specified for testing running torque. Retain this temperature until thermal equilibrium is attained.

e. Perform the test procedures of step e of Paragraph 6.2.9.1.

f. Gradually reduce test chamber temperature to within the standard ambient test region of 60 degrees F. to 90 degrees F. Record the stabilized temperature.

g. Repeat the post temperature test procedures of steps g and h of Paragraph 6.2.9.1.

6.2.10 Transportability

Subject the test item to applicable procedures of MTP 10-2-503 and the following:

a. Visually inspect the test item for defects prior to testing. Record the findings of this inspection.

b. Upon completion of the test, visually inspect the test item for damage and record evidence of damages observed.

c. Determine if the operation of the test item has been affected by subjecting the test item to the Mechanical Evaluation of Paragraph 6.2.1.

6.2.11 Maintainability and Reliability Evaluation

Evaluate the maintenance-related factors of the test item as described in MTP 10-2-507 with emphasis on the following:

a. Organizational (O), Direct Support (F), and General Support (H) Maintenance requirements.
b. Operator through General Support Maintenance Literature.
c. Repair parts.
d. Tools.
e. Test and handling equipment.
f. Calibration and maintenance facilities.
g. Personnel skill requirements.
h. Maintainability.
i. Reliability.
j. Availability.

6.2.12 Safety

Subject the test item to the applicable procedures of MTP 10-2-508 and observe and record the following through the test:

NOTE: Issue safety regulations in accordance with USATECOM Regulation 385-6 and observe all normal precautions governing the operation of the test item and test equipment.

a. Any dangerous or unsafe condition or any condition that might present a safety hazard including the cause of the hazard and the steps taken to alleviate any such hazard.

b. The safety features incorporated into test item design.

c. Adequacy of warning instructions and markings.

d. Suggestions to improve the existing safety precautions.

6.2.13 Human Factors

Evaluate the human factors characteristics of the test item by subjecting it to the applicable procedures of MTP 10-2-505 and the following:

a. Determine whether the item can be carried and used as designed by 5th and 95th percentile combat soldiers and whether this will adversely affect the combat effectiveness. (Portability).

b. Determine the ease with which the system can be erected - if used with tripod.

c. Observe test team members during conduct of tests 6.2.1 through 6.2.9 and record evidence of the following:

1) Telescope eyepiece shield compatibility with personnel wearing spectacles.
2) Discomfort to telescope user caused by eyepiece material.
3) Confusion as a result of optical controls which operate in the opposite direction to the observed affect, i.e., focusing for distant objects by moving a control in rather than out.
4) Misalignment or overtravel by operator personnel caused by controls which have no "built-in" turning resistance.
5) Misalignment by operator personnel caused by critical control or controls not being protected by locks, guards, or recesses.
6) Misalignment by operator personnel due to placement of the controls, i.e., controls not accessible from normal operating position.
7) Confusion to operators caused by critical controls not containing positive "snap-action" feedback when changing settings.
8) Confusion to operators caused by lengthy narrative label(s) or improperly marked control label.

d. Record any inadequacies of telescope design affecting ease of vision, user comfort, etc.

e. Record any recommendation(s) to improve man-item effectiveness.

6.2.14 Value Analysis

Determine whether the test item has any non-functional, costly, or "nice-to-have" features as stated in USATECOM Regulation 700-1 by performing the following:

a. During operation of the test item, observe the test item for

features which could be eliminated without compromising performance, reliability, durability, or safety.

b. Question test personnel regarding features of the test item which could be eliminated without decreasing the functional value of the test item or decrease man-item effectiveness.

c. Record the following:

1) Non-functional, costly, or "nice-to-have" features of the test item.
2) Test personnel comments and opinions regarding features to be eliminated.

6.3 TEST DATA

6.3.1 Preparation for Test

6.3.1.1 Initial Inspection

Record the following:

a. Applicable data as indicated in MTP 10-2-500
b. For each test item component:

1) Manufacturing defects
2) Material defects
3) Workmanship defects

6.3.1.2 Physical Characteristics

Record the data required by MTP 10-2-500 and the following:

a. Weight, in pounds.
b. Overall length, in inches.
c. Diameter of lens barrel, in inches.
d. Effective objective lens diameter, in mm.
e. Effective eyepiece lens diameter, in mm.
f. Azimuth setting circle calibration, in applicable units.
g. Elevation setting circle calibration, in applicable units.
h. Reticle calibration, in mils, degrees, etc., including ammunition type, when applicable.
i. Rated angular magnification, in diameters.
j. Rated resolution, in seconds of arc.
k. Rated field of view, in degrees.
l. Eyepiece focus range, in diopter.
m. Rated parallax, in mils.
n. Filters, by type, loss, transmission frequency range.

6.3.1.3 Operator Training and Familiarization

Record the applicable data as indicated in MTP 10-2-501.

6.3.2 Test Conduct

6.3.2.1 Mechanical Evaluation

6.3.2.1.1 Vibration -

Record the following:

a. Vibration frequency, in cycles per second.
b. Vibration amplitude, in inches.
c. Evidence of the following:

1) Loose parts
2) Damaged components
3) Internal dirt or lint particles:

a) Number of particles grouped by dig size.
b) Location of particles in respect to optical axis.
c) Extent to which dust or lint particles interfere with test item observation or adversely affect image quality.

d. Overall soundness of test item construction and degree of internal cleanliness.

6.3.2.1.2 Leakage (for Non-Pressurized Telescopes) -

Record the following:

a. Length of time simulated rainfall was directed onto the test item, in hours.
b. For each phase of the rainfall exposure:

1) Rainfall direction, in degrees from the vertical
2) Test chamber temperature, in °F
3) Length of exposure, in minutes
4) Rainfall type, by digs description
5) Rainfall dispersion
6) Rate of rainfall, in inches per hour

c. Evidence of water penetration into telescope internal spaced or optical cavities.
d. Description of internal damage to test item.
e. Description of external damage to test item.

6.3.2.1.3 Optical Cavity Dew Point -

Record the temperature at which condensation appears on the internal lens surface of the test item.

6.3.2.1.4 Pressurization -

Record the following:

a. Test item initial internal pressure, in psig.
b. Test item internal pressure following the timed period, in psig.
c. Time of pressurization, in minutes and seconds.
d. Test item internal pressure prior to resealing, in psig.
e. Dew point of internal gas mixture prior to resealing, in degrees F.

6.3.2.1.5 Running Torque -

Record the following:

a. Test area temperature, in degrees F
b. For each adjustment knob tested:

1) Adjustment knob identification
2) Running torque value
3) Direction of travel

6.3.2.1.6 Backlash -

Record the following:

a. Test area temperature, in degrees F.
b. Range between the test item and the test target, in inches.
c. Azimuth reading of test target vertical line pair as obtained by clockwise rotation, in degrees and tenths of a degree.
d. Deviation of test item vertical crosshair from the central position between test target vertical lines when the azimuth control has been moved clockwise and then counterclockwise to the azimuth value recorded by c, in mils.
e. Elevation reading of test target horizontal line pair as obtained by depressing test item line of sight, in degrees and tenth of a degree.
f. Deviation of test item horizontal crosshair from the central position between test target horizontal lines when the elevation control has been depressed and then elevated to the elevation value recorded by d, in mils.

6.3.2.2 Reticle Accuracy

6.3.2.2.1 Reticle-Image Parallelism and Image Tilt -

Record the following:

a. Angular deviation of test item vertical crosshair extremity from local vertical, in mils.
b. Angular deviation of test item horizontal crosshair extremity from a line perpendicular to local vertical, in mils.
c. Range between test target and test item, in inches.
d. Test item image tilt measured in respect to the auxiliary telescope crosshairs representing ideal image orientation, in mils.

6.3.2.2.2 Reticle Scale Spacing -

Record the following:

a. Cumulative scale error, in reticle calibration units.
b. Identification of individual reticle calibration marks which are improperly etched.

6.3.2.2.3 Reticle Parallax -

Record the following:

a. Range between test item and test target, in inches
b. Parallax observed at optical center, in mils

6.3.2.3 Eyepiece Focus

Record the following:

a. Error in test item diopter calibration at zero diopter, in diopter.
b. Error in each test item diopter calibration mark, in ± diopter.
c. Inability to obtain an actual diopter value.

6.3.2.4 Resolution

Record the following:

a. Identification of resolution chart utilized.
b. Range distance between the resolution chart and the test item, in feet.
c. Line count for specified resolution requirement at center field.
d. Line count for specified resolution requirement at vertical extremity of pattern lines.
e. Line count for specified resolution requirement at horizontal extremity of pattern lines.
f. Vertical and horizontal line count for each test item filter, if applicable.

6.3.2.5 Angular Magnification

Record the following:

a. Distance between the test item and the target scale, in feet.
b. Scale interval selected for reference, in inches or cm.
c. Scale interval observed to be opposite reference interval, in inches or cm.

6.3.2.6 Linear Distortion

Record the following:

a. Distance between test item and test target, in feet.
b. Angular height of test target center line, in degrees, minutes and seconds.
c. Angular height of test target right line, in degrees, minutes and seconds.
d. Angular height of test target left line, in degrees, minutes and seconds.

6.3.2.7 Field of View

Record the following:

a. For the test target:

1) Line separation, in inches
2) Line width, in inches
3) Line height, in inches

b. Perpendicular distance in feet, between the test target and the test item.

1) At time of initial set-up
2) At which one or both lines disappear from view
3) At which both lines appear

6.3.2.8 Relative Light Efficiency

Record the following:

a. Light source operating voltage, in volts
b. Light source operating current, in amperes
c. Photomultiplier high voltage, in kilo-volts
d. Photomultiplier current, in milliamperes
e. Image loss of brightness, in percent

6.3.2.9 Extreme Temperature Affects

Record the following:

a. Temperature test performed (cold temperature, hot temperature)
b. For adjustment operability tests:

1) Temperature of test item
2) Running torque adjustment data as required in Paragraph 6.2.1.5

c. Damage to test item, including:

1) Lens cement separation
2) Glass breakage
3) Casting failure

d. Data as required by the following tests (at standard ambient temperature):

1) 6.2.1 Mechanical Evaluation
2) 6.2.2 Reticle Accuracy
3) 6.2.3 Eyepiece Focus
4) 6.2.4 Resolution
5) 6.2.5 Angular Magnification
6) 6.2.6 Linear Distortion
7) 6.2.7 Field of View
8) 6.2.8 Relative Light Efficiency

6.3.2.10 Transportability

Record the following:

a. Data required by applicable procedures of MTP 10-2-503
b. Damages observed, if any
c. Mechanical Evaluation data as required in Paragraph 6.2.1

6.3.2.11 Maintainability and Reliability Evaluation

Record data collected as described in the applicable sections of MTP 10-2-507.

6.3.2.12 Safety

Record the following:

a. Data collected as described by the applicable sections of MTP 10-2-508.
b. Dangerous or unsafe condition which presents or might present a safety hazard including the cause of the hazard and steps taken to alleviate any observed test item hazard.
c. Safety features incorporated into test item design.
d. Adequacy of warning instructions and markings.
e. Suggestions to improve existing test item safety precautions.

6.3.2.13 Human Factors

Record the following:

a. Data collected as described by applicable sections of MTP 10-2-505.
b. Portability of test item and adverse effects on the combat effectiveness of personnel carrying the test item.
c. Ease with which the system is erected, if used with a tripod.
d. Observed telescope eyepiece compatibility with personnel wearing spectacles.
e. Observed discomfort to the telescope user caused by eyepiece material.

f. Observed confusion by telescope user as a result of controls which operate in the opposite direction to the observed affect.

g. Observed misalignment by telescope operator personnel caused by controls which have no "built-in" turning resistance.

h. Observed misalignment by operator personnel caused by critical controls not being protected by locks, guards, or recesses.

i. Observed misalignment by operator personnel due to placement of controls.

j. Observed confusion to telescope operator personnel caused by critical controls not containing positive "snap-action" feedback when changing settings.

k. Observed confision to telescope operator personnel caused by lengthy narrative label(s) or improperly marked control label.

l. Observed telescope features of design which affected ease of vision, user comfort, etc.

m. Recommendations to improve man-item effectiveness.

6.3.2.14 Value Analysis

Record the following:

a. Non-functional, costly, or "nice-to-have" test item features.

b. Test personnel comments and opinions regarding test item features which could be eliminated.

6.4 DATA REDUCTION AND PRESENTATION

Data should be summarized to reveal significant discrepancies between the specified requirements and the observed performance of the test item and be presented in chart, tabular, or graphic form, as appropriate. Presentation shall be as described in the applicable sections of the reference MTP's and as follows:

6.4.1 Telescope Linear Distortion Test Data Reduction

a. Determine test item linear distortion, as follows:

$$\%\text{Linear Distortion} = \frac{(\text{Hgt. of Center Line}) - (\text{Hgt. of Right Line})}{(\text{Hgt. of Center Line})} \times 100$$

$$\%\text{Linear Distortion} = \frac{(\text{Hgt. of Center Line}) - (\text{Hgt. of Left Line})}{(\text{Hgt. of Center Line})} \times 100$$

b. Display the results as appropriate

6.4.2 Telescope Field of View Test Data Reduction

a. For test items which do not meet the specified field of view requirement, the test item is moved a greater distance from the test target. For these cases, calculate the actual field of view, with the specified test target, at the new perpendicular distance from the test target.

b. For test items which meet the specified field of view requirement, the test item is moved closer to the test target. For these cases, calculate the actual field of view, with the specified test target, at the new perpendicular distance from the test target.

c. Display these results as appropriate.

APPENDIX A

*Table A-I. Permissible Scratch and Dig Dimensions

Focal planes and near focal planes			Central zone 1/2 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

*This table is a reproduction of Table I of MIL-O-13830A