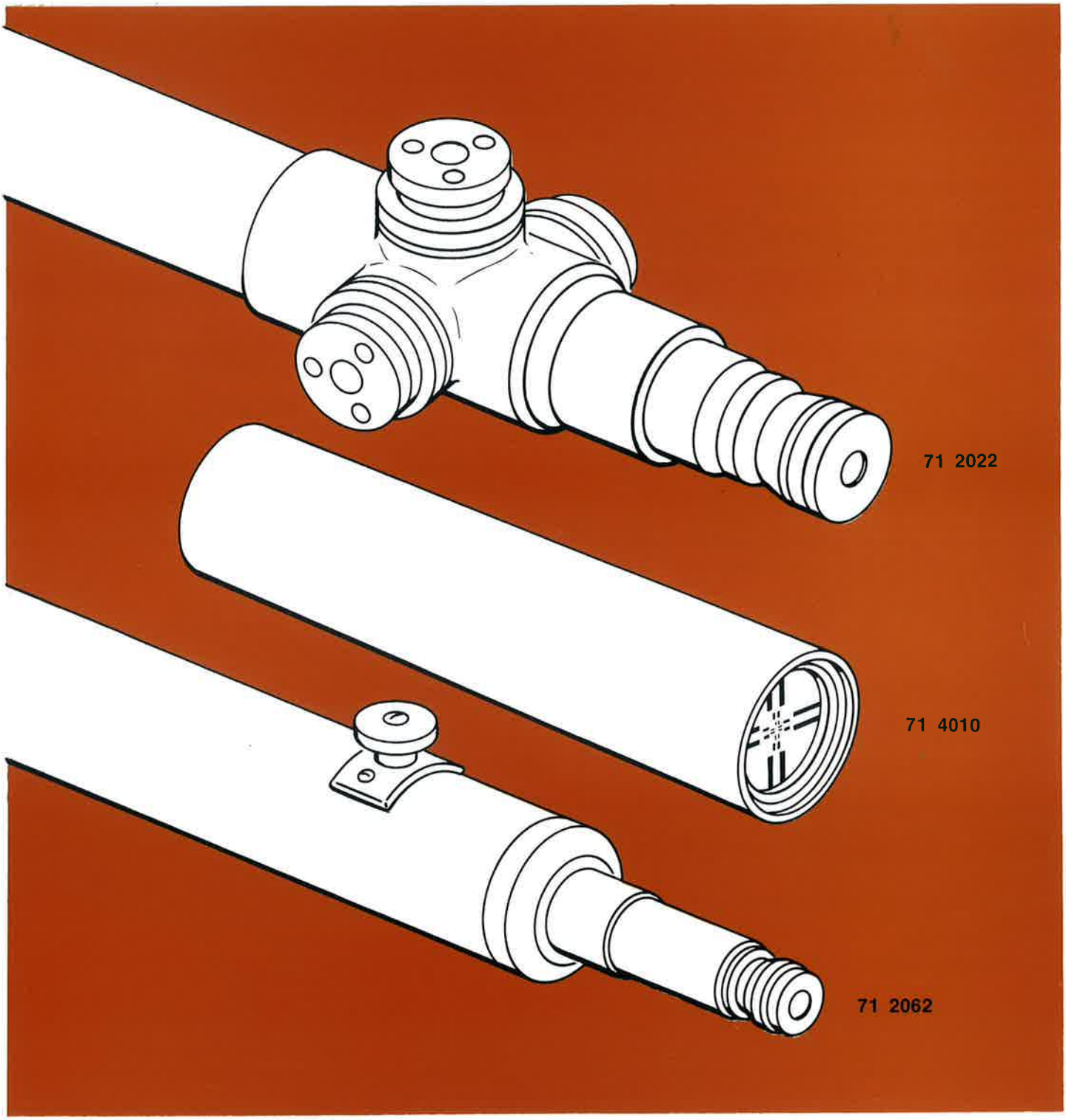
Alignment Telescope
Bright Line Alignment Telescope
Line of Sight Telescope & Alignment Collimator
Straightness of Line of Sight Collimator
Operating Manual

Manual No. 71 1000-1



METROLOGY SOLUTIONS INCORPORATED DBA
CUBIC PRECISION

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Product Number
71 1001 Optical Alignment Equipment Operating Manuals

Set of four operating manuals with illustrations and complete instructions for the use, care and adjustment of Optical Alignment Equipment. Also includes a comprehensive glossary of Optical Alignment Terms for easy and convenient referral.

The set includes the following manuals:

1. Alignment Telescope, Bright Line Alignment Telescope, Line of Sight Telescope and Alignment Collimator, Straightness of Line of Sight Collimator Operating Manual.
2. PARAGON® Tilting level, PARAGON Leveling Kit Operating Manual.
3. PARAGON® Jig Transit, PARAGON Jig Transit Telescope Square Operating Manual.
4. Alignment/Auto-Collimating Laser System Operating Manual.
5. Glossary of Optical Alignment Terms.

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TABLE OF CONTENTS

SECTION 1. INTRODUCTION

SECTION 2. OPERATION

SECTION 3. MAINTENANCE

APPENDIX-ACCESSORIES

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APPENDIX-ACCESSORIES (Continued)

LIST OF ILLUSTRATIONS

LIST OF TABLES

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Figure 1-1. Alignment Telescopes, Line of Sight Telescopes and Collimators

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SECTION 1 — INTRODUCTION

1-1. PURPOSE OF MANUAL

This manual provides operating and maintenance instructions for Cubic Precision Alignment Telescopes, Line of Sight Telescopes, Alignment Collimators and Straightness of Line of Sight Collimators. (See Figure 1-1.) Appendix A to this manual provides descriptive data and instructions for use of accessories that can be used with these instruments.

1-2. PURPOSE OF EQUIPMENT

Alignment Telescopes and Line of Sight Telescopes are used to establish a precise reference line of sight from which measurements can be taken. The Alignment Collimator is used to establish positions in reference to a line of sight and for checking and adjusting optical alignment and surveying instruments. It can also be used as an auto-collimator when it is equipped with an accessory Auto-Collimation Eyepiece. The Straightness of Line of Sight Collimator is used in testing and adjusting all optical metrological and surveying instruments. It checks the straightness of the line of sight of any telescope from minimum focus to 100 feet. Cubic Precision offers the following models:

71 2022 Alignment Telescope
71 2030 Bright Line Alignment Telescope
71 2062 Line of Sight Telescope
71 4010 Alignment Collimator
71 4030 Straightness of Line of Sight Collimator

1-3. DESCRIPTION

1-4. 71 2022 Alignment Telescope

The barrel of the 71 2022 Alignment Telescope consists of a heavy, through-hardened, stabilized tool-steel tube. The objective end is a cylinder approximately 9 inches long with a hard chrome surface ground to a 2.2498 + 0.0000/−0.0003 inch (Aircraft Industries Association standard diameter.) The rear section contains horizontal and vertical optical micrometers, the focusing knob, and the eyepiece. The line of sight is adjusted so that it coincides with the axis of the cylinder.

1-5. The telescope is erecting, and can be focused from zero to infinity. Magnification varies automatically from 4x at zero focus to 46x at infinity focus. It has an effective aperture of 42 mm. Resolving power is 3.4 seconds of arc (according to the Bureau of Standards test procedure). The image is especially bright and clear, with excellent definition. Coated optics are used throughout. An all-purpose, double glass reticle gives a cross-pattern with single lines top and right, and paired lines bottom and left. An auto-reflection target and an auto-collimation illumination unit are built in.

1-6. 71 2030 Bright Line Alignment Telescope

The 71 2030 Bright Line Alignment Telescope is similar to the 71 2022, but with the following differences:

1. The 71 2030 Bright Line Alignment Telescope has a right-angle eyepiece with a two-reticle system that consists of a dark field, bright line reticle, and a bright field, dark line reticle.

2. It does not include the built-in auto-reflection target.

1-7. The 71 2030 Bright Line Alignment Telescope, with the illumination switch on and the instrument focused at specific finite distances, will auto-reflect directly off spherical lens surfaces with or without anti-reflection coatings, and can be used to align optical trains.

1-8. 71 2062 Line of Sight Telescope

The barrel of the 71 2062 Line of Sight Telescope consists of a heavy, through-hardened, stabilized steel tube with a hard chrome surface that is ground to a 2.2498 + 0.0000/−0.0003 inch (Aircraft Industries Association standard diameter.) The telescope focusing knob is mounted on the barrel. The eyepiece is an erecting, achromatic eyepiece with a removable blank that permits installation of an accessory Auto-Collimation Conversion Unit.

1-9. The telescope is especially bright, with excellent definition. Magnification varies automatically from 23x at 7 inches to 35x at infinity. The effective aperture is 38 mm. Resolving power is 3.5 seconds of arc (according to the Bureau of Standards test procedure). Fully coated optics are used throughout. An all-purpose, doubleglass reticle gives a cross-pattern with single lines top and right and paired lines bottom and left. The instrument is furnished with a built-in auto-reflection target and an Auto-Collimation Illumination Unit.

1-10. Alignment Collimator

The 71 4010 Alignment Collimator consists of a hardened, stabilized steel tube with a hard chrome surface. Its outside diameter is 2.2498 + 0.0000/

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-0.0003 inches (Aircraft Industries Association standard). An achromatic lens is mounted near the front of the tube, and a special infinity target is mounted near the end of the tube at the principle focus of the lens. The rear end of the tube is threaded to accept an accessory lamp housing that illuminates the infinity target. The infinity target is graduated every 30 seconds with a total of 18 minutes of arc in four directions from zero. A second, paired-line target is centered on the collimator objective lens.

1-11. 71 4030 Straightness of Line of Sight Collimator

The 71 4030 Straightness of Line of Sight Collimator consists of a hardened steel tube which contains seven reticles placed so that they simulate targets placed at different distances. These reticle patterns form virtual images at the following approximate distances from the objective: 0, 4 feet, 10 feet, 25 feet, 50 feet, 100 feet, and infinity. The reticles have been centered as closely as possible on a single straight line.

1-12. ACCESSORIES

Accessories are available for use with instruments listed in Table 1-1. A brief functional description of each is provided in Section 2, starting with paragraph 0-0. For installation, operating procedures and adjustments, refer to the Appendix to this manual.

TABLE 1-1. ACCESSORIES AND APPLICABILITY

	Applicability				
Accessory	**71 2022**	**71 2030**	**71 2062**	**71 4010**	**71 4030**
71 1211 Auto-Collimation Conversion Unit			X		
71 1231 Right-Angle Eyepiece			X		
71 1241 Combination Auto-Collimation, Projection Right Angle Eyepiece			X		
71 2230 Right-Angle Eyepiece	X	X			
71 2240 Combination Auto-Collimation, Projection, Right-Angle Eyepiece	X	X			
71 2302 Angle Reading Attachment	X	X			
71 2410 Optical Square	X	X	X		
71 2412 Double Sphere Optical Square	X	X	X		
71 3205 Cross Level	X	X	X	X	
71 3220 Coincidence Striding Level	X	X	X		
71 3230 Coincidence Striding Level					X
71 4111 Auto-Collimation Eyepiece				X	
71 5100 Spherical Adapter (with Collet)	X	X	X		
71 5103 Spherical Adapter (without Collet)	X	X	X		

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TABLE 1-1. ACCESSORIES AND APPLICABILITY (Continued)

Accessory	Applicability				
	71 2022	71 2030	71 2062	71 4010	71 4030
71 5511 Auto-Collimation Illumination Unit	X		X		
71 5520 Lamp Housing				X	X

1-13. INSTRUMENT SPECIFICATIONS

Table 1-2 lists pertinent instrument specifications for the Alignment Telescopes and Line of Sight Telescopes. Table 1-3 lists pertinent specifications for the Alignment Collimators and Straightness of Line of Sight Collimators.

TABLE 1-2. ALIGNMENT TELESCOPE AND LINE OF SIGHT TELESCOPE SPECIFICATIONS

Characteristic	71 2022	71 2030	71 2062
Optical System	Fully coated optics throughout	Same as for 71 2022	Same as for 71 2022
Magnification	Varies automatically from 4x at zero to 46x at infinity	Same as for 71 2022	Varies automatically from 23x at 7 in. to 35x at infinity
Focusing Range	0 to infinity	Same as for 71 2022	7 in. to infinity
Resolving Power (per Bureau of Standards Test Procedure)	3.4 seconds of arc	Same as for 71 2022	3.5 seconds of arc
Field of View	37 minutes at infinity, 42 mm at zero focus	Same as for 71 2022	47 minutes at infinity, 7.4 mm at near distance
Effective Aperture	42 mm	42 mm	38 mm
Reticle	All purpose, double glass, dust-proof, cross-pattern with single lines top and right, paired lines bottom and left	Two reticle system, consisting of dark field, bright line, and bright field, dark line reticles	Same as 71 2022
Eyepiece	Fully erect image, diopter scale	Right-angle eyepiece	Erecting, achromatic; removable blank for auto-collimation conversion unit
Optical Micrometer	Built-in horizontal and vertical; ±0.050 in. displacement, direct reading to 0.001 in., ±0.0002 in. accuracy over full range, red and black scale graduations	Same as for 71 2022	None

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TABLE 1-2. ALIGNMENT TELESCOPE AND LINE OF SIGHT TELESCOPE SPECIFICATIONS (Continued)

Characteristic	71 2022	71 2030	71 2062
Focusing Knob	Drum graduated to show focusing distance in feet	Same as for 71 2022	6½ in. from end of eyepiece
Barrel Diameter	2.2498 +0.0000/−0.0003 inches (A.I.A. Specification)	Same as for 71 2022	Same as for 71 2022
Barrel Length	9 3/16 inches	Same as for 71 2022	Same as for 71 2022
Overall Length	17¾ inches	Same as for 71 2022	13¼ inches
Weight	11½ pounds (approximately)	Same as for 71 2022	5 pounds 11 ounces (approximately)

TABLE 1-3. COLLIMATOR SPECIFICATIONS

Characteristic	71 4010	71 4030
Targets	Infinity target graduated every 30 seconds with total of 18 minutes of arc four directions from zero; paired line target centered on objective lens	N/A
Reticles	N/A	Seven, simulate distances of 0, 4, 10, 25, 50, and 100 feet, and infinity
Barrel Length	12 inches	17 inches
Barrel Diameter	2.2498 +0.0000/−0.0003 inches (A.I.A. Specification)	Same as for 71 4010
Weight	5 pounds (approximately)	12½ pounds (approximately)

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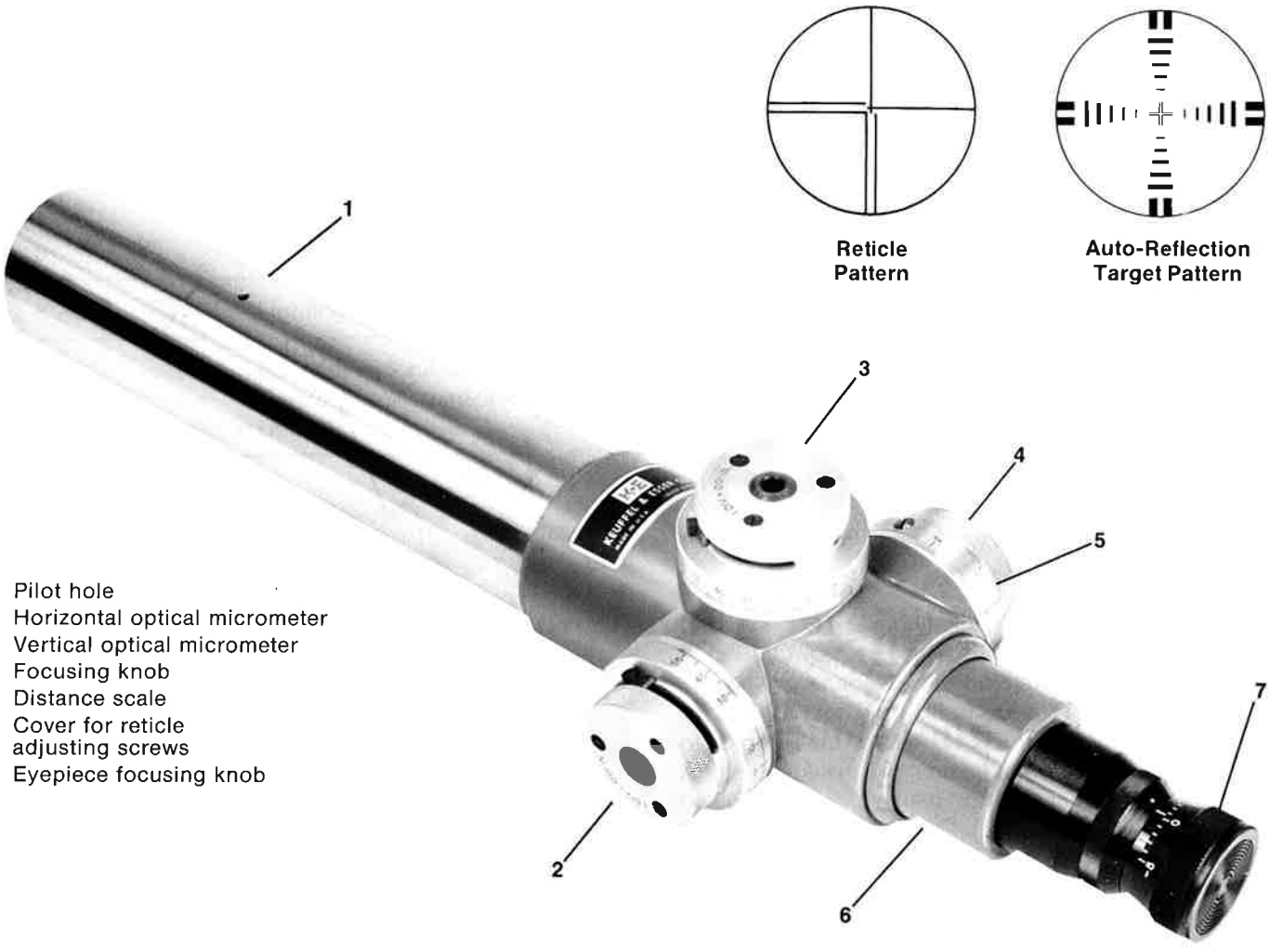
SECTION 2 — OPERATION

2-1. UNPACKING AND INSPECTION

Upon receipt of the instrument, a complete mechanical check should be made. Remove the instrument carefully from the shipping container. Ensure that all ordered items have been received. Inspect the instrument completely for any signs of damage that may have occurred during shipment. Inspect especially all glass parts for cracks and breakage.

2-2. OPERATING CONTROLS

The main operating features of the Alignment Telescope and Line of Sight Telescope are shown in Figures 2-1 through 2-3, and their functions are described in Table 2-1. The Alignment and Straightness of Line of Sight Collimators have no operating controls.



1. Pilot hole
2. Horizontal optical micrometer
3. Vertical optical micrometer
4. Focusing knob
5. Distance scale
6. Cover for reticle adjusting screws
7. Eyepiece focusing knob

Figure 2-1. 71 2022 Alignment Telescope

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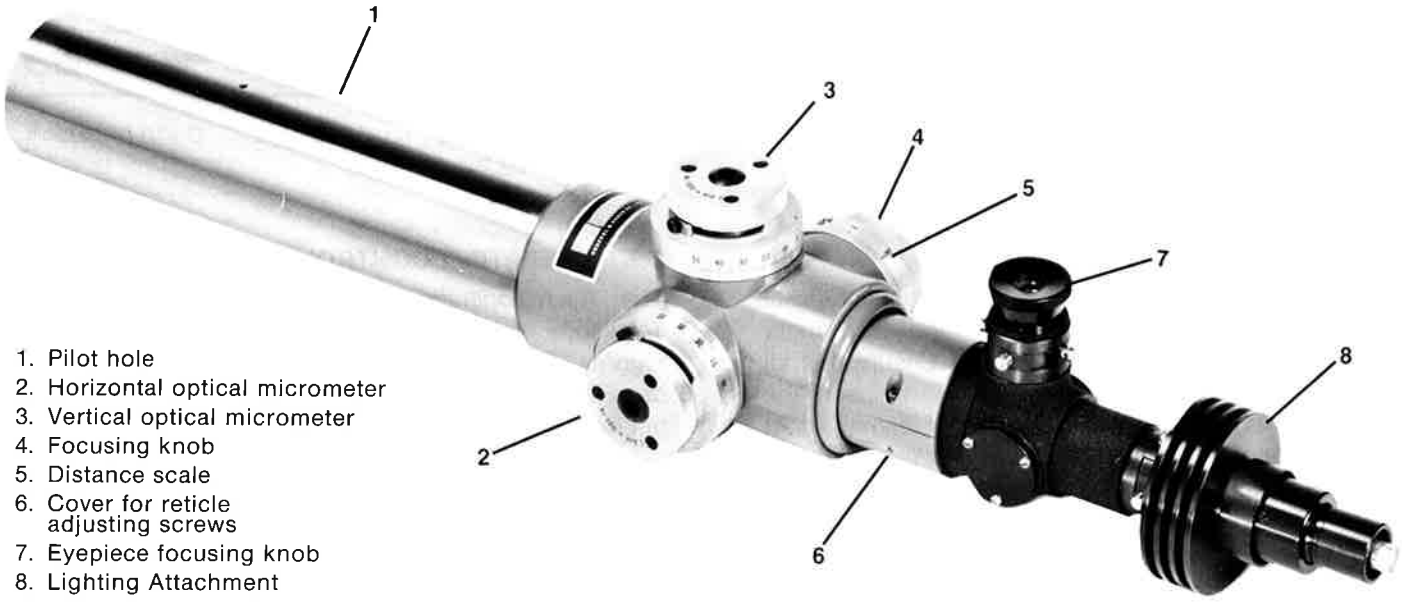
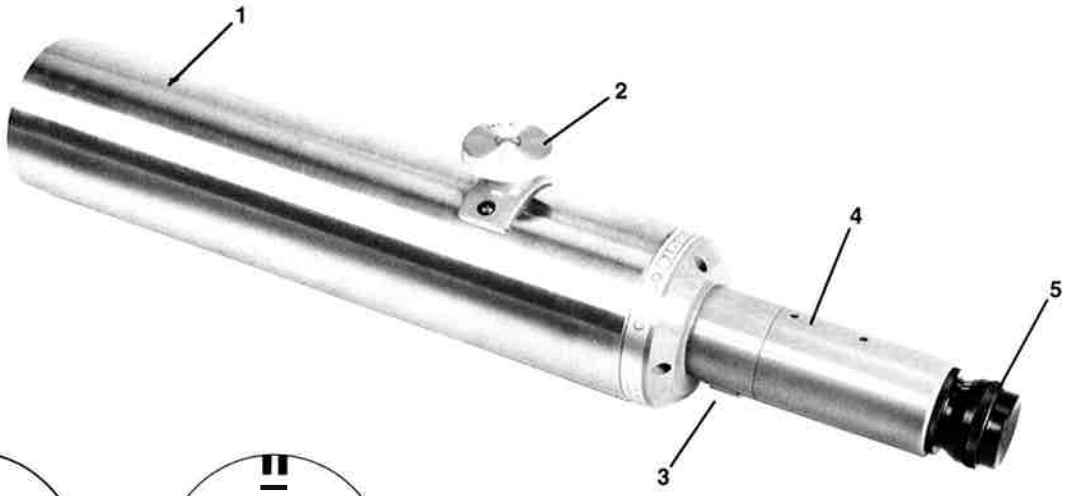
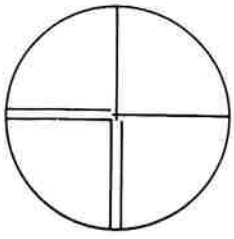


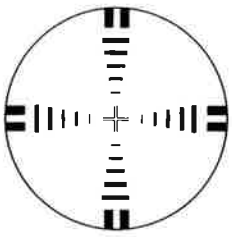
1. Pilot hole
2. Horizontal optical micrometer
3. Vertical optical micrometer
4. Focusing knob
5. Distance scale
6. Cover for reticle adjusting screws
7. Eyepiece focusing knob
8. Lighting Attachment

Figure 2-2. 71 2030 Bright Line Alignment Telescope with Lighting Attachment





Reticle Pattern



Auto-Reflection Target Pattern

1. Pilot hole
2. Focusing knob
3. Coverplate for Auto-Collimation illumination unit.
4. Cover for reticle adjusting screws
5. Eyepiece focusing knob

Figure 2-3. 71 2062 Line of Sight Telescope

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TABLE 2-1. ALIGNMENT TELESCOPE AND LINE OF SIGHT TELESCOPE, OPERATING CONTROLS

Fig. and Index No.	Nomenclature	Function
2-1, 1 2-2, 1 2-3, 1	Pilot hole	Serves as locating hole for accessory cross level.
2-1, 2 2-2, 3	Horizontal optical micrometer	Used to measure horizontal displacements from line of sight.
2-1, 3 2-2, 3	Vertical optical micrometer	Used to measure vertical displacements from line of sight.
2-1, 4 2-2, 4 2-3, 2	Focusing knob	Focuses instrument on target.
2-1, 5 2-2, 5	Distance scale	When instrument is focused on target, indicates distance to target.
2-1, 6 2-2, 6 2-3, 4	Cover for reticle adjusting screws	Protects reticle adjusting screws during use of instrument.
2-1, 7 2-2, 7 2-3, 5	Eyepiece focusing knob	Focuses reticle cross lines.
2-2, 8	Lighting Attachment	Auto-Collimation Illumination Unit.
2-3, 3	Cover plate for Auto-Collimation Illumination Unit.	Access to illumination unit receptacle.

2-3. DESCRIPTION AND FUNCTIONS OF ACCESSORIES

2-4. 71 1211 Auto-Collimation Conversion Unit. The unit can be used to convert the 71 2062 Line of Sight Telescope into an auto-collimating telescope and includes a light plug assembly, cord, switch and fixed 6-volt transformer.

2-5. 71 1231 Right-Angle Eyepiece. The eyepiece can be used in place of a standard eyepiece on the 71 2062 Line of Sight Telescope for very low setups or when working close to walls, columns or other obstructions. The Right-Angle Eyepiece maintains a fully erect image and can be rotated through 360 degrees for sighting from any perpendicular angle.

2-6. 71 1241 Combination Auto-Collimation, Projection, Right-Angle Eyepiece. This combination eyepiece can be interchanged with the standard eyepiece on the 71 2062 Line of Sight Telescope to provide the functions of both the Auto-Collimation Conversion Unit and Right-Angle Eyepiece. The combination eyepiece can easily be converted in the field from a right-angle system to a straight-through system.

2-7. 71 2230 Right-Angle Eyepiece. This eyepiece functions in the same way as 71 1231, except that it is designed for use with the 71 2022 Alignment Telescope and the 71 2030 Bright-Line Alignment Telescope.

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2-8. 71 2240 Combination Auto-Collimation, Projection, Right-Angle Eyepiece. This combination eyepiece functions in the same way as 71 1241, except that it is designed for use with the 71 2022 Alignment Telescope and the 71 2030 Bright-Line Alignment Telescope.

2-9. 71 2302 Angle Reading Attachment. This attachment fits over the objective end of a standard 71 2022 Alignment Telescope or 71 2030 Bright Line Alignment Telescope and converts it into an angle reading type telescope. With the Angle Reading Attachment in place, the micrometers read directly to one second of arc over a range of 50 seconds at infinity only. Maximum usable distance for auto-collimation is approximately 30 ft. Infinity setting on focusing knob is approximately 17 ft.

2-10. 71 2410 Optical Square. The Optical Square is mounted on a 71 2022 Alignment Telescope, 71 2030 Bright Line Alignment Telescope or 71 2062 Line of Sight Telescope. It establishes a plane perpendicular to the basic line of sight at right angles to it, with an accuracy of within one second of 90 degrees. No adjustments are necessary to set the right angle. The basic line of sight can be checked while the Optical Square is attached to the telescope, since the square has both a front and a side aperture. The optical system is mounted in a spherical housing with the vertex of the right angle at the center of the sphere.

2-11. 71 2412 Double Sphere Optical Square. This optical square can be used with the 71 2022 Alignment Telescope, the 71 2030 Bright Line Alignment Telescope and the 71 2062 Line of Sight Telescope. It is similar to the 71 2410 Optical Square except that a second sphere is located behind the sphere with the prism. With the rear sphere placed in a 71 5140 Cup Mount, the Double Sphere Optical Sphere can be rotated and provides a clear right-angle view through a full 360 degrees.

2-12. 71 3205 Cross Level. This level can be used with the 71 2022 Alignment Telescope, the 71 2030 Bright Line Alignment Telescope and the 71 2062 Line of Sight Telescope. It establishes the reticle crosslines of the telescopes vertically and horizontally. The Cross Level is positioned by means of a stud fitting into a hole in the barrel of the instrument tube. When the level bubble is centered, the crosslines of the instrument will be vertical and horizontal. The level vial has a sensitivity of 90 seconds of arc per 2 mm movement.

2-13. 71 3220 Coincidence Striding Level. This level can be used with the 71 2022 Alignment Telescope, the 71 2030 Bright Line Alignment Telescope and the 71 2062 Line of Sight Telescope to establish a level line of sight. It is placed directly on the barrel of the instrument and secured with a spring clip. It utilizes a 71 3250 Coincidence Level with a sensitivity of 20 seconds per 2 mm movement.

2-14. 71 3230 Coincidence Striding Level. This level functions the same as 71 3220, except that it is designed for use with the 71 4030 Straightness of Line of Sight Collimator.

2-15. 71 4111 Auto-Collimation Eyepiece. This eyepiece is used with the 71 4010 Alignment Collimator to convert it to an auto-collimator. With the back plate removed, the eyepiece can be attached by screwing it into the end of the Alignment Collimator, making it a 30x infinity focus telescope. The eyepiece is provided with a plug-in type illumination unit.

2-16. 71 5100 Spherical Adapter (with Collet). This adapter can be used with the 71 2022 Alignment Telescope, the 71 2030 Bright Line Alignment Telescope, and the 71 2062 Line of Sight Telescope. It is a hardened steel sphere with a 3½ inch diameter and a collet for clamping the adapter to any point along the barrel of a telescope of 2¼ inches in diameter. A 71 5101 Target Stop Ring and 71 5102 Spanner Wrench are used to position a target in the center of the sphere.

2-17. 71 5103 Spherical Adapter (without Collet). This adapter is similar in function to 71 5100 except that it is secured to the telescope barrel with a set screw. In addition, three tapped holes with set screws are provided in the sphere to secure 71 5520 Lamp Housing or any 2¼ inch diameter target.

2-18. 71 5511 Auto-Collimation Illumination Unit. This unit is used with the 71 2022 Alignment Telescope and the 71 2062 Line of Sight Telescope and consists of a transformer, cord, switch and light plug assembly. It may be used with all auto-collimation illumination attachments.

2-19. 71 5520 Lamp Housing. This accessory can be used with the 71 4010 Alignment Collimator and the 71 4030 Straightness of Line of Sight Collimator to provide illumination for the reticle pattern of the collimator or any transparent target positioned in a spherical adapter such as 71 5100 or 71 5103.. The lamp is 15 watts and requires 110 VAC.

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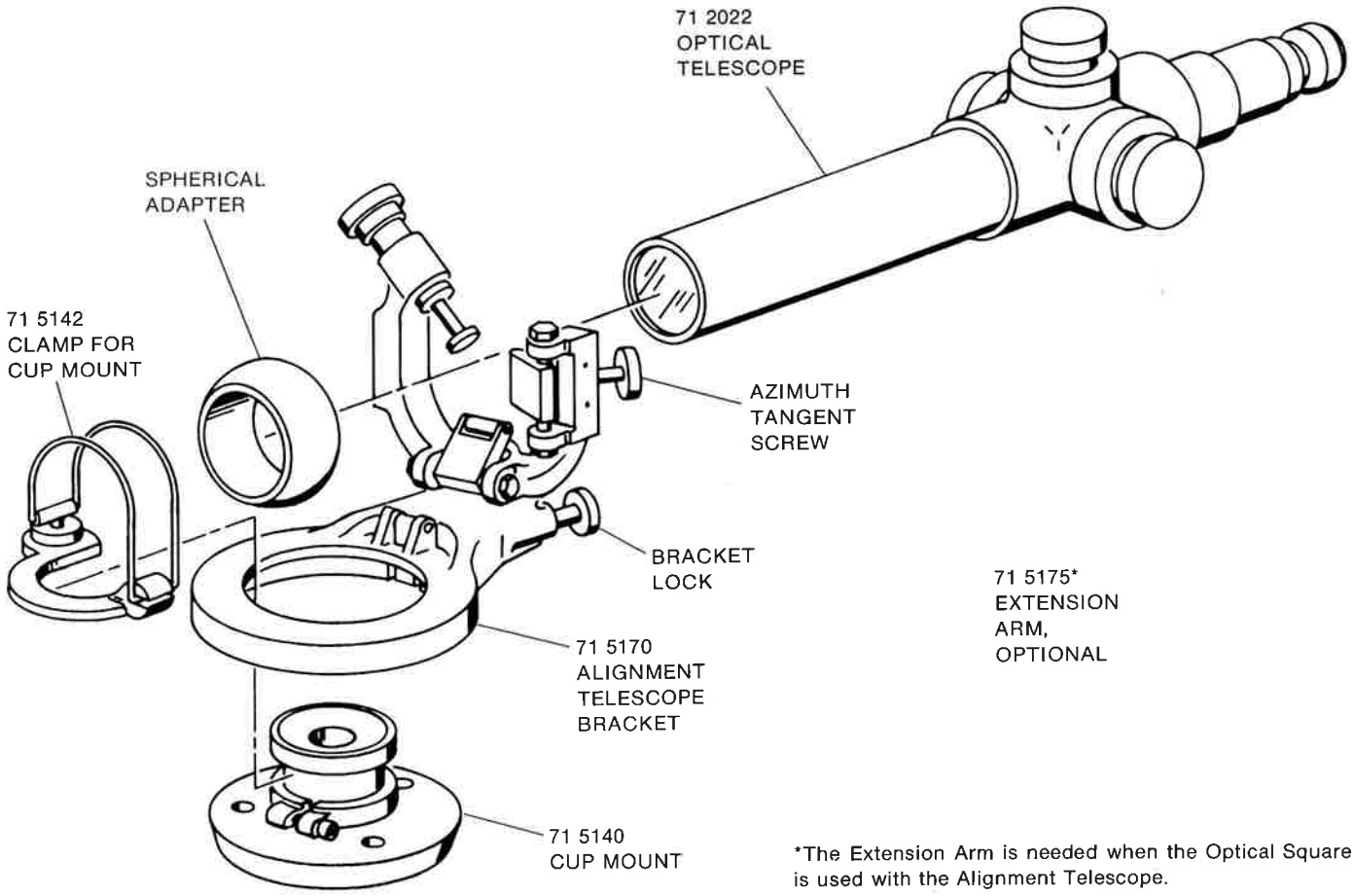

Figure 2-4. Assembly of Cup Mount, Spherical Adapter, Bracket, and Alignment Telescope

2-20. BASIC INSTRUMENT CONCEPTS

2-21. Alignment Telescopes and Line of Sight Telescopes. Alignment Telescopes and Line of Sight Telescopes were designed for one specific application — optical tooling for the airframe industry. The original concept was that a line could be established in space by locating two Spherical Adapters, one at each end of the line. This was usually accomplished by supporting each of the Spherical Adapters in a Cup Mount and measuring to the OD of the sphere, thereby positioning the center of the sphere where required. Once the spheres were properly located, the base of each Cup Mount was pinned to the structure or tool, and the vertical adjusting screw of the Cup Mount was clamped and usually pinned; therefore, the Cup Mount became a permanent locater fastened directly to the tool itself.

2-22. To establish the optical reference line with this arrangement, it is necessary to place a target in one of the Spherical Adapters and mount it on the Cup Mount at one end, and to place an Alignment Telescope or Line of Sight Telescope in the other Spherical Adapter and place it, along with a suitable bracket, on the Cup Mount at the other end. (See Figures 2-4 and 2-5.) The bracket supports the rear end of the telescope, and its fine motion tangent screws aid in aiming the telescope. It is then only necessary to aim the telescope at the target to establish an optical line of sight from the center of one sphere to the center of the other sphere. (See Figure 2-6.) Intermediate targets indexed to part locators by permanently mounted special fixtures can then be aligned to the reference line of sight. At this point, the telescope and Spherical Adapters can be removed from the Cup Mounts, and the intermediate targets from their fixtures, and put away. At any future time, any set of targets, any two Spherical Adapters, and the telescope and target can be used to reestablish the reference line of sight and to check the location of the various part locators. This had been done previously by stretching a tight wire instead of the reference line of sight.

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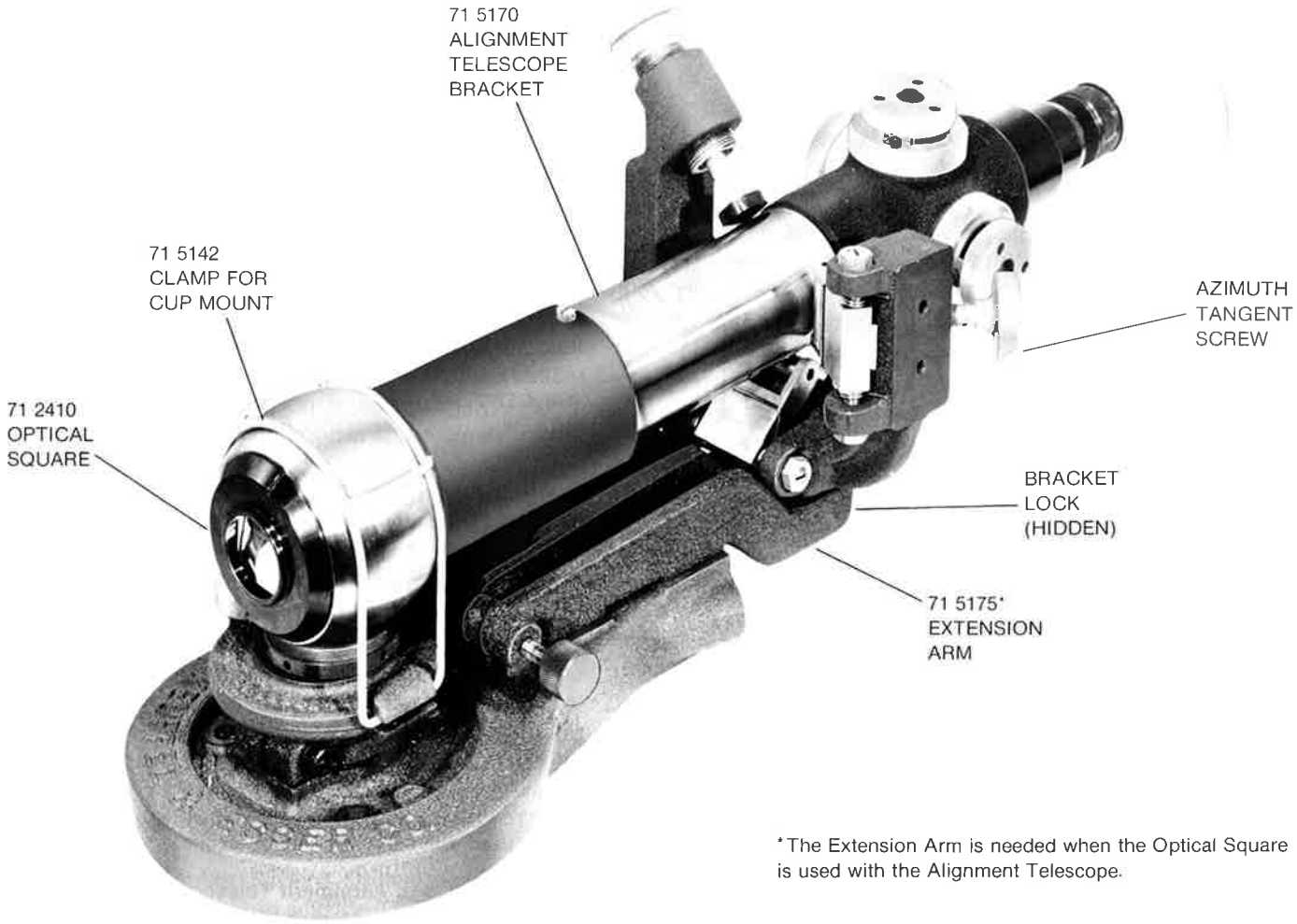

Figure 2-5. 71 5170 Alignment Telescope Bracket

2-23. It was the "optical tight wire" concept that allowed the Alignment Telescopes and Line of Sight Telescopes, designed specifically for the airframe industry, to be adapted for other applications. One of the first such applications was in the shipbuilding industry. Although telescopes had been used previously to align the bearings for the main drive shafts of vessels, the Alignment Telescopes and Line of Sight Telescopes offered many advantages over such juryrigged telescopes. Unfortunately, the bracketry used in the airframe industry, specifically Cup Mounts and Spherical Adapters, proved somewhat impractical for most applications outside the airframe industry, and V-blocks of some sort are most commonly used instead. A pair of adjustable cones, for example, provide a fully adjustable V-block to support the barrel of the Alignment Telescopes and Line of Sight Telescopes.

2-24. When a V-block is used, the precision-ground barrel of the telescope, originally designed to center in a Spherical Adapter, is important because it provides a self-proving feature to the adjustment or relationship of the line of sight to the outside barrel of the telescope. More importantly, the outside barrel of the telescope can be used to locate the optical center of the instrument, and the telescope can be reversed in the V-block so that the line of sight can be extended in the opposite direction.

2-25. There is another basic difference between the airframe industry concept of optical tooling and the concept in most other industries. Instead of the line-in-space concept, where a reference line of sight is established and a tool built around it, there is already something existing in most other applications; for

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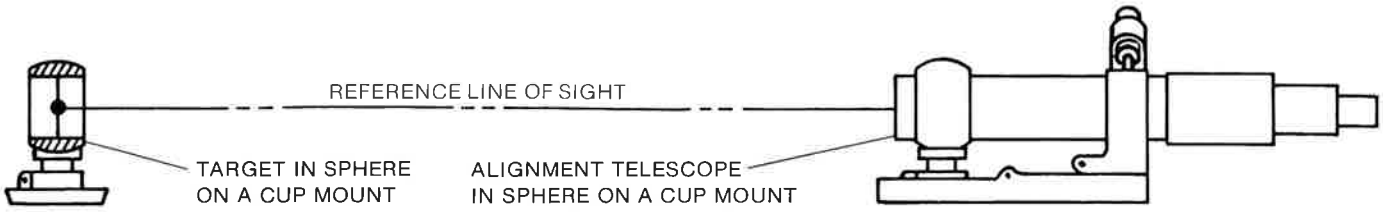

Figure 2-6. Establishing a Reference Line of Sight

example, one or more bearings on a shaft section, or a stern tube to which everything else must be aligned. For this reason, the bracketry must enable the operator to align the telescope to a specific line in space that already exists, rather than to establish the line in space arbitrarily. The Cup Mount and spherical adapter system is seldom used in industries outside the airframe and aerospace industries for this reason. Instead, the telescope may be mounted in a fixture that has a 2¼ inch diameter hole to accept the telescope and an outside diameter that matches the bearing or bore to which the telescope is to be aligned. V-blocks, either of the standard variety or adjustable V-blocks in the form of cones, are also often used.

2-26. Alignment Collimator. The Alignment Collimator is a device that can be made to coincide with an optical line of sight in *direction* and *position* to a very high degree of accuracy. It is usually mounted on a facility gauge or other small jig part so that the tilt and position of the part can be controlled by the line of sight of an Alignment Telescope or Line of Sight Telescope.

2-27. The Alignment Collimator is essentially a fixed infinity focused telescope without an eyepiece. A reticle or tilt target is located at the principle focus of the lens, as shown in Figure 2-7. Since the Alignment Collimator is focused at infinity, the light rays emerging from the Alignment Collimator are parellel to each other. When some of these light rays strike the lens of an Alignment Telescope or Line of Sight Telescope, the tilt target can be made to appear in the telescope if the telesope is focused at infinity.

2-28. When the Alignment Collimator is tilted with respect to the Alignment Telescope or Line of Sight Telescope, the center of the tilt target will not appear on the cross lines of the telescope. (See A, Figure 2-8.) To bring the center of the tilt target on the cross lines of the telescope, the Alignment Collimator must be directed so that the light rays emerging from it are parallel with the line of sight of the telescope as shown in B, Figure 2-8. After the tilt has been corrected, the Alignment Collimator can be moved a small amount parallel to itself, and the center of the tilt target will remain exactly on the cross lines of the telescope as shown in C, Figure 2-8. This must be the case because such movement of the Alignment Collimator keeps the rays from the collimator parallel to the line of sight of the telescope, as was the case before the movement.

2-29. The Alignment Collimator also has a displacement target on the objective lens. After the tilt has been corrected, the alignment target can be made to appear in the Alignment Telescope or Line of Sight Telescope by focusing the telescope on it; the tilt target is then out of focus and disappears. The Alignment Collimator can then be brought on the line of sight as with any alignment target. When the tilt target and the alignment target are both on the line of sight, the axis of the cylindrical surface of the Alignment Collimator coincides with the line of sight.

2-30. Straightness of Line of Sight Collimator. Every type of optical tooling telescope contains optical parts that must be moved to focus the instrument on points at different distances. This movement may affect the direction of the line of sight. If the line of sight is affected, points aligned with such a telescope will not be on a straight line, and the line of sight is said to be curved.

2-31. The straightness of the line of sight can be tested by taking careful measurements to the line of sight at different distances from the telescope and then repeating the procedure with the telescope rotated 180 degrees on its axis. Any difference in the measurements would indicate curvature or out-of-roundness of the telescope barrel or collars. The Straightness of Line of Sight Collimator is designed to offer a practical means of making this test.

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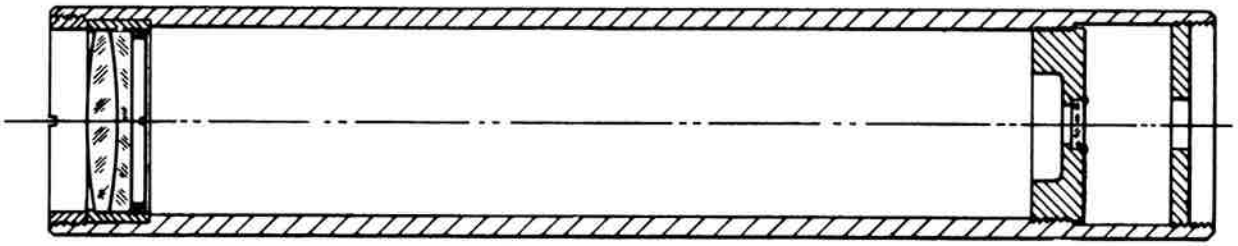
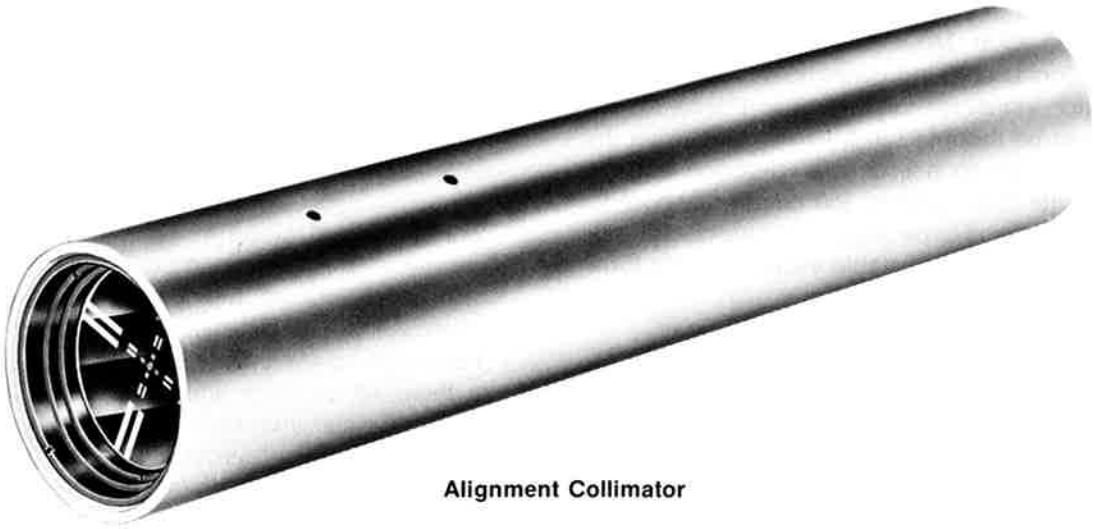
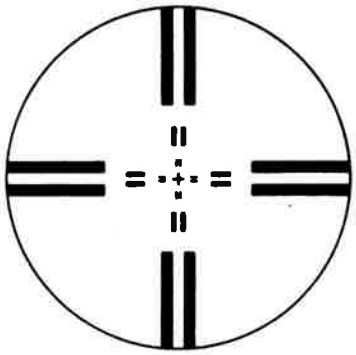


Cross Section of the Alignment Collimator

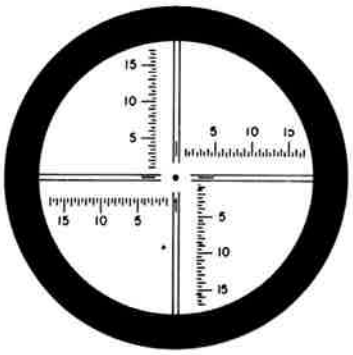


Alignment Collimator



Alignment Target

Scales Read in
Minutes of Tilt



Tilt Target

Figure 2-7. Alignment Collimator

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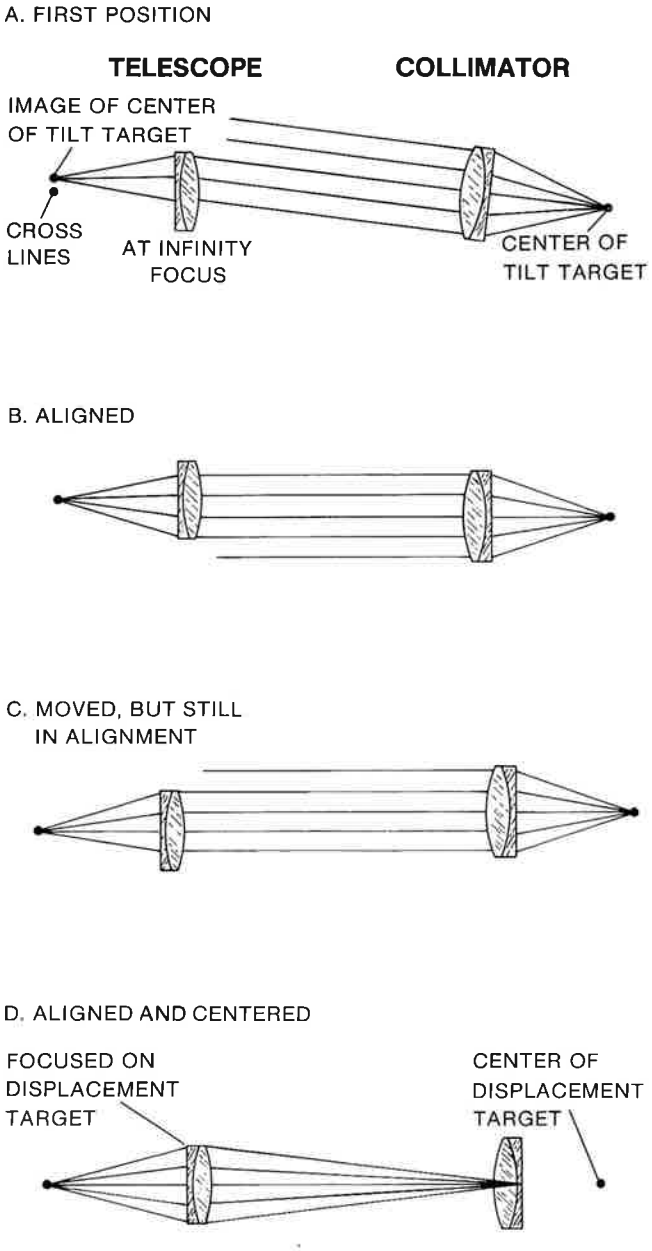

Figure 2-8. Alignment Collimator Used with Alignment Telescope

2-32. The Straightness of Line of Sight Collimator contains seven reticle patterns placed so that they simulate targets placed at different distances. When any telescope is aimed into the objective, its focus must be regulated as though the reticles were actually at these distances. The targets have been centered as closely as possible at the factory. After a telescope has been bucked in between the 0 and 100 foot reticle targets, its line of sight should remain centered on each of the other reticle targets as the instrument is focused on each of these targets in turn. Any deviation indicates curvature of the line of sight. The displacement of the line of sight can be measured using an optical micrometer on the instrument being tested.

2-33. The Straightness of Line Sight Collimator can also be used in a similar manner to check the conventional adjustments of other optical instruments. It is used on a Cubic Precision instrument test stand for this purpose.

2-34. BRACKETS AND SUPPORTS

2-35. Brackets. Cubic Precision can supply a variety of brackets and supports for the Alignment Telescopes, Line of Sight Telescopes and Collimators. The 71 5170 Alignment Telescope Bracket is shown in Figures 2-4 and 2-5, and its use is described in Section 2, Para. 2-22., "Basic Instrument Concepts." The brackets support and provide a means for adjusting the position of the Alignment Telescope, Line of Sight Telescope or Alignment Collimator. Brackets can be attached to any cup mount. Two tangent screws are provided; one adjusts the aim of the instrument left and right, and the other adjusts the aim up and down. The yoke of the bracket can be repositioned easily to permit setups with the bracket secured in a horizontal, vertical, inclined, or upside-down position.

2-36. Cone-Type V-Blocks. A cone-type V-block consists of two or four cones on elevating screws. The cones are separately adjustable in height, and can be locked in position by clamps. The telescope cylinder is held on the cones by springs. The two-screw type V-block can be used with a cup mount, in place of a bracket, to aim the telescope. The four-screw type V-block provides complete control of the telescope. Aiming of the telescope is accomplished by adjusting the height of the cones, as illustrated in Figures 2-9 and 2-10, and detailed below. In Figure 2-9, it is assumed that screws 1 and 2 are the forward screws. The numbers in the table below refer to the screws turned for the corresponding operation. All screws are turned equal amounts for each operation. The adjusting screw clamps should be snugged up to the point where there is a slight drag on the adjusting screws as they are turned. This will minimize any motion when the clamps are fully tightened after the adjustments have been completed.

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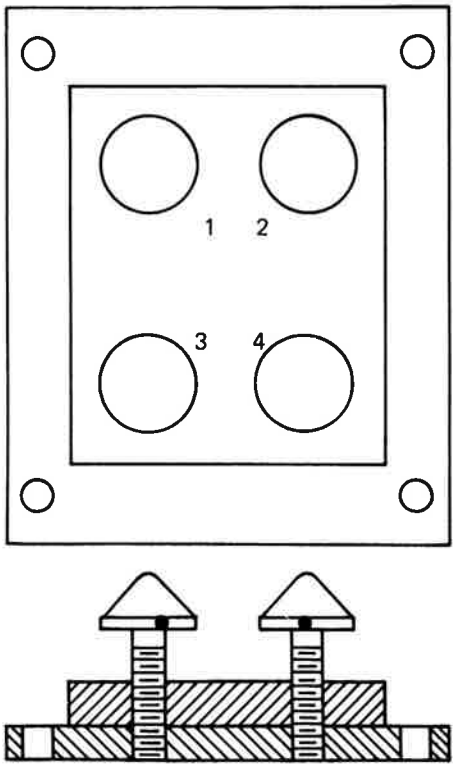

Figure 2-9. Schematic of Cone Type V-Block

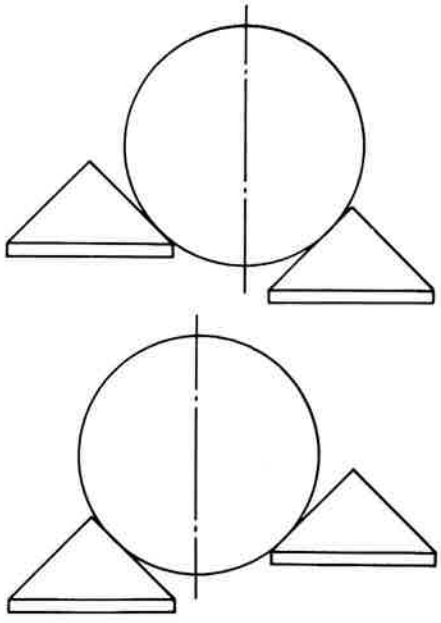

Figure 2-10. Use of Cones to Change Aim Left or Right

Operation	Screws Turned Clockwise	Screws Turned Counterclockwise
Raise	None	1, 2, 3, 4
Lower	1, 2, 3, 4	None
Move right	2, 4	1, 3
Move left	1, 3	2, 4
Aim up	3, 4	1, 2
Aim down	1, 2	3, 4
Aim right	2, 3	1, 4
Aim left	1, 4	2, 3

With the four-screw type V-block, measurement is made to the telescope cylinder itself, rather than to the spherical adapter.

2-37. Other Supports. The many other types of telescope support equipment are described in Cubic Precision Catalog 9. Support equipment is available for mounting the instruments on the work, on an instrument stand, or on a tooling bar.

2-38. TARGETS AND MIRRORS

2-39. Targets and Target Holders. Although Cubic Precision produces a number of targets of different types for various applications, two targets are most commonly used. One is the 71 6110 Glass Alignment Target. In cases where several targets are to be set in line and it is desirable to be able to focus through one target to the next beyond, the 71 6170 Open Alignment Target is used. Both of these targets have a nominal 2 1/4 inch diameter and can be mounted in any 2 1/4 inch diameter hole, in a spherical adapter, in a fixture that is indexed to some kind of locator, or in a fixture that centers in a bore.

Target centering devices are available for use with bores greater than 2 1/4 inches in diameter. The 71 6450 Adjustable Target Holder can be used with bores of 6 to 21 1/2 inches in diameter, and the 71 6410 Adjustable Target Holder can be used with bores from 18 inches to 68 1/2 inches in diameter. The 71 6450 Adjustable Target Holder uses a stick micrometer to center the target in the bore; the 71 6410 Adjustable Target Holder uses a dial indicator on a sweep arm for the same purpose. If bores of identical diameters are to be aligned on a day in, day out production basis, it is best to fabricate special fixtures rather than use the Adjustable Target Holders; however, if bores vary in size, the Adjustable Target Holders are required.

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2-40. Mirrors. To set a piece perpendicular to the line of sight of a telescope, or to set the line of sight of a telescope perpendicular to a reference surface, either the 71 6202 Magnet Back Mirror or the 71 6204 Magnet Back Mirror may be used. The back of the mirror is lapped when the mirror is perpendicular to the line of sight of a telescope, the surface to which the mirror is indexed is also perpendicular to the line of sight. Perpendicularity can be checked by auto-reflection or auto-collimation.

2-41. It is often necessary to set the line of sight of a telescope so that it is coaxial with the axis of rotation of a shaft. The 71 6240 Adjustable Spindle Mirror Target is used for this purpose. Such alignment is accomplished as a two-step operation. First, the mirror is adjusted in tilt so that it is perpendicular to the axis of rotation of the spindle, and the target is centered with it. This is done by rotating the spindle back and forth or around and around in 180 degree increments while checking first for auto-collimation off the mirror and adjusting the mirror in tilt to establish the condition where the mirror is perpendicular to the shaft; then, observing the target and shifting it laterally until it is centered with the axis of rotation of the shaft. Having accomplished this, the telescope is adjusted to the mirror so that it is perpendicular to the mirror surface and centered with the target pattern. The line of sight of the telescope is then coaxial with the axis of rotation of the spindle.

2-42. OPERATION OF ALIGNMENT TELESCOPES AND LINE OF SIGHT TELESCOPES

2-43. To Establish A Reference Line of Sight. To use an Alignment Telescope or Line of Sight Telescope after it is mounted:

1. On the Alignment Telescope only, set the optical micrometers to zero.

2. Turn the eyepiece focusing knob (Figure 2-1, 2-2, or 2-3) until the reticle cross lines appear sharp when the instrument is aimed at a well illuminated white surface. On the Alignment Telescope only, it is helpful to note the resulting setting (the diopter setting) on the scale in front of the eyepiece focusing knob for future use. This setting is often different for different observers and sometimes for different instruments, but it is the same for sights of different lengths.

3. Aim the instrument at the target, focus on the target using the focusing knob, and then refine the aim of the instrument at the target by adjusting the tangent screws or by regulating the cones, as applicable.

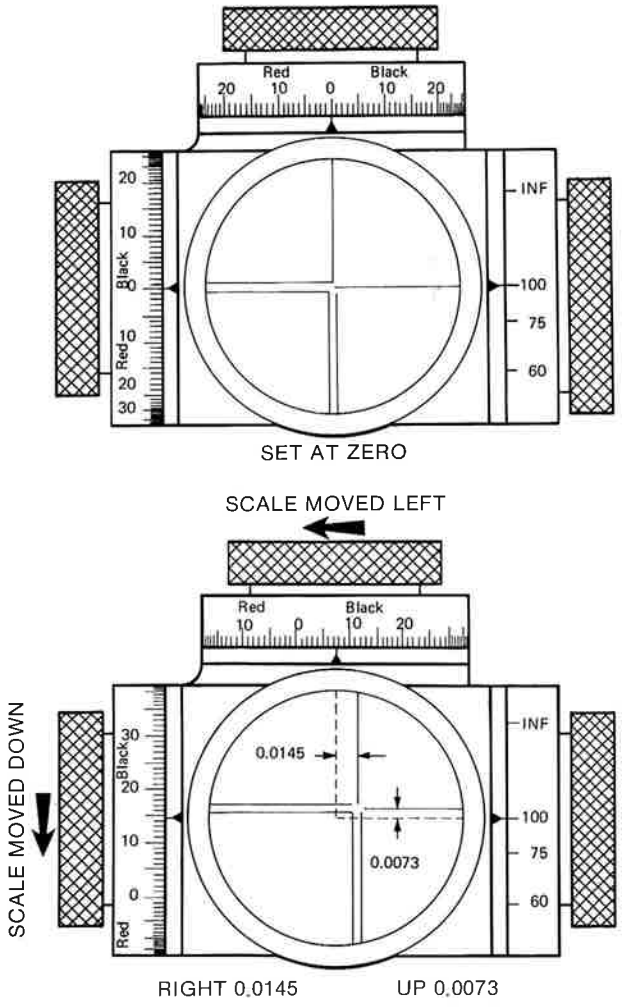

Figure 2-11. Operation of Optical Micrometers

2-44. Measuring Displacements from the Line of Sight (Alignment Telescopes Only). The Alignment Telescope has three control knobs. (See Figures 2-1 and 2-2.) Viewed from the eyepiece end with the telescope in its normal position, the right-hand knob is the focusing knob, left-hand knob is the horizontal micrometer knob and moves the line of sight left and right, and the top knob is the vertical micrometer knob and moves the line of sight up and down. Marks on a dial beside the focusing knob show the approximate position of the knob when the focus is at infinity or at various finite distances.

2-45. The extent of movement of the line of sight produced by micrometer knobs is shown by graduated dials. (See Figure 2-11.) The dials are graduated in units of 0.001 inch, and are numbered in both directions from zero at the center to 0.050 inch at the ends. Black

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numbers are used in one direction, and red numbers in the other direction. When the dials are set at 0.000, the line of sight of the Alignment Telescope is on the axis of the cylindrical part of the telescope. When the horizontal micrometer knob (left) is turned clockwise, the face of the dial nearest the observer moves downward, the black numbers are adjacent to the index, and the line of sight moves to the right. Similarly, when the vertical micrometer knob is turned clockwise, the nearest face of the dial moves left, the black numbers are adjacent to the index, and the line of sight moves up.

2-46. Displacements of objects from the line of sight can be measured with optical tooling scales. The lowest graduation of optical tooling scales is 0.100 inch. Because the optical micrometers of the alignment telescope read ±0.050 inch, it is obvious that, when optical tooling scales are used, it may be necessary to adjust the optical micrometers to bring the line of sight onto the nearest graduation of the optical tooling scale and to add or subtract (depending on the direction of displacement) the optical micrometer dial reading to the final optical tooling scale reading.

2-47. Other Applications of Alignment Telescopes and Line of Sight Telescopes. In addition to establishing a reference line of sight, Alignment Telescopes and Line of Sight Telescopes can be used to:

1. Establish a plane perpendicular to a reference line at a given station.
2. Establish a level reference line.
3. Establish a plumb reference plane.
4. Establish a vertical plumb line (Alignment Telescope only).

2-48. To Establish a Plane Perpendicular to a Reference Line. A perpendicular plane is established with one of two types of Cubic Precision Optical Squares: the 71 2410 Optical Square or the 71 2412 Double Sphere Optical Square. (See Figures 2-12, 2-13 and 2-14.) Both Optical Squares provide one line of sight that passes straight through and, by means of a pentaprism, a second line of sight that is turned 90 degrees, ±1 second of arc, from its entering direction. The apex of the 90 degree angle is at the center of the sphere; therefore, adjustments about the sphere do not change the position of the intersection of the two lines.

Figure 2-12. 71 2410 Optical Square

2-49. When either Optical Square is mounted on the instrument, the 90 degree line can be turned in the direction needed by rotating the instrument and the optical square together. Only the Double Sphere Optical Square can establish the 90 degree line through a full 360 degree of rotation; the 90 degree line of the single sphere Optical Square is partly obstructed by the mount and bracket. If the Double Sphere Optical Square is mounted on its rear sphere, adjustment will move the intersection of the 90 degree lines; if it is mounted on the forward sphere, it will function as a single sphere Optical Square.

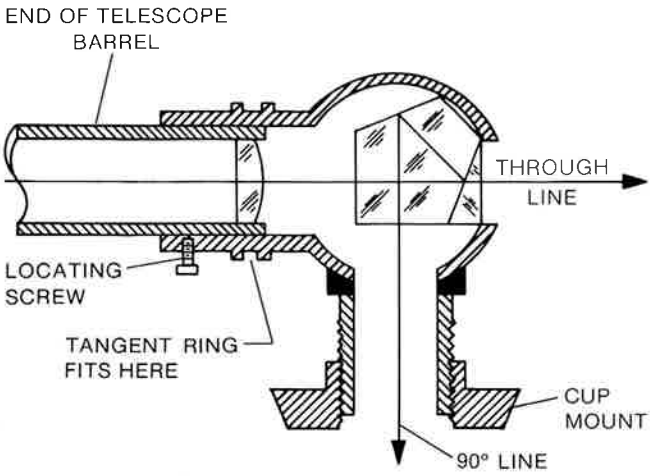

Figure 2-13. Schematic View of Optical Square

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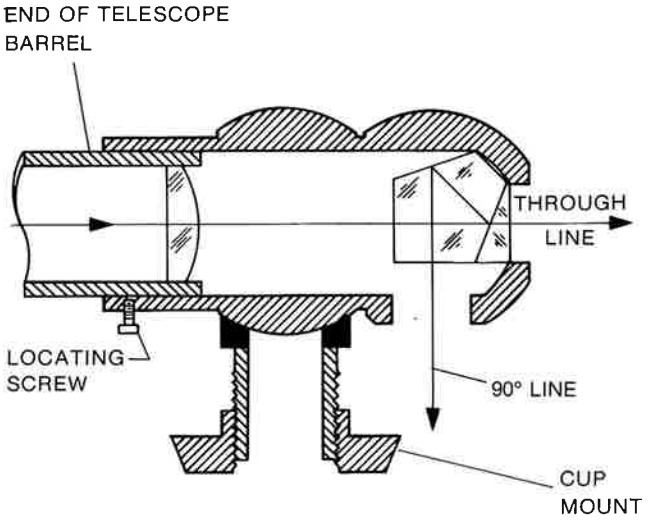

Figure 2-14. Schematic View of Double Sphere Optical Square

2-50. To use an Alignment Telescope or Line of Sight Telescope and Optical Square to establish a perpendicular plane:

1. Mount the instrument with the attached Optical Square on a bracket. Either sphere of the Double Sphere Optical Square can be placed in the cup mount.

2. Cover the 90 degree opening of the Optical Square with the cap provided, and open the front window.

3. Adjust the bracket so that the center of the opening in the Optical Square is on the reference line when the instrument is aimed at the center of the objective of a reference telescope. Set infinity focus on both instruments, and aim the cross lines of the Alignment Telescope or Line of Sight Telescope at the cross lines of the reference telescope using the bracket tangent screws.

4. Remove the cap from the 90 degree opening, close the front window, and aim the 90 degree line where desired.

2-51. Generally, when sighting through the 90 degree window, the aim in the vertical or roll direction is arbitrary and is adjusted by hand.

2-52. To Place the Perpendicular Plane at a Given Station. The plane swept by the 90 degree line can be placed at the desired station by aiming the 90 degree line at the station mark.

2-53. To Establish a Level Reference Line and Plumb Plane. To establish a level reference line, place a 71 3220 Coincidence Striding Level on the barrel of the Alignment Telescope or Line of Sight Telescope and level the telescope, using the coincidence type level vial of the Striding level.

2-54. To establish a plumb plane, use the Alignment Telescope or Line of Sight Telescope and Optical Square with the Striding Level. When the telescope is level, the through line of sight is level, and the 90 degree line will sweep through a plumb plane when the telescope and Optical Square are rotated.

2-55. To Establish a Vertical Plumb Line. To establish a vertical plumb line, pointed either up or down, the Alignment Telescope can be mounted in a 71 5160 Plumb Aligner Bracket. (See Figure 2-15.)

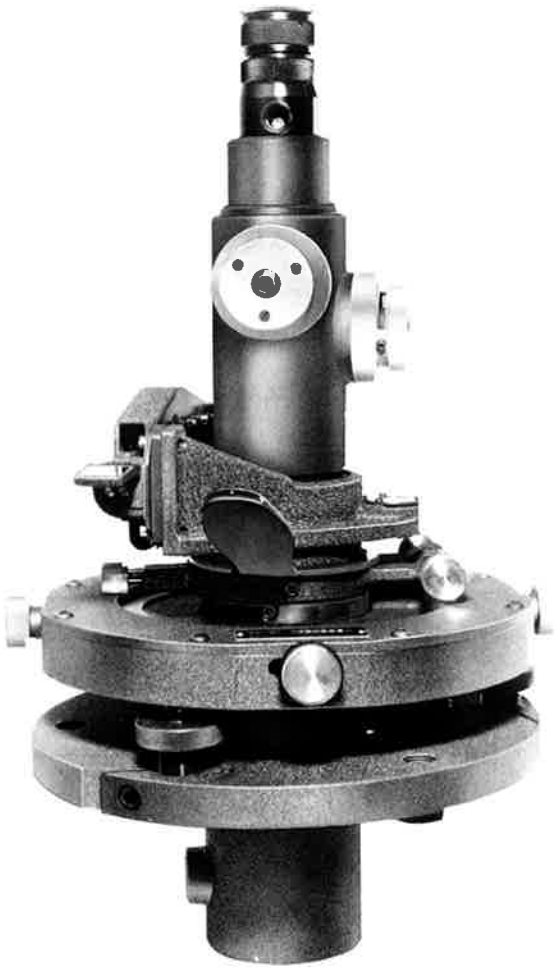

Figure 2-15. 71 5160 Plumb Aligner Bracket with Alignment Telescope Mounted for Downward Sighting

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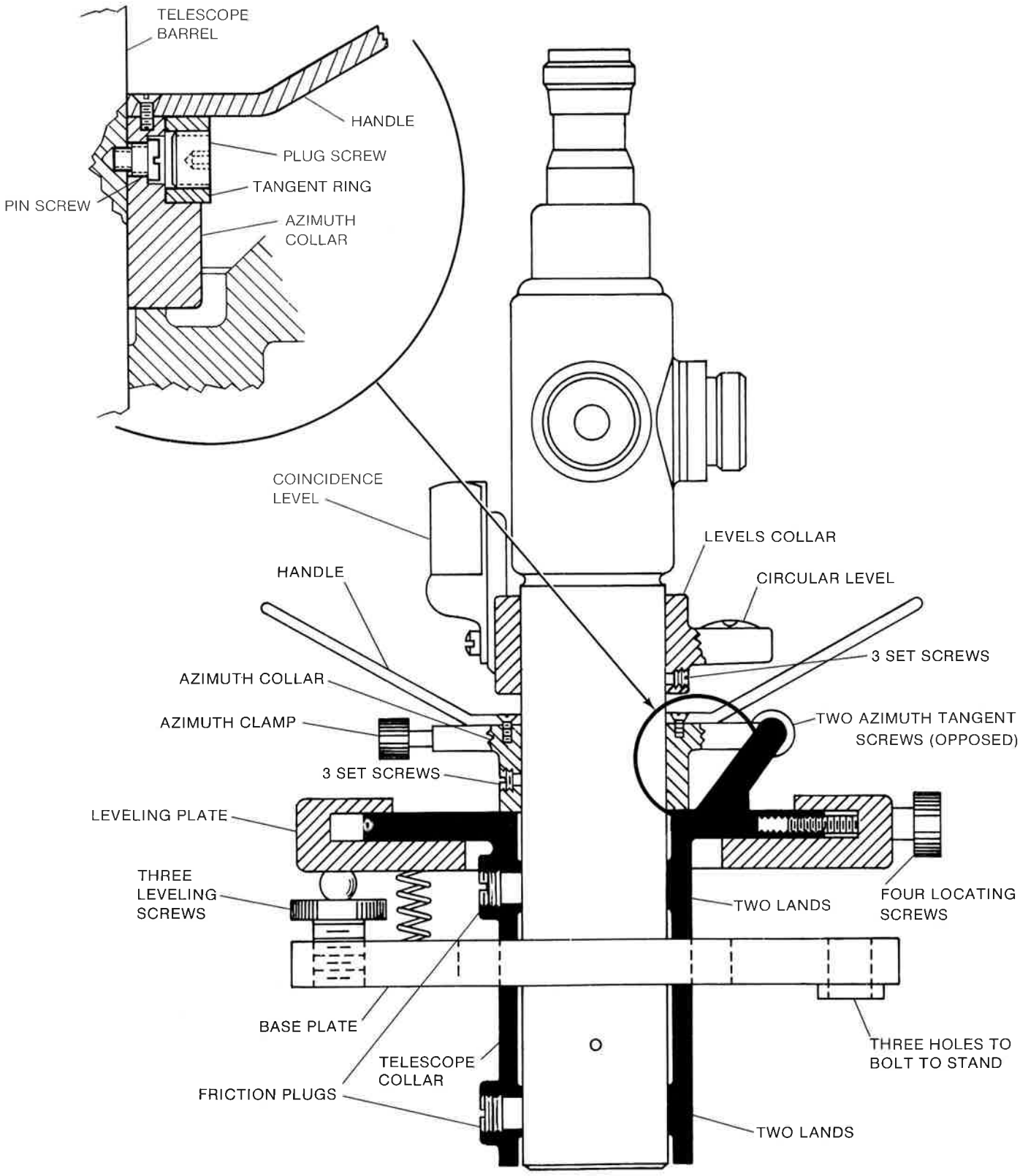

Figure 2-16. Schematic View of 71 5160 Plumb Aligner Bracket with Alignment Telescope in Place

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2-56. To Mount a Plumb Aligner Bracket and Alignment Telescope. The Plumb Aligner Bracket is shown schematically in Figure 2-16. To mount the Alignment Telescope for a downward sight:

1. Slide the level collar onto the Alignment Telescope as far as possible without actual contact between the level collar and the enlarged part of the telescope.

2. Turn the coincidence level parallel to one of the telescope cross lines, and lock it in place by tightening the three socket-head setscrews around the circumference of the lower end of the level collar.

3. Make sure that the pin screw is *not* installed in the azimuth collar. Slide the azimuth collar, which holds the azimuth tangent screws and clamps and the handle, onto the telescope as close to the level collar as possible, but free of contact with it. Tighten the three socket-head setscrews around the lower end of the azimuth collar.

4. Bolt the base plate, with attached leveling plate and telescope collar, in place on a stand with a hole large enough (4 inches in diameter) to admit the telescope collar. There are three holes around the circumference of the base plate, each of which extends through a small foot plate for bolting.

5. Lower the telescope, with attached level collar and azimuth collar, into the telescope collar until the bottom of the azimuth collar rests on the three bosses at the top of the telescope collar.

6. Tighten the two large, slot-head friction plugs in the telescope collar only enough to assure proper three-point contact. Excessive tightening of these plugs may cause deformation of the telescope barrel or may prevent tangent motion. Tangent movement is accomplished by means of two opposing screws, and no spring and plunger is used.

2-57. To Plumb and Position the Telescope. After the Plumb Aligner Bracket and Alignment Telescope have been mounted:

1. Center the circular level bubble with the leveling screws. (See Figure 2-16.) The bubble will move in the direction of any leveling screw that is turned clockwise.

2. Focus on the point over which the plumb line is to be established.

3. Using the four locating screws, bring the cross lines of the Alignment Telescope on the point. Use the locating screws, which are in tension, in pairs, loosening one and tightening the one opposite simultaneously and equally. Leave them firm. It may be necessary to loosen one or both of the other pair before the telescope will move.

4. Using the handles of the Plumb Aligner Bracket, turn the Alignment Telescope so that the coincidence level is in line with any two leveling screws. (See Figure 2-17, position 1.)

5. Turn leveling screws A and B simultaneously in opposite directions until the ends of the coincidence level bubble coincide.

6. Using the Plumb Aligner Bracket handles, turn the Alignment Telescope 90 degrees to position 2.

7. Turn leveling screw C until the ends of the coincidence level bubble coincide.

8. Reposition the cross lines with leveling screws A and B. Check the coincidence level, and repeat the procedure if necessary.

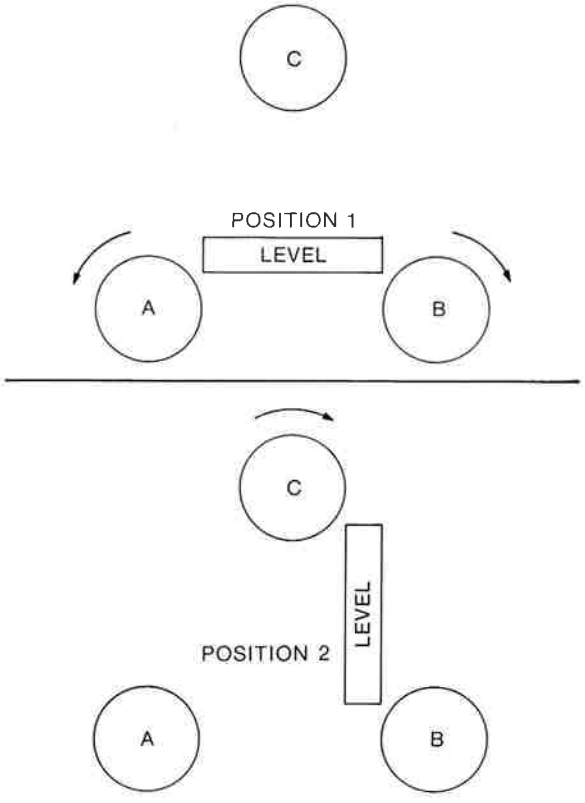

Figure 2-17. Method of Leveling with Three Leveling Screws

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2-58. To Mount the Alignment Telescope for an Upward Sight.

1. Mount the base plate of the Plumb Aligner Bracket, with attached leveling plate and telescope collar, on the stand.

2. Slide the Alignment Telescope upward through the telescope collar as far as possible without allowing the enlarged part of the telescope to come into contact with the bottom of the collar. Support the telescope in this position.

3. Position the azimuth collar over the Alignment Telescope.

4. Remove the socket-heat plug screw located in the azimuth collar. (See Figure 2-16.)

5. Rotate azimuth clamp (Figure 2-16) until the hole is in line with the hole in the azimuth collar; then, tighten the azimuth lock screw.

6. Rotate the combination until it is aligned with the locating hole in the telescope barrel. Screw in the pin screw. (The pin screw is in an envelope or bag with other accessories.)

7. Replace the socket-head plug screw over the pin screw.

8. Remove the supports from the telescope. Tighten the three setscrews in the azimuth collar.

9. Slide the level collar over the telescope as far as possible without touching the azimuth collar. Turn the coincidence level parallel to one of the telescope cross lines, and lock it in place by tightening the three socket-head setscrews at the lower end of the level collar.

10. Focus the Alignment Telescope on the point, and level as in the preceding paragraph. It may be necessary to install an accessory Right-Angle Eyepiece on the Alignment Telescope to facilitate sightings through the telescope.

2-59. OPERATION OF ALIGNMENT COLLIMATOR

The Alignment Collimator is usually mounted on a facility gauge or other small jig part so that the tilt and position of the gauge or part can be controlled by the line of sight of an Alignment Telescope or Line of Sight Telescope. Figure 2-18 illustrates the basic method of positioning a part using an Alignment Collimator and shop level.

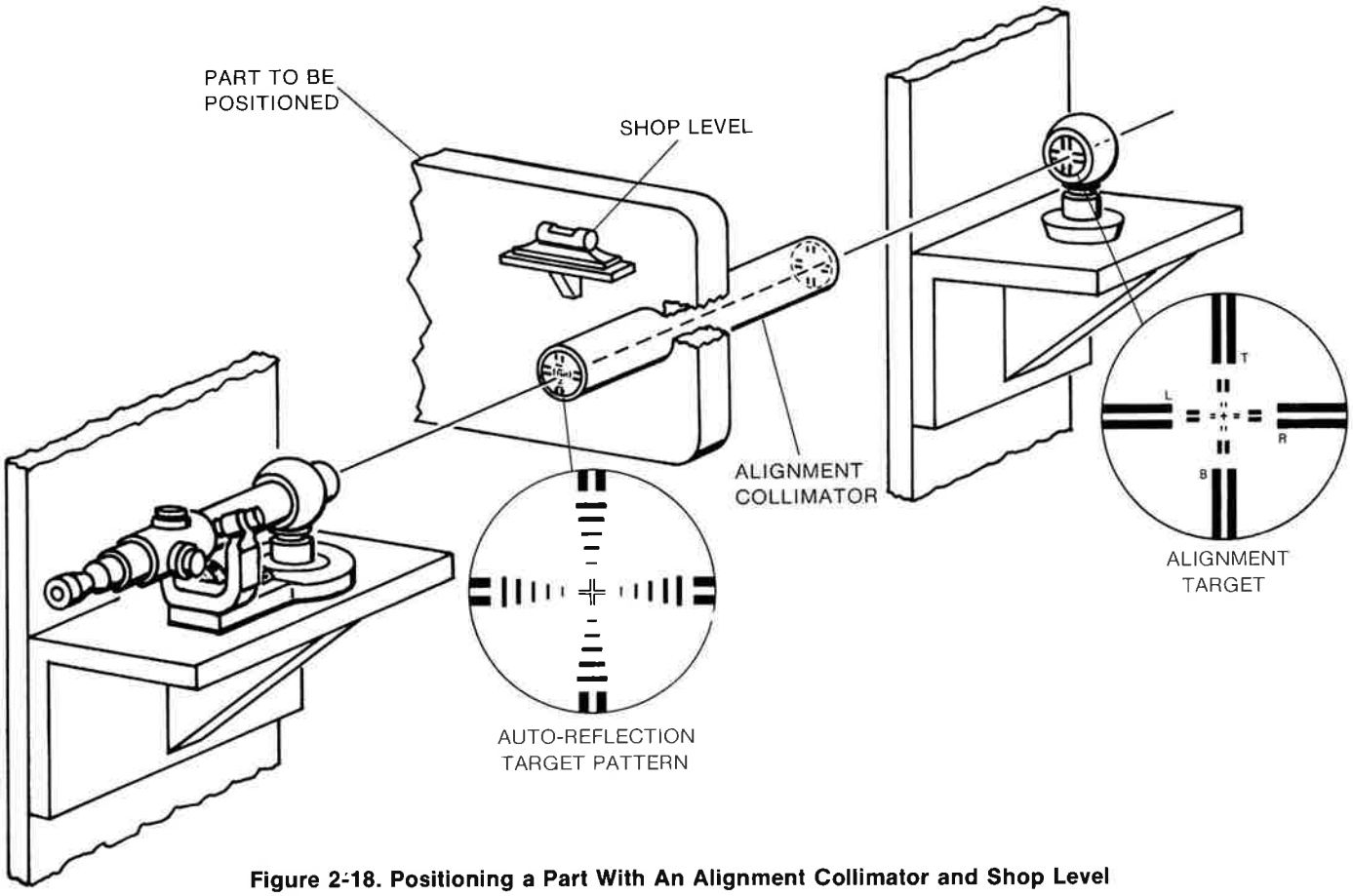

Figure 2-18. Positioning a Part With An Alignment Collimator and Shop Level

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2-60. To adjust the tilt and position of a part relative to the line of sight:

1. Level the part using the shop level.

2. Adjust the Alignment Telescope or Line of Sight Telescope to infinity focus and view the tilt target of the Alignment Collimator through the Alignment Telescope or Line of Sight Telescope. Tilts of up to 18 minutes of arc can be read directly off the tilt target.

3. To eliminate all tilt, adjust the part as necessary to bring the center of the tilt target of the Alignment Collimator on the cross lines of the Alignment Telescope or Line of Sight Telescope. Keep the part level.

4. Focus the Alignment Telescope or Line of Sight Telescope on the displacement target of the Alignment Collimator. The tilt target of the Alignment Collimator will now be invisible.

5. Adjust the lateral and vertical position of the part as required to bring the displacement target of the Alignment Collimator on the line of sight.

6. Refine the tilt, positioning, and leveling of the part as required.

READINGS TAKEN ON TARGETS OF LINE OF SIGHT COLLIMATOR

Horizontal Readings

100 Ft. Target

Direct		Reversed	
-0.6	-0.1	+6.1	+4.5
+0.5	+0.7	+4.5	+5.8
-0.1	0.0	+4.4	+4.4
+0.8	-0.6	+4.9	+4.4
0.0	+0.7	+4.8	+4.4
Avg. +0.13		**Avg. +4.82**	

MEAN OF AVERAGES +2.47

50 Ft. Target

Direct		Reversed	
0.0	+0.6	+1.3	+2.3
-0.4	+0.4	+1.9	+2.0
-0.2	+0.7	+1.6	+3.0
-0.4	+0.2	+2.3	+1.5
+0.5	-0.4	+1.7	+2.0
Avg. +0.10		**Avg. +1.96**	

MEAN OF AVERAGES +1.03

25 Ft. Target

Direct		Reversed	
-0.4	+0.2	-0.3	-0.3
-0.2	-0.3	-0.2	+0.3
-1.0	+0.1	-0.6	-0.3
-0.6	-0.4	-0.2	-0.4
-0.5	-0.1	+0.3	-0.2
Avg. -0.32		**Avg. -0.19**	

MEAN OF AVERAGES -0.25

10 Ft. Target

Direct		Reversed	
-0.0	-0.6	+1.3	+2.5
-0.4	-0.5	+1.9	+2.0
-0.2	-0.7	+1.9	+3.0
-0.4	-0.2	+2.6	+1.6
-0.6	-0.6	+1.7	+2.0
Avg. -0.39		**Avg. +2.05**	

MEAN OF AVERAGES -1.2

4 Ft. Target

Direct	Reversed
-1.2	-2.1
-1.4	-1.8
-1.3	-1.9
-1.3	-2.0
-1.4	-2.0
Avg. -1.32	**Avg. -1.96**

MEAN OF AVERAGES -1.64

0 Ft. Target

Direct	Reversed
-1.9	-2.0
-1.8	-2.1
-1.8	-2.2
-1.9	-2.2
-1.8	-2.1
Avg. -1.84	**Avg. -2.12**

MEAN OF AVERAGES -1.98

Thus values to plot are: 100 Ft. +2.47, 50 Ft. +1.03, 25 Ft. -0.25, 10 Ft. -1.2, 4 Ft. -1.64, 0 Ft. -1.98

Figure 2-19. Typical Computations of Horizontal Deviations of Line of Sight From Straight Line

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2-61. OPERATION OF STRAIGHTNESS OF LINE OF SIGHT COLLIMATOR

The Straightness of Line of Sight Collimator can be used to check Alignment Telescopes, Line of Sight Telescopes, Jig Transits, or any transits, levels, or other optical sighting devices, provided that these instruments can be equipped with optical micrometers. To use the Straightness of Line of Sight Collimator to check any of these instruments:

1. Place a light behind the collimator. (A 71 5120 Lamp Housing is available as a collimator accessory.)

2. Buck in the instrument that is to be tested between the zero foot target and the 100 foot target of the collimator.

3. Take ten readings on each target of the collimator, using the optical micrometer on the instrument being tested to measure the displacement of the line of sight to the nearest 0.0001 inch. Average the readings of each target.

4. Rotate the collimator 180 degrees on its axis, and repeat steps 2 and 3.

5. Compute and plot the means of the averages of the direct and reversed readings for each target. Plot the points on a graph, and draw a smooth curve through the points. A typical set of readings and the resulting plot are shown in Figures 2-19 and 2-20.

2-62. The plotted curve is free from any possible errors of the collimator, but it will show the average of the errors of position and direction caused by slight discrepancies in bucking in between the zero foot and 100 foot targets. The actual deviation of the line of sight from a straight line is found by connecting any two working points on the curve (the 3 foot and 80 foot points, for example) with a straight line and reading the scale offset from this straight line to the curve at the distance of interest.

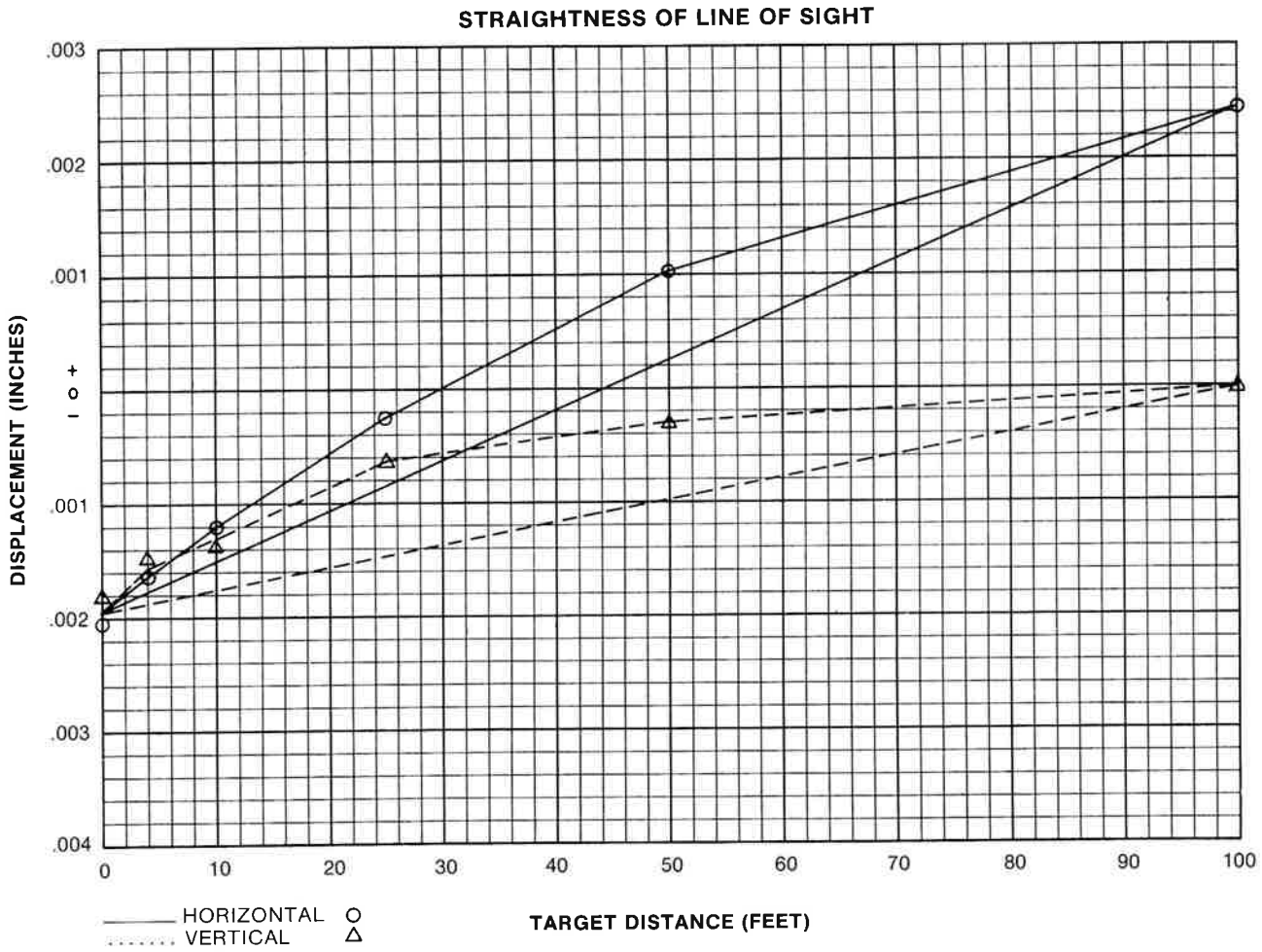

Figure 2-20. Plot of Deviations of Line of Sight

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SECTION 3 — MAINTENANCE

3-1. CARE OF INSTRUMENT

Optical instruments must be given reasonable care. Jarring and vibration may destroy adjustments. The following rules for care of optical instruments are suggested:

1. Always support the instrument in its normal position during storage, use, and adjustment.

2. Never transport an instrument unless it is fully supported on resilient material.

3. Allow the instrument to adjust to surrounding air temperature before operating the instrument.

4. Install any accessories that are to be used with the instrument before making instrument adjustments.

5. When using the instrument, remember that a column of hot or cold air anywhere along the line of sight will destroy the accuracy of the reading.

6. Avoid even partial obstructions along the line of sight when using the instrument. Partial obstructions may make the line of sight unreliable.

7. Protect the instrument from dust as much as possible. Never rub dust or dirt off a lens; blow or brush dust off lightly. If the view through the instrument becomes dim, take the instrument to a competent instrument repair man for cleaning.

3-2. TEST AND ADJUSTMENT

Alignment Collimators and Straightness of Line of Sight Collimators contain no adjustment provisions. Alignment Telescopes and Line of Sight Telescopes should be tested frequently, but adjustments should be made only if three successive tests show the same error. Many adjustments affect other adjustments and should therefore be performed in the order given to minimize interference. Where one adjustment is likely to affect another, this fact is stated in the adjustment procedures that follow.

3-3. ALIGNMENT TELESCOPE AND LINE OF SIGHT TELESCOPE ADJUSTMENTS

3-4. Object 1: To orient the vertical cross line of the reticle so that it lies in a vertical plane when the cross level bubble is in adjustment and is centered. This adjustment destroys Adjustment 2. It is divided into two parts: Adjustments 1a and Adjustment 1b.

1. Object 1a: To center the bubble of a cross level where it is mounted on the telescope and also when the cross level is remounted in the reverse direction; i.e., when it is turned end for end.

a. Test 1a.

(1) Mount the Alignment Telescope in V-blocks arranged so that the telescope can be leveled longitudinally and aimed at a well defined target.

(2) Using a 71 3220 Coincidence Striding Level, level the telescope barrel.

(3) Mount a 71 3205 Cross Level on the telescope.

(4) Rotate the telescope in the V-blocks until the bubble of the cross level is centered.

(5) Reverse the cross level; the bubble should center. If it does not, perform the following adjustments.

b. Adjustment 1a.

(1) Rotate the telescope in the V-blocks until the bubble of the cross level moves halfway back to the center.

(2) Eliminate the remaining centering error by adjusting the adjusting screw at one end of the cross level.

(3) **Repeat Test 1a.**

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2. Object 1b: To align the reticle to the micrometer motions. This adjustment destroys Adjustments 2 and 3.

a. Test 1b.

(1) Adjust one of the micrometer knobs on the telescope to either extreme position.

(2) Aim the telescope at a well defined target.

(3) Rotate the same micrometer knob to its other extreme position. The cross line should remain on the target. If not, perform the following adjustments.

b. Adjustment 1b. (See Figure 3-1.)

(1) Unscrew the eyepiece and reticle cover from the telescope. Reinstall the eyepiece.

(2) Four reticle adjusting screws are now exposed. Loosen two adjacent adjusting screws. Tap the screws gently to make them slide around the telescope until the cross line remains on the target throughout the full micrometer movement.

(3) Tighten the reticle adjusting screws that were loosened.

(4) **Repeat Test 1b.**

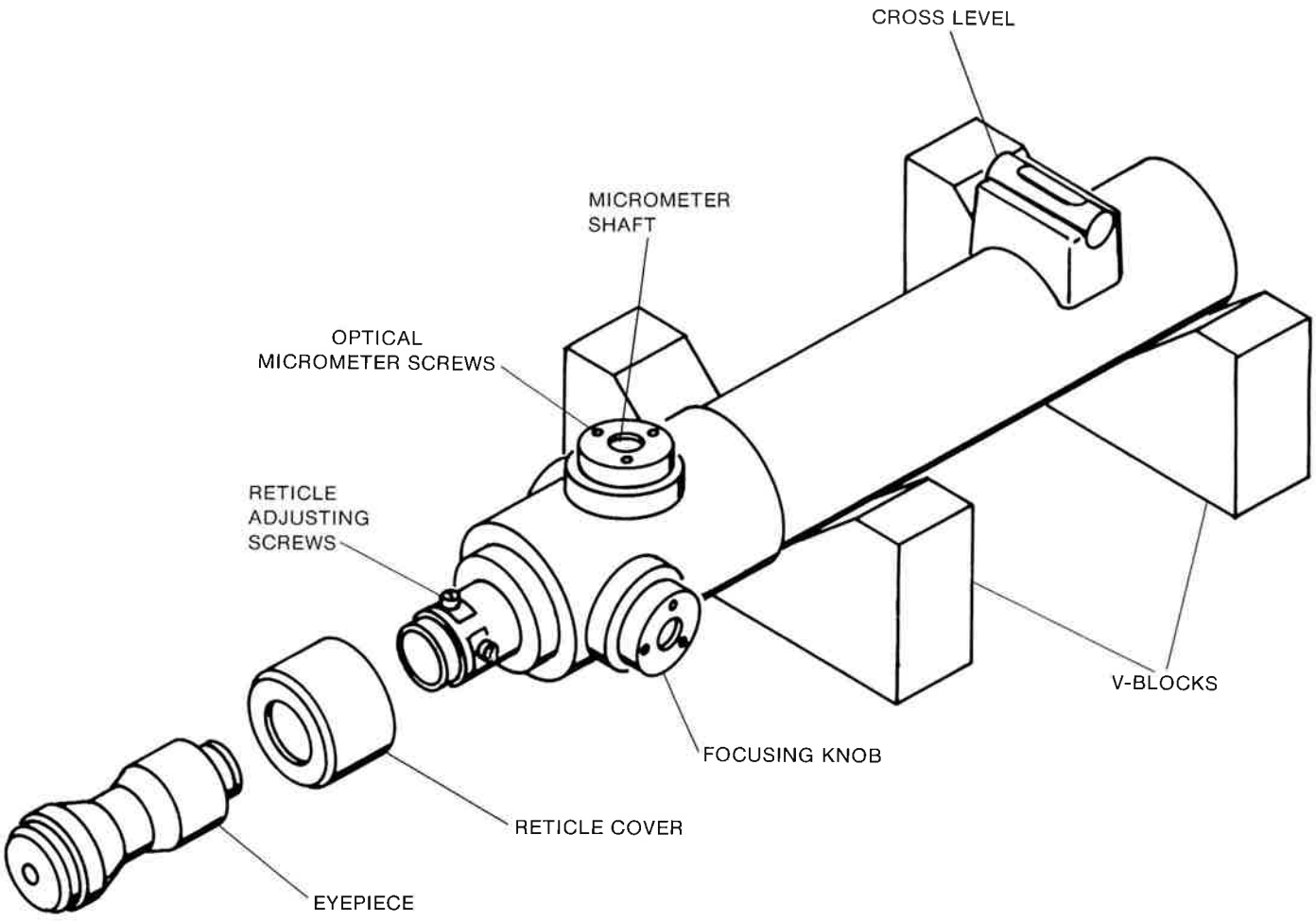

Figure 3-1. Alignment Telescope Prepared for Adjustment

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3-5. Object 2: To make the line of sight parallel with the longitudinal axis of rotation of the Alignment Telescope, i.e., with the outside surface of the telescope barrel.

1. **Test 2.**

   a. If no Spherical Adapter is to be used, support the Alignment Telescope in V-blocks. If a Spherical Adapter is to be used, support the telescope barrel in a cone-type V-block, and support the Spherical Adapter in a Cup Mount.

   b. Unscrew the eyepiece and reticle cover (Figure 3-1). Reinstall the eyepiece.

   c. Aim at a distant target, preferably at a collimator reticle.

   d. Rotate the telescope 180 degrees. The cross lines should remain on the target. If not, perform the following:

2. **Adjustment 2.**

   a. Using the reticle adjusting screws, bring the horizontal and vertical cross lines halfway toward the target. In using the screws, be careful to retain tension; otherwise, Adjustment 1 will be destroyed.

   b. Repeat Test 2.

3-6. Object 3: To make the line of sight coincide with the longitudinal axis of rotation of the Alignment Telescope, i.e., with the outside surface of the telescope barrel. This is a shop adjustment for Alignment Telescopes.

1. **Test 3.**

   a. Mount the Alignment Telescope as in Test 2.

   b. With the optical micrometers on the instrument set at zero, aim at a target set as close as possible to the Alignment Telescope.

   c. Rotate the telescope 180 degrees. The cross lines should remain on the target. If not, perform the following:

2. **Adjustment 3.**

   a. Adjust the optical micrometers so that the cross lines move halfway to the target.

   b. Loosen the three screws at the top of the drum of vertical optical micrometer (Figure 2-1 or 2-2). While holding the shaft of the vertical optical micrometer with a finger, turn the vertical optical micrometer scale carefully until it reads zero.

   c. Tighten the three screws at the top of the vertical optical micrometer drum.

   d. Repeat steps b and c for the horizontal optical micrometer.

   e. Repeat Test 3.

3-7. PLUMB ALIGNER BRACKET ADJUSTMENT

3-8. Object 1: To make the coincidence level indicate level when the longitudinal axis of the Alignment Telescope is vertical. The longitudinal axis is the axis of the surface of the cylindrical section of the Alignment Telescope. This adjustment affects no other adjustment.

1. **Test 1.**

   a. Mount the Alignment Telescope in the Plumb Aligner Bracket, pointing either upward or downward depending upon the direction in which it will be used.

   b. Level the Alignment Telescope with the leveling screws. 180 degrees in azimuth. The bubble ends of the coincidence level should remain in coincidence. If they do not, perform the following:

   c. Rotate the Alignment Telescope.

2. **Adjustment 1.** Eliminate half the error as follows:

   a. Located behind the coincidence level, between the level and the telescope barrel, are three capstan head screws aligned horizontally. The two end capstan head screws are clamps. Free these two screw clamps.

   b. The center capstan head screw turns an eccentric that moves the mirrors forward and back, thereby regulating the position of coincidence. Turn the center capstan head screw as required to eliminate half the error. If this movement is sufficient, set the two end screw clamps. **Repeat Test 1.**

   c. If the movement of the mirrors in step b is insufficient to eliminate half the error, note the limits of movement of the adjusting pin when the eccentric is turned as far as possible in each direction. Move the adjusting pin to the half-way point between these limits.

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d. Remove the plug screws on the top and bottom near the viewing end of the cover of the level. The two exposed socket-head screws bear against the top and bottom of one end of the bubble-vial tube. Loosen one screw and tighten the other by small increments until coincidence very nearly occurs when Test 1 is made. Make sure that the screws are tightened firmly when the adjustment has been finished.

e. Complete the adjustments by repeating step b.

f. Replace the plug screws and tighten the end capstan head screw clamps.

g. Repeat Test 1.

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APPENDIX — ACCESSORIES

71 1211
Auto-Collimation
Conversion Unit

71 1231
Right-Angle Eyepiece

71 1241
Combination Auto-Collimation,
Projection, Right-Angle Eyepiece

71 2230
Right-Angle
Eyepiece

71 2240
Combination Auto-Collimation,
Projection, Right-Angle Eyepiece

71 2302
Angle Reading
Attachment

71 2410
Optical Square

71 2412
Double Sphere
Optical Square

71 3205
Cross Level

71 3230
Coincidence Striding Level

71 3220
Coincidence Striding Level

71 4111
Auto-Collimation
Eyepiece

71 5100
Spherical Adapter

71 5103
Spherical Adapter

71 5511
Auto-Collimation Illumination Unit

71 5520
Lamp Housing

Figure A-1. Accessories

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A-1. 71 1211 AUTO-COLLIMATION CONVERSION UNIT

Description

The 71 1211 Auto-Collimation Conversion Unit can be used to convert the Line of Sight Telescope into an auto-collimating telescope. It is supplied complete with a lightplug assembly, cord, switch and fixed 6-volt transformer. It operates directly from 110 volts AC, 50-60 Hz. The Auto-Collimation Conversion Unit consists of two major parts: the beam splitter with its mount, and the illumination unit. The illumination unit may be ordered separately for replacement as 71 5511 Auto-Collimation Illumination Unit. (See Paragraph A-14.)

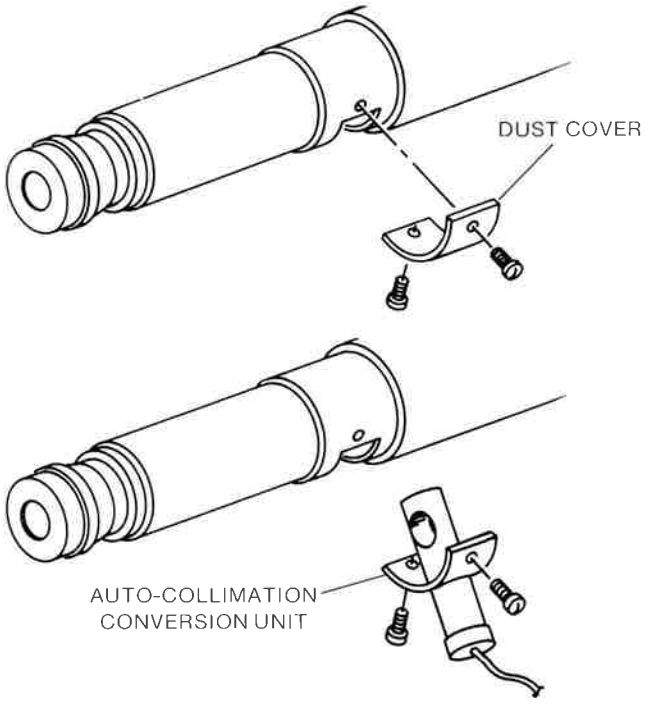

Figure A-2. Installation of Auto-Collimation Conversion Unit

Installation

To install the 71 1211 Auto-Collimation Conversion Unit on the Line of Sight Telescope, proceed as follows:

1. Locate the dust cover plate on the underside of the telescope tube just forward of the eyepiece. (See Figure A-2.)

2. Remove the two dust cover plate attaching screws, then remove the dust cover plate. The same two screws are used to mount the Auto-Collimation Conversion Unit.

3. Insert the Auto-Collimation Conversion Unit into the opening in the telescope tube. Note that the mounting holes are off-center so that the Unit can be mounted only in its proper orientation. The Unit should be mounted with its wide edge forward of the holes. When the Unit has been properly positioned, Insert the mounting screws and snug the screws tight.

4. The 71 5511 Auto-Collimation Illumination Unit is provided with an on-line 6-volt transformer with a 3-prong, twist-lock male connector. (This is in accordance with AIA requirements.) Plug the male connector into a suitable 110 volt AC outlet or extension cord connected to such an outlet. If a 3-prong, twist-lock outlet or extension cord is not available, the unmounted female connector supplied with the Auto-Collimation Conversion Unit can be used to fabricate an extension cord or short pig-tail to adapt to the available AC outlet or extension cord.

5. Turn on the switch and check the light in the Auto-Collimation Illumination Unit. It is used to illuminate the cross lines of the telescope.

Use

The auto-collimation process can be used to position a part perpendicular to the line of sight of the telescope. With the Auto-Collimation Conversion Unit installed, mount an optically flat target mirror on the part that is to be positioned so that the reflective surface of the mirror is approximately centered on the line of sight of the telescope. When the telescope is aimed at the mirror and focused, it serves as a telescopic sight and both the illuminated cross lines and the reflection of those cross lines in the mirror can be seen through the telescope. By adjusting the part so that the reflection of the cross lines coincides with the actual cross lines of the reticle, both the mirror and the part are perpendicular to the line of sight cf the telescope. (See Figure A-3.)

A-2. 71 1231 RIGHT-ANGLE EYEPIECE

The 71 1231 Right-Angle Eyepiece can be used on the Line of Sight Telescope in place of the standard eyepiece for very low setups or when working close to walls, columns, or other obstructions. The Right-Angle Eyepiece maintains a fully erect image and can be rotated through 360 degrees for sighting from any perpendicular angle.

Installation and Adjustment

Unscrew the standard eyepiece from the instrument telescope tube and install the Right-Angle Eyepiece. Observe the reticle. If the reticle cannot be brought into sharp focus using the eyepiece focusing ring, the following adjustment is required:

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1. Set the Right-Angle Eyepiece at the midpoint of its total movement.
2. Remove the eyepiece and adapter from the Eyepiece assembly. (See Figure A-4.) Loosen setscrew "A" with a 0.023 inch socket wrench.
3. Move the lens mount in or out in small increments, installing the eyepiece and adapter and rechecking the focus after each adjustment, until the reticle can be focused sharply with the Eyepiece focusing ring.
4. Remove the eyepiece and adapter and tighten setscrew "A".
5. Recheck reticle focusing. If necessary, repeat steps 1 through 4.

Use

The Right-Angle Eyepiece is used and focused in the same manner as the standard eyepiece, except that is is displaced 90 degrees relative to the line of sight of the instrument telescope. Position Eyepiece for most convenient sighting.

A-3. 71 1241 COMBINATION AUTO-COLLIMATION, PROJECTION, RIGHT-ANGLE EYEPIECE

Description

The 71 1241 Combination Auto-Collimation, Projection, Right-Angle Eyepiece is interchangeable with the standard eyepiece of the Line of Sight Telescope. This Eyepiece can be converted in the field as required to form a straight-through vision system or a right-angle vision system. The unit includes a variable output transformer for use with 110 volts AC, 50-60 Hz.

Installation and Adjustment

Unscrew the standard eyepiece from the Line of Sight Telescope, and screw on the Combination Auto-Collimation, Projection, Right-Angle Eyepiece in its place. Observe the reticle through the Eyepiece; if the reticle cannot be brought into sharp focus using the Eyepiece focusing ring, adjust the Eyepiece as follows:

1. Set the Eyepiece to the approximate center of its movement. Then, unscrew the entire unit.
2. Loosen setscrew "A" (Figure A-5) with a 0.035 inch hexagon key.
3. Move the lens mount in or out in small increments. Check the reticle focusing after each incremental adjustment.
4. When the reticle can be focused sharply with the Eyepiece focusing ring, tighten setscrew "A".
5. Focus the telescope at infinity.
6. Hold a piece of white paper approximately two feet from the end of the telescope.
7. Connect the projection unit to the transformer, switch on AC power, and observe the projected filament on the white paper. If the filament does not appear sharp, loosen the four projection unit adjusting screws and move the lamp forward or backward until the filament appears sharp.
8. Adjust the lamp with the four projection unit adjusting screws until the filament appears centered in the projected circle of the field.
9. Refocus the telescope until the reticle appears sharp on the white paper. The projected circle should be bright and evenly illuminated. If a shadow appears in the field, the lamp (filament) is not centered properly; repeat step 8.

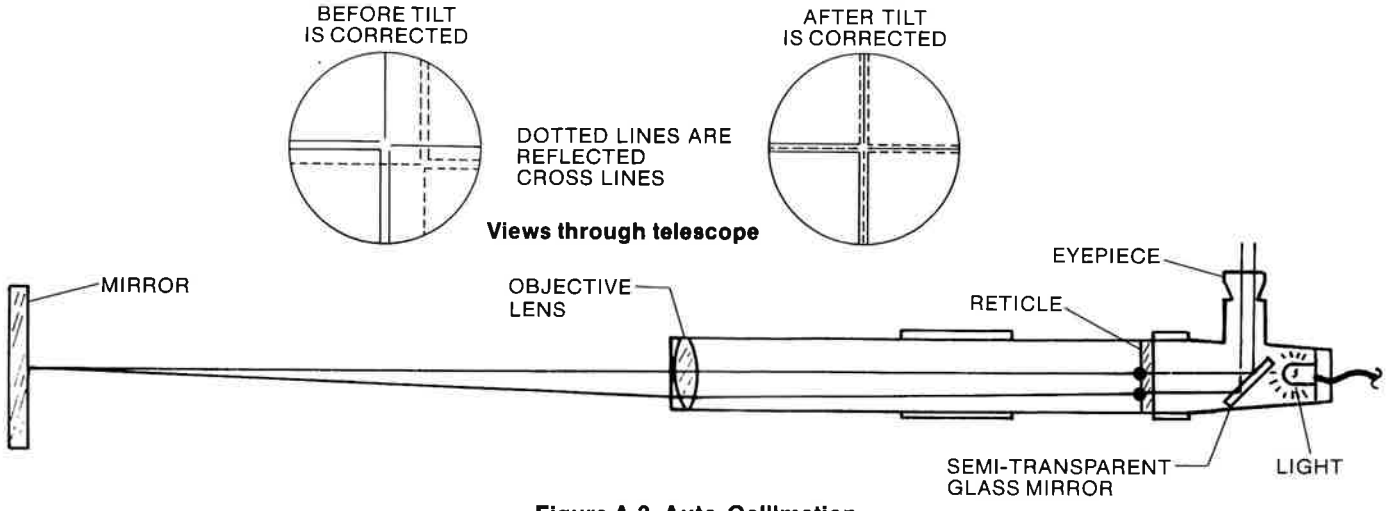

Figure A-3. Auto-Collimation

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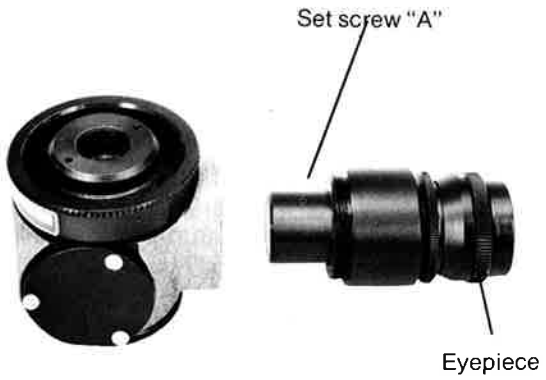

Figure A-4. Right Angle Eyepiece

Figure A-5. Installation of Combination Auto-Collimation, Projection, Right-Angle Eyepiece

Use

1. To use the Combination Auto-Collimation, Projection, Right-Angle Eyepiece for right-angle viewing, merely position the Eyepiece for most convenient viewing, and focus and use the Eyepiece in the same manner as the standard eyepiece.

2. To use the Combination Auto-Collimation, Projection, Right-Angle Eyepiece for straight-through viewing, interchange the projection unit and the eyepiece/eyepiece mount assembly. Then, focus and use the Eyepiece in the same manner as the standard eyepiece.

3. To use the Combination Auto-Collimation, Projection, Right-Angle Eyepiece, for auto-collimation, connect the projection unit to its transformer, switch on AC power, and push the prism slide assembly to the right. The auto-collimation process is the same as that described for the 71 1211 Auto-Collimation Conversion Unit.

4. To use the Combination Auto-Collimation, Projection, Right-Angle Eyepiece as a projection eyepiece, connect the projection unit to its transformer, switch on AC power and push the prism slide assembly to the left.

A-4. 71 2410 OPTICAL SQUARE

Description

The 71 2410 Optical Square can be used with either the Alignment Telescope or the Line of Sight Telescope. It consists of a pentaprism optical system mounted in a spherical housing with a diameter of 3.500 inches, which turns the line of sight 90 degrees (±1 second) from its entering direction. In addition to establishing a plane that is perpendicular to the basic line of sight, the Optical Square also permits sighting straight through since it has both front and side apertures. The desired line can be selected by covering the line not wanted with a cap attached to the Square. (See Figure A-6.)

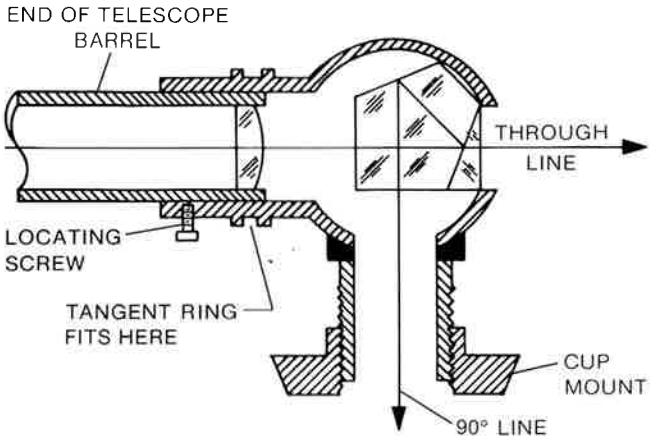

Figure A-6. Schematic View of Optical Square

Installation

To mount the Optical Square on the telescope tube, remove the locating screw from the Square. Clean the inside bearing rings. With the telescope tube held securely so that it extends over the edge of a table, carefully slide the Square onto the telescope tube and match the locating hole on the Square with the one on the telescope tube. Insert and tighten the locating screw. Mount the telescope with the Optical Square on a bracket such as 71 5170 with Extension Arm 71 5175, or Bracket 71 5180. The Optical Sphere is secured by a 71 5140 Adjustable Cup Mount and a 71 5142 Clamp (See Figure 2-5.)

Use

Refer to Section 2, Paragraph 2-47, "To Establish a Plane Perpendicular to a Reference Line".

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A-5. 71 2412 DOUBLE SPHERE OPTICAL SQUARE

Description

The 71 2412 Double Sphere Optical Square is similar to the 71 2410 Optical Square except that a second sphere is located 2.250 inches behind the sphere that houses the pentaprism. (See Figure A-7.) When the second sphere is placed in a cup mount, the Optical Square can be rotated to provide a clear right-angle view through a full 360 degrees.

Use

Refer to Section 2, Paragraph 2-47, "To Establish a Plane Perpendicular to a Reference Line".

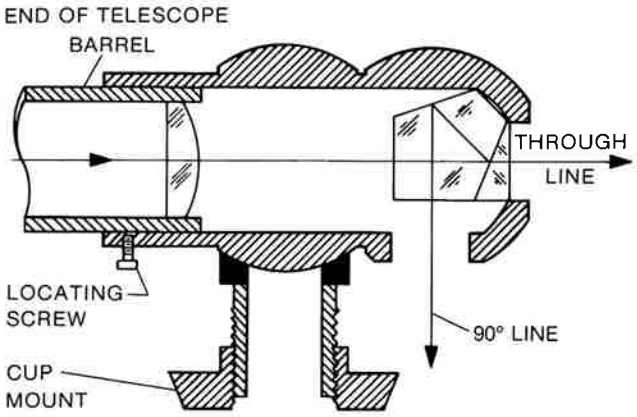

Figure A-7. Schematic View of Double-Sphere Optical Square

A-6. 71 2302 ANGLE READING ATTACHMENT

Description

The 71 2302 Angle Reading Attachment converts the Alignment Telescope into an angle-reading type telescope.

Use

The 71 2302 Angle Reading Attachment fits over the objective end of the Alignment Telescope. With this attachment in place, the micrometers of the Alignment Telescope read directly to one second of arc over a range of 50 seconds at infinity only. Maximum usable distance for auto-collination is approximately 30 feet. The infinity setting on the instrument focusing knob is approximately 17 feet.

A-7. 71 2230 RIGHT-ANGLE EYEPIECE

Description

The 71 2230 Right-Angle Eyepiece can be used in place of the standard eyepiece on the Alignment Telescope for low setups, at floor level, or when working close to a wall or other obstruction. It maintains a fully erect image and can be rotated through 360 degrees for sighting from any angle perpendicular to the line of sight.

Installation and Adjustment

(See Paragraph A-2.)

Use

(See Paragraph A-2.)

A-8. 71 2240 COMBINATION AUTO-COLLIMATION, PROJECTION, RIGHT-ANGLE EYEPIECE

Description

The 71 2240 Auto-Collimation, Projection, Right-Angle Eyepiece can be used in place of the standard eyepiece on the Alignment Telescope. It consists of a Right-Angle Eyepiece plus a 71 5571 Illumination Unit that can be used to project an image of the reticle onto a target or for auto-collimation. The Eyepiece can be converted in the field as required to form a straight-through vision system or a right-angle system. The unit includes a variable transformer for use with 110 volts, 50-60 Hz.

Installation and Adjustment

(See Paragraph A-3.)

Use

(See Paragraph A-3.)

A-9. 71 3205 CROSS LEVEL

Description

The 71 3205 Cross level can be used with The Alignment Telescope, Line of Sight Telescope and Alignment Collimators to establish the reticles vertically and horizontally. The Level vial has a sensitivity of 90 seconds of arc per 2 mm movement.

Installation

The Cross Level is positioned on the barrel of the instrument by means of a stud that fits into a hole in the instrument barrel. When the Cross Level bubble is centered, the cross lines of the instrument are vertical and horizontal.

A-10. 71 3220 COINCIDENCE STRIDING LEVEL

Description

The 71 3220 Coincidence Striding Level can be used with the Alignment Telescope and Line of Sight Telescope to establish a level line of sight. The Level vial has a sensitivity of 20 seconds of arc per 2 mm movement.

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Installation
The Level is placed directly on the barrel of the instrument and is held in place by a spring clip. When the instrument is adjusted so that the two Level vial bubble ends coincide, the line of sight of the instrument is level.

A-11. 71 3230 COINCIDENCE STRIDING LEVEL

Description
The 71 3230 Coincidence Striding Level can be used with the Straightness of Line of Sight Collimator to establish the collimator in a level position. The Coincidence Striding Level vial is accurate to within 1 second of arc.

Installation
The Striding Level is placed directly on the barrel of the Collimator and is held in place with a spring clip. When the Collimator is positioned so that the two Level vial bubble ends coincide, the Collimator is level.

A-12. 71 4111 AUTO-COLLIMATION EYEPIECE

Description
The 71 4111 Auto-Collimation Eyepiece can be used to convert the 71 4010 Alignment Collimator into an auto-collimator.

Installation
After removing the filter plate, the eyepiece can be attached by screwing it into the end of the Alignment Collimator, thereby making the collimator function as a 30X infinity focus telescope. A plug-in 71 5511 Auto-Collimation Illumination Unit for use with 110 volts AC, 50-60 Hz is included. The auto-collimation principle is illustrated in Figure A-3 and the operating procedure is basically the same as for the 71 1211 Auto-Collimation Conversion Unit, except for the instrument involved.

A-13. 71 5100 SPHERICAL ADAPTER (WITH COLLET)

Description
The 71 5100 Spherical Adapter is a hardened steel sphere ground to a diameter of 3½ inches, and conforming to A.I.A. specifications. It has a collet for clamping the Adapter on any point along the barrel of an Alignment Telescope, Line of Sight Telescope or Alignment Collimator, or any other tube 2¼ inches in diameter.

Use
It can be used to facilitate mounting the telescopes in a Cup Mount, or to hold a target. The 71 5101 Target Stop Ring is used to position a target in the center of the Spherical Adapter.

A-14. 71 5103 SPHERICAL ADAPTER (WITHOUT COLLET)

Description
The 71 5103 Spherical Adapter is a through hardened steel sphere ground to a diameter of 3½ inches, and conforming to A.I.A. specifications.

Use
It is designed to accommodate any tube or target with a diameter of 2¼ inches. Three tapped holes with set screws are provided in the sphere to secure any of the 2¼ inch diameter targets or 71 5520 Lamp Housing. A fourth hole and set screw is provided to secure the Spherical Adapter to a telescope barrel.

A-15. 71 5511 AUTO-COLLIMATION ILLUMINATION UNIT

Description
The 71 5511 Auto-Collimation Illumination Unit is part of the 71 1211 Auto-Collimation Conversion Unit, although it may be ordered separately for replacement purposes. It consists of a transformer, cord, switch, and light plug assembly, can be used with Alignment Telescopes and Line of Sight Telescopes. It is designed for 110 volts AC, 50-60 Hz, and may be used with all auto-collimation illumination attachments.

Use
(See Paragraph A-1.)

A-16. 71 5520 LAMP HOUSING

Description
The 71 5520 Lamp Housing can be used with Alignment Telescopes, Straightness of Line of Sight Collimators, or any transparent target positioned in a Spherical Adapter such as 71 5100 or 71 5103. The lamp housing provides illumination for the reticle pattern of the collimator. The lamp is rated at 15 watts and requires 110 volts AC, 50-60 Hz.

A-17. 71 5535 LAMP HOUSING HOLDER

Description
The 71 5535 Lamb Housing Holder positions the 71 5520 Lamp Housing behind a Straightness of Line of Sight Collimator when the collimator is supported on a 71 5192 V-Block Cone Assembly.

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