OPTICAL TOOLING INSTRUMENT

CALIBRATION AND ADJUSTMENT

USING THE

MODEL 270-BN UNIVERSAL

SHORT-RANGE CALIBRATOR

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FOREWORD

This manual was developed as a result of requests from students attending the Brunson Instrument Company's courses in practices and procedures for instrument adjustment. The lack of written information prompted this writing.

Contained herein are specific, detailed procedures for use with the Brunson model 270-BN Universal Short-Range Calibrator. These procedures, while applicable in principle to a transit, level, or line scope, are meant specifically for instruments produced by the Brunson Instrument Company. For information on other makes, the manufacturer should be consulted.

No amount of printed material can be substituted for sound instruction, and actual experience under the guidance of a qualified instructor. This manual is not intended as a "short course" in instrument calibration, but as a help for those who have been properly trained. Before attempting any work to the degree of accuracy required of optical tooling, PROPER INSTRUCTION IS AN ABSOLUTE NECESSITY.

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NOTES ON HANDLING AND OPERATION OF OPTICAL INSTRUMENTS

Following are some general guidelines for handling and use of optical tooling and surveying instruments. These rules are by no means a substitute for instruction by qualified and experienced personnel, but are, in general, things to remember when using or calibrating the instruments.

1. Get comfortable. When making measurements or observations with any precision instrument, the operator must be in a comfortable physical position in order to maintain accuracy. Various stools, steps, etc. may be required in order to position the operator's body properly near the instrument.

2. Handle instruments as the delicate, precise measuring tools they are. The most ruggedly constructed transit or level cannot be expected to perform accurately when handled as a common hand tool. Even setting the instrument down roughly on a hard surface can cause calibration changes and damage.

3. Always make sure the eyepiece of any instrument is properly focused for the eye of the operator. Aim the telescope at a diffused light source, or hold a piece of white paper in the front of the objective lens. Adjust the eyepiece until the sharpest, blackest image of the reticle is obtained. This should automatically become the first thing an operator does when making a sighting.

4. If there are to be two or more operators using or testing one instrument, one operator should be allowed to make a complete reading or series of readings before the second operator ever looks into the instrument. Each observer must make his own setup and take measurements uninterrupted in order to maintain accuracy.

5. Use extreme care when using the AA Gauge "Ultradex" fixture found on the Test Instrument mounting post of the model 270-BN test stand. The unit's accuracy of 1/4 arcsecond cannot be maintained without treating it as if you were "walking on eggs" every time it is used. When operating the Ultradex's release lever, do not simply pull it, but first anchor your hand on the base of the Ultradex to balance the force required to move the lever. When indexing an instrument mounted atop the Ultradex, turn the table around slowly. This prevents the inertia of the instrument itself from disturbing the azimuth setting.

6. When using tangent screws to accurately point an instrument, make a setting, and then tap on the head of the tangent screw with a finger. This will aid the tangent clamp mechanism in "settling in" to a stable position. (In effect, this is a kind of stress-relief.) Observation should then be made to verify the accuracy of the setting, and more correction made with the tangent screw as necessary.

7. Become familiar with the characteristics of the instrument before attempting to use or calibrate it. Some transit type instruments' telescopes will only allow one end of the telescope to plunge through the standards. Similarly, most optical micrometers will not pass through the standards of a transit, particularly when they are not in an upright position. A little care in determining the physical limitations of the instrument's motion may save expensive damage in use.

8. When mounting or dismounting an instrument from a post or stand, use two hands. Grip a structurally strong part of the instrument with one hand, and manipulate the instrument base with the other.

9. When removing an instrument from its case, make sure all parts and projections are free of the case as the instrument is lifted. Check to make certain any accessories, such as optical micrometers, are secured so as not to fall off during handling.

10. When replacing an instrument in its case, make sure all parts of the instrument are positioned properly to fit the contours of the case when closed. The tangent clamps should be snug, not tight, when the instrument is in its case. Many instruments will only fit their cases one way, and external index marks are provided on some for proper positioning. Closing a case on an improperly positioned instrument can result in damage.

INITIAL SET-UP

Most instruments to be calibrated on the model 270-BN collimation test stand are mounted on the Test Instrument's mounting post in the same manner (i.e., a female screw thread in the base of the Test Instrument fitted to a male thread on the mounting post). This procedure describes, in general, how an instrument should be set up in order to begin calibration on the model 270-BN.

1. Determine the kind and size of instrument mounting thread on the Test Instrument in question. If this is not a 3-1/2 inch, 8-thread American Standard size, the proper adapter must be chosen and fixed in place atop the Test Instrument's mounting post.

2. Fix the Test Instrument to the mounting post firmly, but not with extreme force. In the case of a four-screw leveling base on the Test Instrument, leveling screws may need to be loosened from pressing tightly against the bottom plate, in order that the mounting may be threaded completely together. Align one opposing pair of leveling screws on a line parallel to the Multiple Target Collimator (M.T.C.), and the other pair on a line perpendicular to the M.T.C.

3. In the case of a tribrach leveling base, do not tighten excessively; the greater the force applied to the Test Instrument's mounting threads, the tighter the leveling screws will become, and damage may result. Snug is sufficient, especially for tribrachs.

4. Manipulate the Test Instrument's leveling screws so that the "rough-in" level vial(s) show a level condition. (On some instruments there is a circular or "bull's-eye" vial for this purpose. Others use a pair of tubular vials mounted at right angles to each other.)

5. Set the T. I. telescope level using its level vial.

6. Loosen the clamp on the Test Instrument's mounting post, and, using the handwheel, raise or lower the Test Instrument to a height that allows a finite target in the M.T.C. to be sighted. (Turn on collimator lights using the toggle switch on the test stand control panel.) Tighten the clamp on the Test Instrument's mounting post.

   NOTE: Before loosening the clamp on the Test Instrument's mounting post, BE SURE the hand-wheel is rotated clockwise until snug. This eliminates any play in the mounting post gears and protects the Test Instrument's bearings from shock during mounting post adjustment.

7. Using the eyepiece of the Test Instrument only, achieve the sharpest possible focus on the Test Instrument's reticle. This is essential to the accuracy of all measurements made, and should be constantly re-verified throughout calibration of any instrument.

8. Focus the Test Instrument at infinity and sight the infinity target of the M.T.C. Using the Test Instrument's tangent screws, achieve approximate register between the Test Instrument's reticle and the M.T.C. infinity target.

9. Focus the Test Instrument on the 4-ft. M.T.C. target. (For some surveying instruments, the 6 or 16 ft. M.T.C. target must be used.) At this short-focus distance, note whether or not the Test Instrument's horizontal reticle line is in approximate register with that in the M.T.C. If not, achieve approximate register by raising or lowering the Test Instrument accordingly. (If the movement required is beyond the range of the precision lift in the Test Instrument's mounting post, the clamp must be loosened, and the entire post moved up or down using the handwheel.)

10. Focus the Test Instrument at infinity, and achieve accurate register between the Test Instrument's reticle and the M.T.C. infinity target, using the Test Instrument's tangent screws.

11. Focus the Test Instrument at the near-focus target. Achieve register between the Test Instrument's reticle and the near-focus target, using the precision lift and lateral slide in the Test Instrument's mounting post. (Do not disturb the Test Instrument's tangent screws.)

12. If the Test Instrument is a level, the initial set-up is now complete. If the Test Instrument is a transit, the spindle of the Ultradex fixture must be made nominally parallel to the Test Instrument's vertical axis. (Continue this procedure.)

13. Verify that the "rough-in" leveling vial(s) are properly adjusted, see pg. 21, and are centered to indicate a level condition.

14. Index the entire Test Instrument 180° using the Ultradex fixture. (Do not rotate the Test Instrument on its own vertical axis bearings.)

15. Observe any out-of-level condition indicated by the "rough-in" vials. Correct half this error using the Test Instrument's leveling screws, and the other half using the leveling screws in the Ultradex fixture mounting base. (Two knobs found at left front and left rear of Ultradex mounting base.)

16. Repeat steps 14, 15, and 16 of this procedure until the Test Instrument can be indexed 180° on the Ultradex fixture and no error is observed in the "rough-in" level vial(s).

17. Initial set-up is now complete and calibration procedures may be performed.

CALIBRATION ATTRIBUTES OF OPTICAL TOOLING INSTRUMENTS

OPTICAL MICROMETERS -- Model nos. 160, 190, include models with "-M", or "-50" suffix.

1. Backlash: Repeatability on a target approaching from either direction.
   Tol: ± 1/2 minor graduation.

2. "Zero" Center Adjustment: Optical flat of micrometer is perpendicular to the instrument's line-of-sight when the scale reads "zero".
   Tol: ± 1/2 minor graduation.

3. Range Accuracy: Micrometer scale accurately determines the displacement of the line-of-sight.
   Tol: ± 1/2 minor graduation.

TRANSITS - Model nos. 71, 771, 75, 76, 79, 376, 379, include models with "-1", "H", "RH", or "RHN" suffix.

1. Bull's-eye or Circular Level Vial: "Reading" surface of the vial is perpendicular to the vertical axis.
   Tol: Bubble stays within black circular line.

2. Vertical Axis Bearing Runout: Instrument rotates accurately about the vertical axis to describe a horizontal plane.
   Tol: 2.0 arcseconds.

3. Horizontal Axis Bearing Runout: Telescope rotates accurately about the horizontal axis to describe a vertical plane.
   Tol: 1.0 arcsecond.

4. Reticle Orientation: Vertical reticle line is perpendicular to the horizontal axis.
   Tol: ± 2.0 arcseconds.

5. Horizontal Collimation: Instrument's line-of-sight is perpendicular to the horizontal axis when focused at infinity.
   Tol: ± 1.0 arcsecond.

6. Vertical Centering: Line-of-sight and horizontal axis intersect.
   Tol: ± .001 inch.

7. Horizontal Line-of-sight Straightness: Line-of-sight as measured from the vertical reticle line is straight throughout the focusing range.
   Tol: ± .001 inch, or ± 1 arcsecond, whichever is greater.

8. Vertical Line-of-sight Straightness: Line-of-sight as measured from the horizontal reticle line is straight throughout the focusing range.
   Tol: ± .001 inch, or ± 1 arcsecond, whichever is greater.

9. Horizontal centering: Line-of-sight and vertical axis intersect.
   Tol: ± .001 inch.

10. Plumb Line: The horizontal and vertical axis are perpendicular to each other.
   Tol: ± 1.0 arcsecond

11. Front-to-Back Centering (Instruments with hollow vertical axis only): Line-of-sight is concentric to the vertical axis.
 Tol: ± .001 inch.

12. Mirror Collimation: The reflective surface of the mirror is perpendicular to the horizontal axis.
 Tol: ± 1.0 arcsecond

13. Collimation--Fixed Focus Cross Scope: The line-of-sight is parallel to the horizontal axis.
 Tol: ± 1.0 arcsecond

14. Collimation--Adjustable Focus Cross Scope: The line-of-sight is parallel to the horizontal axis.
 Tol: ± 1.0 arcsecond

15. Line-of-sight Straightness and Centering--Adjustable Focus Cross Scope: The line of sight is straight, both vertically and horizontally, and concentric to the horizontal axis at all focal distances.
 Tol: ± .002 inch, or ± 2.0 arcseconds, whichever is greater for line-of-sight straightness;
 ± .002 inch for centering.

16. Coincidence Level Vial: The axis of the coincidence vial is parallel to the line-of-sight.
 Tol: ± 1.0 arcsecond

PRECISE LEVELS - Model Nos. 545, 545-1.

1. Bull's-eye or Circular Level Vial: "Reading" surface of vial perpendicular to vertical spindle.
   Tol: Bubble stays within black circular line.

2. Reticle Orientation: Horizontal reticle line perpendicular to vertical spindle.
   Tol: ± 2.0 arcseconds

3. Vertical Spindle Runout: Instrument rotates accurately about its vertical axis to describe a horizontal plane.
   Tol: 5.0 arcseconds

4. Horizontal Line-of-sight Straightness: Line-of-sight as measured from the vertical reticle line is straight throughout the focusing range.
   Tol: ± .001 inch, or 1 arcsecond, whichever is greater.

5. Vertical Line-of-sight Straightness: Line-of-sight as measured from the horizontal reticle line is straight throughout the focusing range.
   Tol: ± .001 inch, or 1 arcsecond, whichever is greater.

6. Coincidence Level Vial: The axis of the coincidence vial is parallel to the line-of-sight.
   Tol: ± 1.0 arcsecond

ALIGNMENT SCOPES - LINE SCOPES - Model Nos. 81, 83, 381, include models with "-1" or "-M" suffix.

1. Collimation: Line-of-sight is parallel to barrel O.D. when focused at infinity.
   Tol: ± 1.0 arcsecond

2. Line-of-sight Straightness and Centering: Line-of-sight is straight, horizontally and vertically, and concentric at all focal distances.
   Tol: ± .001 inch, or ± 1.0 arcsecond, whichever is greater.

3. Auto Reflection Target: Target is concentric to barrel O.D.
   Tol: ± .001 inch.

4. Micrometer Backlash: Repeatability on a target approaching from either direction.
   Tol: ± 1/2 minor graduation.

5. Micrometer "Zero" Center Adj.: Optical flat of micrometer is perpendicular to line of sight when scale reads "zero".
   Tol: ± 1/2 minor graduation.

6. Range Accuracy: Micrometer scale accurately determines the displacement of the line-of-sight.
   Tol: ± 1/2 minor graduation.

OPTICAL MICROMETERS

Brunson model nos. 160, 190, include models with "-M", or "-50" suffix.

Principles also applicable to micrometers found in model 83 alignment telescope.

OPTICAL MICROMETER NOTES

A graduated scale used to verify the accuracy of optical micrometers is mounted directly above the M.T.C. in the model 270-BN calibration test stand. Other targets may also be used, such as; targets physically manipulated by a mechanical micrometer, calibrated glass reticles, or white-face tooling scales.

This procedure deals with optical micrometers which are detachable from the Test Instrument's telescope. Those which are contained as a unit within the telescope, such as the model 83 alignment telescope, are dealt with in the section on line scopes.

OPTICAL MICROMETER ADJUSTMENT - MODEL 160

The model 160 micrometer has two axes of operation for coordinate measurement. Each of the two micrometer elements in the model 160 is adjusted in exactly the same manner as the model 190. The entire test must be performed for each element separately.

OPTICAL MICROMETER ADJUSTMENT - MODEL 190

NOTE: THE TEST INSTRUMENT'S RETICLE LINES AND THOSE OF THE MICROMETER CALIBRATION TARGET MUST BE PARALLEL FOR ACCURACY IN THIS TEST.

BACKLASH MEASUREMENT

Description:	Repeatability on a target approaching from either direction.
Tolerance:	± 1/2 minor graduation
Affected Parameters:	All

1. With the model 190 micrometer secured on the Test Instrument's telescope in the upright position, sight the micrometer calibration target, and focus accurately on that target.

2. Set the graduated dial on the micrometer precisely at zero. Using the Test Instrument's horizontal tangent screw, achieve accurate register between the Test Instrument's vertical reticle line and that of the micrometer calibration target. (The horizontal reticle line should also be approximately in register.)

3. Turn the micrometer graduated dial clockwise at least 10 minor divisions. Sight into the Test Instrument and, turning the micrometer dial counterclockwise, bring the vertical reticle line back into register with the micrometer calibration target. Do not turn past this point, or "rock" the micrometer dial back and forth. Observe any error from the zero point.

4. Turn the micrometer graduated dial counterclockwise at least 10 minor divisions. Sight into the Test Instrument and, turning the micrometer dial clockwise, bring the vertical reticle line back into register with the micrometer calibration target. Do not turn past this point, or "rock" the micrometer dial back and forth. Observe any error from the zero point.

5. If an error greater than 1/2 a minor graduation is measured in steps 3 or 4, the micrometer has backlash error. Return it to the factory for repair.

ZERO-CENTER MEASUREMENT AND ADJUSTMENT

Description:	Optical flat of micrometer is perpendicular to the instrument's line-of-sight when the scale reads "zero".
Tolerance:	± 1/2 minor graduation
Affected Parameter:	None

1. Unclamp the model 190 micrometer and slide it forward on the end of the Test Instrument's telescope barrel, just until the notch in the micrometer body is clear of the locating pin attached to the telescope barrel. Lightly clamp the micrometer clamp screw, but only until the micrometer may be rotated about the end of the telescope barrel with the feel of a "bushing fit." Leave the micrometer upright on the Test Instrument's telescope barrel.

2. Make certain the micrometer graduated dial is set precisely at zero. Using the Test Instrument's horizontal tangent screw, achieve accurate register between the Test Instrument's vertical reticle line and the micrometer calibration target.

3. Gently rotate the micrometer 180° on the end of the Test Instrument's telescope barrel. Extreme care must be used in this movement so that the Test Instrument is not moved, in order not to disturb the zero reference setting of step 2.

4. Measure any error in register between the Test Instrument's vertical reticle line and the micrometer calibration target, by turning the micrometer graduated dial until accurate register is achieved. Half this measurement is the actual error and should be no more than half of one minor division. If in excess of this amount, the zero-center may be adjusted as follows:

   A. Remove the model 190 micrometer from the Test Instrument's telescope barrel, and place front-end down (zero index facing upward) on a flat surface. Be sure the surface is clear of any particles that might scratch or break the front cover glass.

   B. Set the graduated dial to the exact amount of zero-center correction required, and in the proper direction from zero. While holding the knurled knob above the graduated dial exactly in this position, loosen the three screws near the circumference of the top of the knurled knob. Do not disturb the screw at the exact center of the knurled knob. Extreme care must be exercised in order not to turn the knurled knob as the three screws are loosened (see picture on next page).

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Loosening screws for micrometer zero-center adjustment.

Moving the graduated dial.

C. Still taking care not to turn the knurled knob from the setting made at the beginning of step B, slip the graduated dial around to again read zero. Tighten the three screws in the knurled knob, taking care not to turn either the knob or the graduated dial.

5. Repeat steps 2, 3, and 4 until no error, or an acceptable amount of error, is measured at step 4.

RANGE ACCURACY

Description:	Micrometer scale accurately determines the displacement of the line-of-sight
Tolerance:	± 1/2 minor graduation
Affected Parameters:	Zero-centering

1. Clamp the model 190 micrometer upright on the end of the Test Instrument's telescope barrel, and set the graduated dial precisely at zero. Using the Test Instrument's horizontal tangent screw, achieve accurate register between the Test Instrument's vertical reticle line and that of the micrometer calibration target.

2. While sighting into the Test Instrument, turn the micrometer calibrated dial clockwise until accurate register is achieved between the Test Instrument's vertical reticle line and the graduation on the calibration target corresponding to a full-scale reading of the model 190 micrometer.

3. Repeat steps 1 and 2, but this time turn the graduated dial in a counterclockwise direction.

4. If an unacceptable inaccuracy is found at either end of the micrometer calibrated dial, the micrometer may be adjusted as follows:

   A. If both ends of the calibrated dial read short or long by the same amount, use the small allen-head set screws in the top of the micrometer body to push the "head" of the micrometer (graduated dial, index plate, knurled knob, etc.) from front to back or from back to front as necessary (see picture on next page).

   B. If both ends of the calibrated dial read short or long by different amounts, or if one reads short and the other reads long, use the allen-head set screws in the top of the micrometer body to push the "head" of the micrometer from side to side (see picture on next page).

15. After any adjustment is made for micrometer scale accuracy, check the zero-centering.

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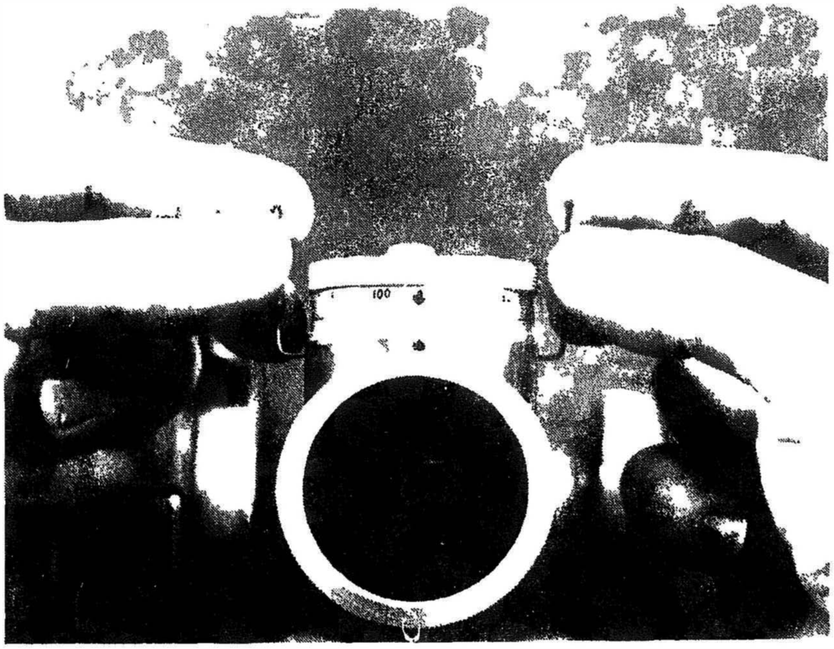
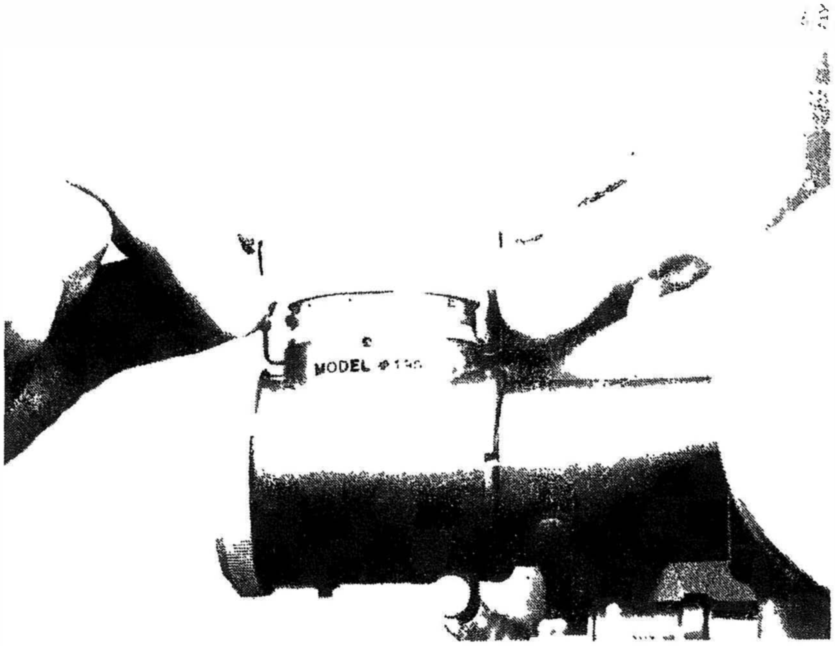


Micrometer range accuracy adjustment. (One side reading shorter or longer than the other.)



Micrometer range accuracy adjustment. (Both sides reading short or long by the same amount.)

OPTICAL TOOLING TRANSITS

Brunson model nos. 71, 771, 75, 76, 79, 376, 379, include models with "-1", "H", "RH", or "RHN" suffix.

BULL'S-EYE OR CIRCULAR LEVEL VIAL

Description:	"Reading" surface of vial is perpendicular to the vertical axis.
Tolerance:	Bubble stays within black lines
Affected Parameters:	None

1. Use the Test Instrument's leveling screws to adjust until bubble is centered.

2. Rotate the Test Instrument about its vertical axis 180° -- observe bubble.

3. Correct one-half the bubble centering error with the vial mounting screws, and the other half with the Test Instrument's leveling screws.

4. Repeat steps 2 and 3 until no error is observed in the vial when the Test Instrument is rotated about its vertical axis.

VERTICAL AXIS BEARING RUNOUT

Description:	Instrument rotates accurately about its vertical axis to describe a horizontal plane.
Tolerance:	2.0 arcseconds
Affected Parameters:	All

Note: In this procedure either an M.T.C. or a line scope can be used as the reference scope; this scope will be referred to as the collimator. If a line scope is used it must be set to infinity focus.

1. Rotate the Test Instrument about its vertical axis roughly 5 times in the same direction. This ensures the individual balls in the vertical axis bearings have all made at least one complete revolution.

2. Point the Test Instrument's telescope at the collimator and focus the instrument to the infinity reticle of the collimator. Using the vertical tangent screw, achieve accurate register between the Test Instrument's horizontal reticle line and the collimator's . Position the vertical reticle line of the Test Instrument in close proximity with that of the collimator's vertical reticle line while keeping the horizontal tangent clamp loose.

3. Gently rotate the Test Instrument about its vertical axis 4 to 5 times re-pointing back to the collimator each time and observe any error. Be sure to reposition the vertical reticle line near its original position.

4. If an error greater than the tolerance is observed, rerun the test to ensure that the observed error is actually bearing runout and not movement of the entire instrument. If it is determined that the error is bearing runout, repairs are required and the Test Instrument should be returned to the manufacturer for repair.

HORIZONTAL AXIS BEARING RUNOUT

Description:	Telescope rotates accurately about the horizontal axis to describe a vertical plane.
Tolerance:	1.0 arcsecond
Affected Parameters:	All

Note: In this procedure either an M.T.C. or a line scope can be used as the reference scope; this scope will be referred to as the collimator. If a line scope is used it must be set to infinity focus.

1. Rotate the Test Instrument about its horizontal axis roughly 5 times in the same direction. This ensures the individual balls in the horizontal axis bearings have all made at least one complete revolution.

2. Point the Test Instrument's telescope at the collimator and focus the instrument to the infinity reticle of the collimator. Using the horizontal tangent screw, achieve accurate register between the Test Instrument's vertical reticle line and the collimator's. Position the horizontal reticle line of the Test Instrument in close proximity with that of the collimator's horizontal reticle line keeping the vertical tangent clamp loose.

3. Gently rotate the Test Instrument about its horizontal axis 4 to 5 times re-pointing back to the collimator each time and observing any error. Be sure to reposition the horizontal reticle line near its original location.

4. If an error greater than the tolerance is observed, rerun the test to ensure that the observed error is actually bearing runout and not movement of the entire instrument. If it is determined the error is bearing runout, repairs are required and the Test Instrument should be returned to the manufacturer for repair.

RETICLE ORIENTATION

Description:	Vertical reticle line is perpendicular to the horizontal axis.
Tolerance:	± 2.0 arcseconds
Affected Parameters:	Horizontal Collimation, Vertical Centering, Coincidence Level Vial

Note: In this procedure either an M.T.C. or a line scope can be used as the reference scope; this scope will be referred to as the collimator. If a line scope is used it must be set to infinity focus.

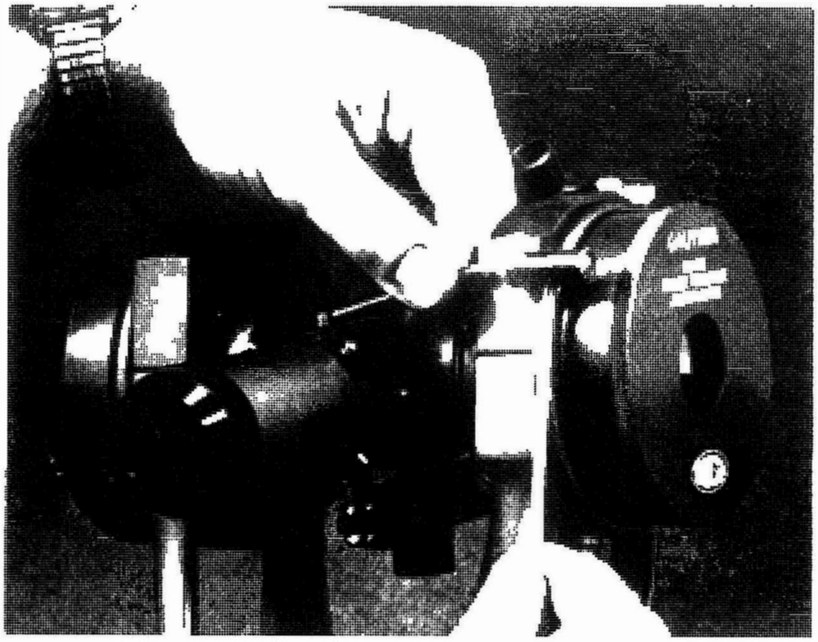
1. Level the Test Instrument using the Bull's-eye Level.

2. Sight the collimator and focus on the infinity reticle. Bring the Test Instrument's reticle into precise register with the infinity reticle of the collimator using the Test Instrument's tangent screws.

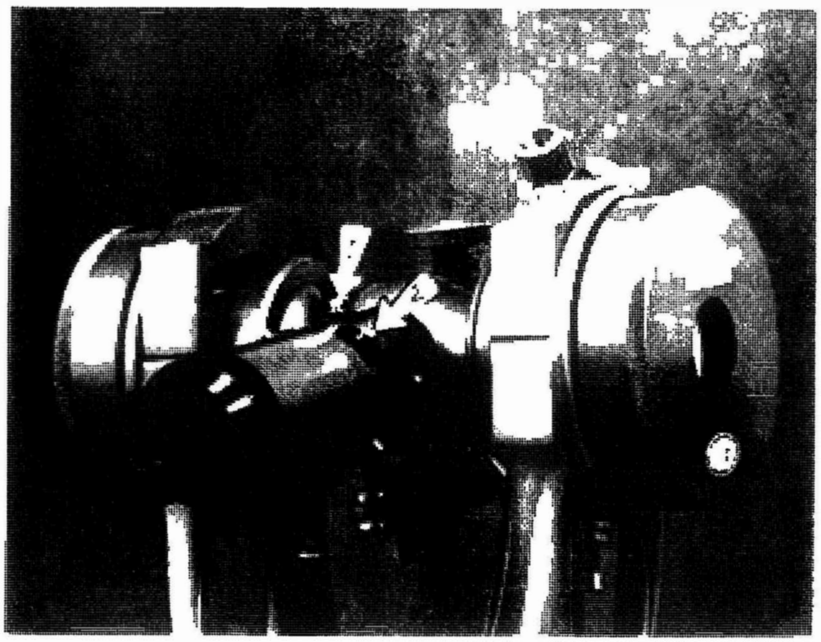
3. Observing a point on the collimator's reticle, use either the Test Instrument's vertical or horizontal tangent screw and "track" across that point. Notice whether the reticle line you are using stays in register with or deviates from the point.

4. If deviation is observed, note which direction the Test Instrument's reticle is tilted. If error is more than the tolerance, use a drift and small hammer to tap against the adjusting screw heads of the Test Instrument's reticle to rotate the reticle into position. These are the four capstan-head screws farthest from the eyepiece and positioned at 12, 3, 6, and 9 o'clock. When adjusting, tap against opposing screw heads, 12 and 6 or 3 and 9, for even adjustment to the reticle. (See picture on following page).

5. Repeat steps 1, 2, and 3 until the Test Instrument's reticle line stays in tolerance with the point.



Adjusting reticle orientation.



Location of telescope adjusting screws. 1) Reticle screw. 2) Erector lens screw.

HORIZONTAL COLLIMATION

Description:	Instrument's line-of-sight is perpendicular to its horizontal axis when focused at infinity.
Tolerance:	± 1.0 arcsecond
Affected Parameters:	reticle orientation

1. For best results, leave the vertical tangent clamp loose and the micrometer drum pointing up or down.

2. Rough level the Test Instrument. Set the barrel so the coincidence vial is reading level across the Ultradex adjusting screws. Rotate the Ultradex 180° and observe the vial reading. Remove one-half the error with the vertical tangent screw and the other half with the Ultradex adjusting screws. Repeat the 180° rotation removing one-half with the instrument and the other half with the Ultradex until the instrument vial stays relatively level. Rotate the Ultradex 90° and bring the Test Instrument's vial into level using the Ultradex adjusting screws. This will be sufficient to perform horizontal collimation.

3. Precisely register the Test Instrument's vertical reticle line with that of the M.T.C.'s infinity target, the horizontal reticle line should be nominally registered.

4. Gently release the Ultradex indexing fixture and rotate 180°. With the Ultradex table secured, plunge the Test Instrument's telescope 180° so as to be sighting back at the M.T.C.

5. Observe any error in register between the vertical reticle lines of the Test Instrument and that of the M.T.C.

6. If the observed error is greater than 2 arcseconds (actual error greater than 1 arcsecond), correct one-half the observed error using the Test Instrument's reticle adjusting screws (the four capstan-head screws farthest from the eyepiece). Adjust the two capstan screws located at 3 and 9 o'clock.

7. Repeat steps 2 through 5 until the observed error is not more than 2 arcseconds as in step 4.

8. If adjustments were made, the affected parameters must be checked and adjusted as required.

VERTICAL CENTERING

Description:	Vertical line-of-sight and horizontal axis intersect.
Tolerance:	± .001 inch
Affected Parameters:	Horizontal collimation, reticle orientation

Note: In this procedure either an M.T.C. or a line scope can be used as the reference scope; this scope will be referred to as the collimator. If a line scope is used, the focus must be set to infinity.

1. The micrometer should be rotated 90° so the micrometer drum is pointing to the side and set to zero. Be careful, as some instruments, such as Brunson's, will not plunge through with the micrometer in this position.

2. Focus the Test Instrument at the collimator's infinity reticle. Precisely register the Test Instrument's reticle with that of the collimator using the horizontal and vertical tangent screws.

3. Focus the Test Instrument at the collimator's closest target. Precisely register the Test Instrument's reticle with that of the collimator's target using the precision lift and slide.

4. Repeat steps 1 and 2 until the Test Instrument can be focused from infinity to the near target of the collimator without making any adjustments to the test instrument.

5. Rotate the Test Instrument 180° about its vertical axis and plunge the scope 180° sighting back to the collimator. Focus the Test Instrument to infinity and precisely register the Test Instrument's reticle with that of the collimator using only the tangent screws. Focus back to the near reticle and measure the amount needed to bring the Test Instrument's horizontal reticle into register with the collimator's horizontal reticle.

6. If the observed error is greater than 0.002" (actual error greater than 0.001"), correct three to four times the observed error using the two reticle adjusting screws found at 12 and 6 o'clock.

7. Repeat steps 1 through 5 until the observed error is no more than 0.002".

8. If adjustments were made, the affected parameters must be checked and adjusted as required.

HORIZONTAL LINE-OF-SIGHT STRAIGHTNESS

Description:	Line-of-sight is straight throughout the focusing range as measured from the vertical reticle line.
Tolerance:	± .001 inch, or ± 1 arcsecond, whichever is greater.
Affected Parameters:	Horizontal Collimation, Vertical Line-of-sight Straightness, Vertical Centering

1. Rotate the micrometer on the Test Instrument to the up position with the micrometer drum set on zero for this test. The barrel should be positioned so that the focus knob is up. This is known as the direct position. If an optical wedge is used to measure the error, position it in place with the zero mark on the vertical index mark.

2. Focus the Test Instrument to the M.T.C.'s infinity target. Precisely register the Test Instrument's reticle with that of the M.T.C. using the horizontal and vertical tangent screws.

3. Focus the Test Instrument to the M.T.C.'s closest target. Precisely register the Test Instrument's reticle with that of the M.T.C. using the precision lift and slide.

4. Repeat steps 2 and 3 until the Test Instrument can be focused at the far and near targets of the M.T.C. without making any adjustments to the Test Instrument.

5. Without disturbing the tangent screws, lateral slide, or precision lift, take readings with either the micrometer or optical wedge as to the displacement of the vertical reticle line from the intermediate targets of the M.T.C. Record readings and note what side of zero the micrometer or wedge reading resides.

6. Release the horizontal tangent clamp and rotate the Test Instrument 180°. Release the vertical tangent clamp and plunge the telescope 180°. This is known as the indirect position. Repeat steps 2 through 5.

7. Compare the two readings taken at each focal length to each other. For micrometers, take one-half the algebraic sum of the two readings. For optical wedges, take one-half the algebraic difference of the two readings.

8. If the number arrived at for straightness of line-of-sight is 0.001" or less at the 16-ft. or less targets, or 1 arcsecond or less at longer focal lengths, results are acceptable. If results are in excess of these tolerances, adjustments are made as follows:

   A. Remove the four regular screws found on the barrel where the telescope rotates around its horizontal axis.

   B. Move the focus knob so as to move the focus slide towards the objective lens. Before the slide reaches its end of travel, a set screw will line up under each hole.

   C. By loosening the pair of set screws on one side and tightening the pair on the opposing side, the focus lens will be moved from side to side inside the focus slide. The lens is pushed in the direction that the reticle looks like it needs to go. **CAUTION, A SMALL TWEAK OF THE LENS IS ALL THAT IS NEEDED.** A tweak could move the line-of-sight by as much as 3 arcseconds.

9. If the lens has to be moved, the affected parameters must be checked and adjusted as required.

10. Repeat the procedures for checking line-of-sight again until step 8 is satisfied.

Note: the Vertical and Horizontal Line-of-sight Straightness calibrations are presented separately for ease of instruction, but it is advantageous for the operator to do both simultaneously as one affects the other.

VERTICAL LINE-OF-SIGHT STRAIGHTNESS

Description:	Line-of-sight is straight throughout the focusing range when measured from the horizontal reticle line.
Tolerance:	± .001 inch or ± 1 arcsecond, whichever is greater.
Affected Parameters:	Horizontal Collimation, Horizontal Line-of-sight Straightness, Vertical Centering

1. Rotate the micrometer on the Test Instrument to the side position with the micrometer drum set on zero for this test. The barrel should be positioned so that the focus knob is up. This is known as the direct position. If an optical wedge is used to measure the error, position it in place with the zero mark on the horizontal index mark.

2. Focus the Test Instrument to the M.T.C.'s infinity target. Precisely register the Test Instrument's reticle with that of the M.T.C. using the horizontal and vertical tangent screws.

3. Focus the Test Instrument to the M.T.C.'s closest target. Precisely register the Test Instrument's reticle with that of the M.T.C. using the precision lift and slide.

4. Repeat steps 2 and 3 until the Test Instrument can be focused at the far and near targets of the M.T.C. without making any adjustments to the Test Instrument.

5. Without disturbing the tangent screws, lateral slide, or precision lift, take readings with either the micrometer or optical wedge as to the displacement of the horizontal reticle line from the intermediate targets of the M.T.C. Record readings and note what side of zero the micrometer or wedge reading resides.

6. Release the horizontal tangent clamp and rotate the Test Instrument 180°. Release the vertical tangent clamp and plunge the telescope 180°. This is known as the indirect position. Repeat steps 2 through 5.

7. Compare the two readings taken at each focal length to each other. For micrometers, take one-half the sum of the two readings, being sure to observe the sign. For optical wedges, take one-half the difference of the two readings, being sure to observe the sign.

8. If the number arrived at for straightness of line-of-sight is 0.001" or less at the 16-ft. or less targets, or 1 arcsecond or less at longer focal lengths, results are acceptable. If results are in excess of these tolerances, adjustments are made as follows:

A. Remove the four regular screws found on the barrel where the telescope rotates around its horizontal axis.

B. Move the focus knob so as to move the focus slide towards the objective lens. Before the slide reaches its end of travel, a set screw will line up under each hole.

C. By loosening either the top or bottom pair of set screws and doing the opposite on the opposing pair of set screws, the focus lens will be moved up or down inside the focus slide. The lens is pushed in the opposite direction that the reticle looks like it needs to go. **CAUTION, A SMALL TWEAK OF THE LENS IS ALL THAT IS NEEDED.** A tweak could move the line-of-sight by as much as 3 arcseconds.

9. If the lens has to be moved, the affected parameters must be checked and adjusted as required.

10. Repeat the procedures for checking line-of-sight again until step 8 is satisfied.

Note: the Vertical and Horizontal Line-of-sight Straightness calibrations are presented separately for ease of instruction, but it is advantageous for the operator to do both simultaneously as one affects the other.

HORIZONTAL CENTERING

Description: Line-of-sight and vertical axis intersect.

Tolerance: ± .001 inch

Affected Parameters: None

Note: In this procedure either an M.T.C. or an alignment scope may be used as the reference scope; this scope will be referred to as the collimator. It needs to be nominally level.

1. Rotate the micrometer so that the micrometer drum is facing up or down and the micrometer is set on zero. Focus the Test Instrument to the infinity reticle in the collimator and achieve precise register of the Test Instrument's vertical reticle line and that of the collimator using the tangent screw, the horizontal reticle line must be nominally registered.

2. Focus the Test Instrument to the near target and achieve precise register between reticle and target using the precision slide and or coordinate adjuster.

3. Repeat steps 1 and 2 until the Test Instrument can be focused at either infinity or the near target and the reticles stay in register.

4. Release the horizontal tangent clamp and rotate the Test Instrument 180° about its vertical axis. Release the vertical tangent clamp and plunge the telescope 180°. Focus the Test Instrument to the infinity reticle of the collimator and achieve precise register of the Test Instrument's reticle and that of the collimator using the tangent screws.

5. Focus the Test Instrument on the near target of the collimator. Obtain accurate register between the vertical reticle line of the Test Instrument and the collimator's target by using the micrometer. Half the reading is the amount by which the line-of-sight is offset from the vertical axis. If this number is greater than 0.002", the Test Instrument's standard must be shifted sideways. This is performed as follows (for more detailed information, refer to the appendixes):

A. Loosen the 8 allen-head screws located under the bottom of the standard of the Test Instrument. Either using a dial indicator or by observing the amount of travel while sighting through the scope, turn the allen-head screws located on the side of the Test Instrument. The screws will push the standard in the direction needed for correction, be sure and loosen the opposite screw (refer to the pictures on the following pages).

B. Tighten the 8 allen-head screws on the bottom

6. Repeat steps 1 through 5 until the observed error is not greater than 0.002".

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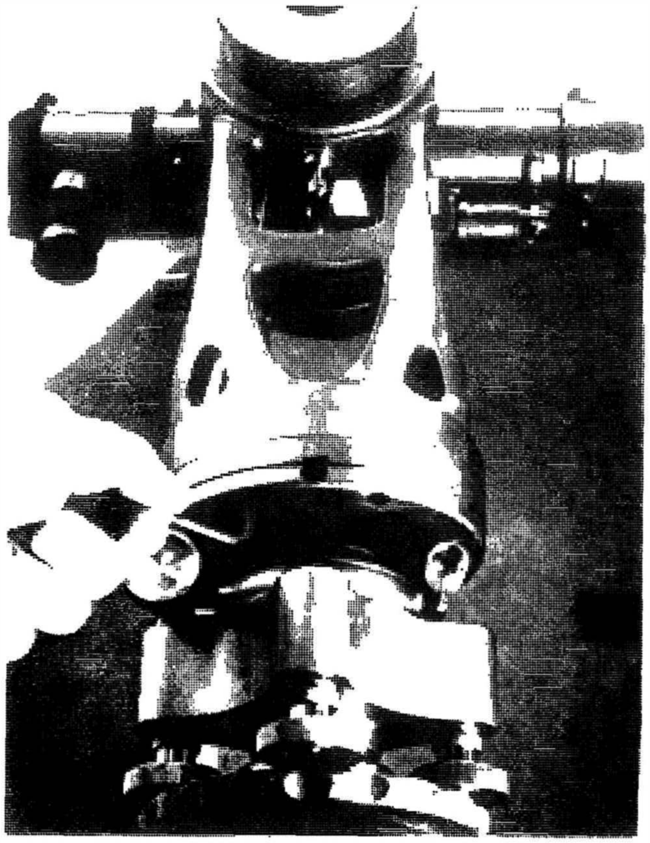
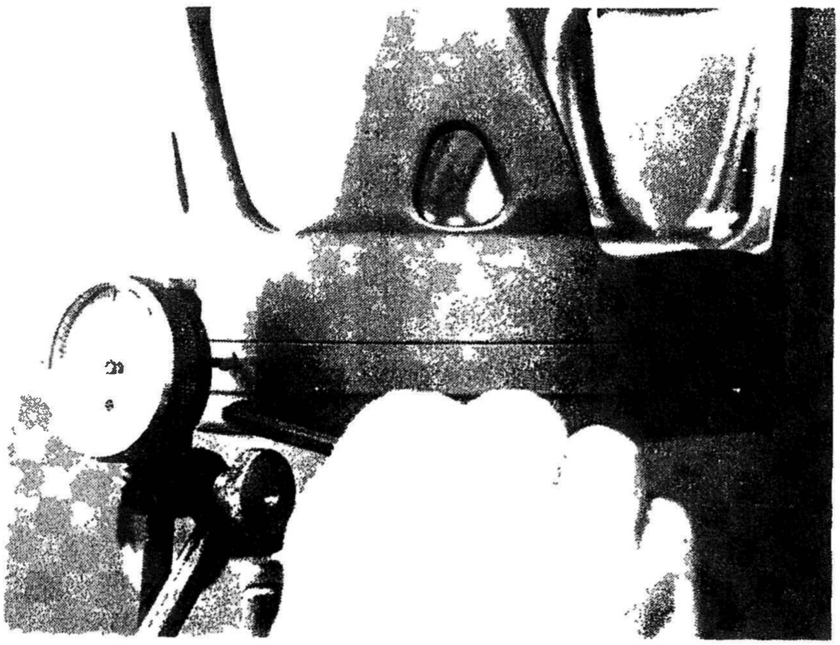
Loosening screws holding the plate to the standard, in preparation for moving the standard. (Adjustment for centering the line of sight with respect to the vertical axis.)



Moving the standard of a transit, using a dial indicator to measure travel.



PLUMB LINE

Description:	Vertical axis is perpendicular to the horizontal axis.
Tolerance:	± 1 arcsecond
Affected Parameters:	Vertical centering, Horizontal centering, Reticle Orientation

1. Focus the Test Instrument to infinity and sight one of the collimators that is at an angle. Using the horizontal tangent screw, precisely register the vertical reticle line of the Test Instrument with that of the collimator. For greater accuracy, leave the vertical tangent clamp loose and the horizontal reticle line should be in close register with that of the collimator's horizontal reticle line.

2. Transit the Test Instrument's telescope to sight the other angled collimator. Using the collimator positioning screws in the test stand, achieve accurate register between the Test Instrument's vertical reticle line and the collimator's reticle line. Do not disturb the Test Instrument's tangent screw.

3. Loosen the horizontal clamp screw and rotate the Test Instrument 180° about its vertical axis. Use the horizontal tangent screw to achieve accurate register between the Test Instrument's vertical reticle line and that of the first collimator. Horizontal reticle lines should also be in approximate register.

4. Transit the Test Instrument's telescope to sight the other collimator. Measure with a wedge or estimate the observed error in register between the Test Instrument's vertical reticle line and that of the collimator. If this error exceeds 2 arcseconds (1 arcsecond actual), adjustment is as follows (refer to picture on next page; for more detail on the adjustments, refer to the appendixes):

   A. Either loosen or tighten the axis-bearing cap screws located on the side with the capstan-head screw adjustment. One-half of the error is all that needs to be removed.

   B. If a large adjustment must be made or the axis bearing cap screws should become too tight or loose, the capstan-head screw may have to be adjusted. This screw is underneath the axis-bearing and pushes the axis up or allows it to settle down.

5. Repeat steps 1 through 4 until no more than 2 arcseconds of observed error is present.

6. If adjustments were made, the affected parameters must be checked and adjusted as required.

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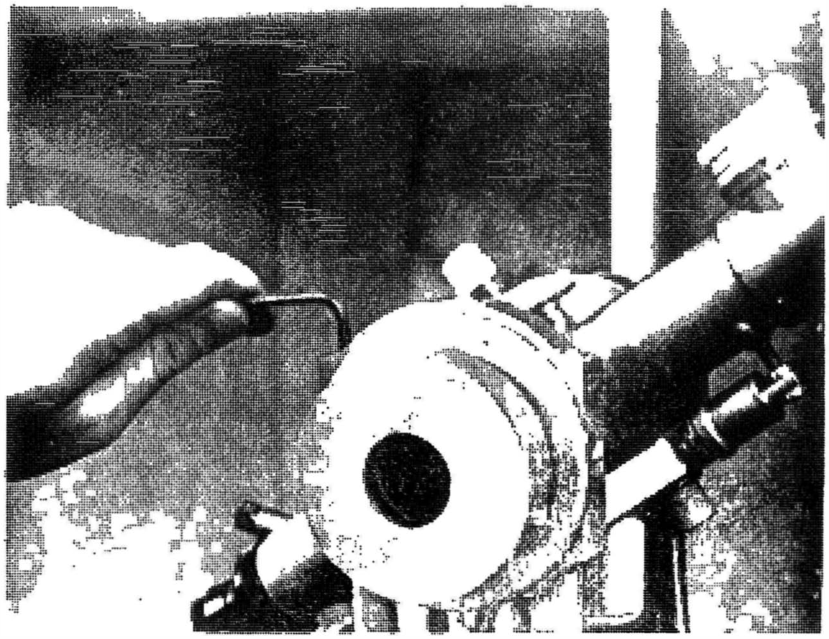
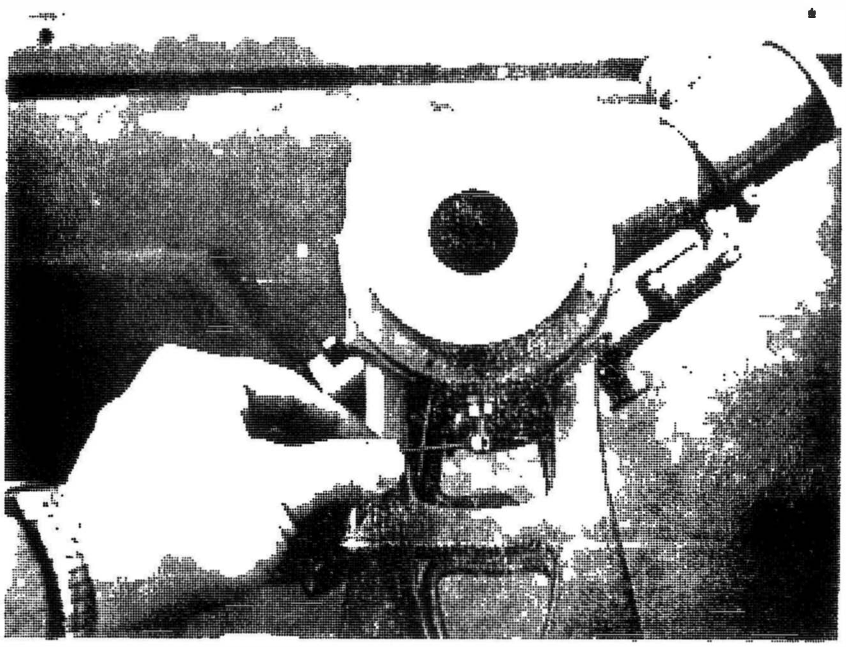


Moving an axis-bearing cap screw to adjust the relationship between the horizontal and vertical axes.



Moving the axis adjustment screw to adjust the relationship between the horizontal and vertical axes.

FRONT-TO-BACK CENTERING--HOLLOW VERTICAL SPINDLE ONLY

Description:	Line-of-sight is concentric to the vertical axis.
Tolerance:	± .001 inch
Affected Parameters:	Horizontal Centering, Plumb Line

1. Transit the Test Instrument's telescope so the objective lens is in the down position between the instrument's standard. Loosen the micrometer clamp and gently rotate the micrometer 90°. Be sure the micrometer is on zero.

2. Rotate the Test Instrument about its vertical axis and observe the eyepiece wobble. Position the telescope barrel so as to eliminate any observable wobble in the eyepiece as the instrument is rotated about its vertical axis.

3. Focus the Test Instrument at infinity and sight the infinity target located in the optical plummet collimator located in the bottom of the mounting post. Rotate the Test Instrument so that the Test Instrument's reticle and that of the plummet collimator are in the same orientation. Achieve accurate register between the Test Instrument's horizontal reticle line and the plummet collimator's horizontal reticle line by using the Test Instrument's vertical tangent screw. Position the vertical reticle line on using the Test Instrument's leveling screws perpendicular to the M.T.C.

4. Rotate the Test Instrument 180° about its vertical axis and return to the same reticle orientation as that of the plummet collimator's reticle.

5. If an error in register is observed between the Test Instrument's horizontal reticle line and that of the plummet collimator's, remove one-half the error with the Test Instrument's vertical tangent screw and the other half with the collimator's positioning hand control. (Electrical control cable on the left side of the metal cabinet.)

6. Repeat steps 4 and 5 until the Test Instrument can be rotated about its vertical axis and the horizontal reticle line of the Test Instrument stays in register with that of the plummet collimator.

7. Focus the Test Instrument on the near target of the plummet collimator (target with heavy, black, paired-line pattern).

8. Use the lateral adjusters on the mounting post to achieve accurate register between the Test Instrument's reticle and that of the plummet collimator's target. Do not disturb the vertical tangent screw or leveling screws on the Test Instrument.

9. Rotate the Test Instrument 180° about its vertical axis and bring the horizontal reticle line back in register with that of the plummet collimator using the micrometer. If the error is less than 0.002", no adjustment is necessary. If the error is greater than 0.002", the Test Instrument's standard must be shifted front to back. This is performed as follows:

   A. Loosen the 8 allen-head screws located under the bottom of the standard of the Test Instrument. Either using a dial indicator or by observing the amount of travel while sighting through the scope, turn the allen-head screws located on the front and back of the Test Instrument. Note that the screws push against the standard so the screw opposite the pushing must be loosened.

   B. Tighten the 8 allen-head screws on the bottom.

10. Repeat steps 3 through 9 until the error is no greater than 0.002".

11. If adjustments were made, the affected parameters must be checked and adjusted as required.

MIRROR COLLIMATION

Description:	The reflective surface of the mirrors are perpendicular to the horizontal axis.
Tolerance:	± 1 arcsecond
Affected Parameters:	none

1. Rough level the Test Instrument if necessary

2. Rotate the Test Instrument about its vertical axis so the mirror on the end of the horizontal axis faces the alignment telescope mounted on the one side of the post. Position the Test Instrument's main scope such that opposing pairs of axis mirror adjusting screws in the mirror mount flange are oriented horizontally and vertically. (The main telescope will not necessarily be horizontal or vertical.) Leave the Test Instrument's vertical tangent clamp loose during the entire test.

3. Sighting into the alignment telescope, achieve an autocollimation image from the Test Instrument's axis mirror by rotating the Test Instrument about its vertical axis. Lock the vertical axis. Achieve precise autocollimation using the tangent screws on the alignment telescope mounting base.

4. Plunge the Test Instrument's telescope 180° and observe the autocollimation error of both reticle lines. If the observed error is less than 4 arcseconds, no adjustment is necessary (note that the observed error is 4 times the actual error). If greater than 4 arcseconds for any reticle line, corrections are performed as follows:

   A. Remove one-half the error using the tangent screws and/or leveling screws located on the alignment telescope's mounting base.

   B. Remove the other half of the error with allen-head set screws located on the mirror mount. Adjust opposing screws by loosening one and tightening the other.

5. Repeat step 4 until autocollimation error observed is 2 arcseconds or less for both reticle lines.

COLLIMATION--FIXED FOCUS CROSS SCOPE

Description:	The cross telescope line-of-sight is parallel to the horizontal axis.
Tolerance:	± 1 arcsecond
Affected Parameters:	None

Note: In this procedure either an M.T.C. or a line scope can be used as the reference scope; this scope will be referred to as the collimator. If a line scope is used it must be set to infinity focus.

1. Turn the Test Instrument's main telescope focusing knob opposite the direction marked "Infinity" until it stops. (To extreme near focus.)

2. Turn the Test Instrument so that the objective lens end of the cross telescope faces the collimator. Sight the collimator with the cross telescope and transit the Test Instrument's main telescope until the Test Instrument's cross telescope reticle lines are exactly parallel to those in the collimator. The Test Instrument's vertical tangent clamp should be left unclamped for this entire test.

3. Achieve accurate register between the vertical reticle lines of the Test Instrument's cross telescope and the collimator using the Test Instrument's horizontal tangent screw. (The horizontal reticle lines should also be in approximate register.)

4. Plunge the Test Instrument's main telescope 180°, again making certain that the Test Instrument's cross telescope reticle lines are positioned exactly parallel to those in the collimator. Observe any error in register of the vertical reticle lines. If the observed error exceeds 2 arcseconds, adjustment is required. Move the allen-head set-screws in the cross telescope objective lens mounting flange to physically push the lens from side to side to correct this error.

5. Repeat steps 3 and 4 until no error in register is observed when the Test Instrument's telescope is plunged 180°.

6. Transit the Test Instrument's main telescope 90°, and position so that the Test Instrument's cross telescope reticle lines are exactly parallel to those in the collimator. (The Test Instrument's cross telescope vertical reticle line has now become horizontal, and vice versa.)

7. Repeat steps 3, 4, 5, and 6 in order, until no error in register is observed between the vertical reticle line of the collimator, and the Test Instrument's cross telescope reticle lines (vertical and horizontal lines), when they are in a vertical position.

Note: the vertical and horizontal reticle line collimation calibrations are presented separately for ease of instruction, but it is advantageous for the operator to do both simultaneously as one affects the other.

COLLIMATION--ADJUSTABLE FOCUS CROSS SCOPE

Description:	The cross telescope line-of-sight is parallel to the horizontal axis.
Tolerance:	± 1 arcsecond
Affected Parameters:	Horizontal and vertical line-of-sight straightness, horizontal and vertical centering

Note: In this procedure either an M.T.C. or a line scope can be used as the reference scope; this scope will be referred to as the collimator. If a line scope is used it must be set to infinity focus.

1. Turn the Test Instrument's main telescope focusing knob opposite the direction marked "Infinity" until it stops. (To extreme near focus.)

2. Turn the Test Instrument so that the objective lens end of the cross telescope faces the collimator. Focus the Test Instrument's cross telescope at infinity and sight the collimator's infinity reticle. Transit the Test Instrument's main telescope until the Test Instrument's cross telescope reticle lines are exactly parallel to those in the collimator. The Test Instrument's telescope tangent clamp should be left unclamped for this entire test. Lock the horizontal tangent clamp.

3. Achieve accurate register between the vertical reticle lines of the Test Instrument's cross telescope and the collimator using the Test Instrument's horizontal tangent screw. (The horizontal reticle lines should also be in approximate register.)

4. Plunge the Test Instrument's main telescope 180°, again making certain that the Test Instrument's cross telescope reticle lines are positioned exactly parallel to those in the collimator. Observe any error in register of the vertical reticle lines. If the observed error exceeds 2 arcseconds, adjustment is required. Move the Test Instrument's cross telescope reticle adjusting screws (allen-head cap screws under shrouding on eyepiece end of cross telescope) to correct this error.

5. Repeat steps 3 and 4 until the error is within tolerance as observed when the Test Instrument's main telescope is plunged 180°.

6. Transit the Test Instrument's main telescope 90°, and position so that the Test Instrument's cross telescope reticle lines are exactly parallel to those in the collimator. (The Test Instrument's cross telescope vertical reticle line has now become horizontal, and vice versa.)

7. Repeat steps 3, 4, 5, and 6 in order, until the error in register is within tolerance as observed between the reticle lines of the collimator, and the Test Instrument's cross telescope reticle lines (vertical and horizontal lines) when they are in the vertical position.

Note: the vertical and horizontal reticle line collimation calibrations are presented separately for ease of instruction, but it is advantageous for the operator to do both simultaneously as one affects the other.

LINE-OF-SIGHT STRAIGHTNESS AND CENTERING
ADJUSTABLE FOCUS CROSS SCOPE

Description:	The line-of-sight is straight, both vertically and horizontally, throughout the focusing range and centered to the mechanical axis of the barrel.
Tolerance:	
Straightness:	± .002 inch, or ± 2 arcsecond, whichever is greater
Centering:	± .002 inch
Affected Parameters:	All

1. Determine that collimation at infinity focus is acceptable.

2. Place the Test Instrument's main telescope in the direct position. With the Test Instrument's cross telescope optical micrometer set precisely at zero, focus the cross telescope on the 4-ft. M.T.C. target. Make certain that the cross telescope reticle lines are exactly parallel to those in the M.T.C.

3. Using the Test Instrument's horizontal tangent screw, achieve accurate register between the Test Instrument's cross telescope vertical reticle line and the M.T.C. 4-ft. target. (The horizontal reticle lines should also be approximately in register.)

4. Plunge the Test Instrument's main telescope 180° to the indirect position, again making certain the Test Instrument's cross telescope reticle lines are exactly parallel to those in the M.T.C. Measure and record any observed error in register on the vertical reticle lines using the Test Instrument's cross telescope optical micrometer or wedge.

5. Return the Test Instrument's main telescope to the direct position, and repeat steps 2 through 4 using the 16-ft. M.T.C. target, as well as any other M.T.C. targets deemed necessary or desirable.

YOU HAVE NOW TAKEN READINGS TO DETERMINE STRAIGHTNESS AND CENTERING OF THE LINE-OF-SIGHT IN A HORIZONTAL DIRECTION. READINGS MUST ALSO BE TAKEN TO DETERMINE STRAIGHTNESS AND CENTERING IN A VERTICAL DIRECTION.

6. Turn the Test Instrument's cross telescope optical micrometer 90° on the end of the telescope barrel.

7. Repeat steps 2, 3, 4, and 5, this time starting with the Test Instrument's main telescope at 90° from its original position (direct). For example, start with the main telescope pointing up, achieve register, plunge 180°, take measurement, etc.

8. For any target, half the error observed at step 4 of this procedure is the actual deviation of the Test Instrument's line-of-sight from a straight line at that focal distance. If the actual error exceeds .002 inch at the 4 or 16-ft. targets, or 1 arcsecond at any target farther away than 17 ft., the Test Instrument should be returned to the manufacturer for repair.

PRECISION SIGHT LEVELS

Brunson model nos. 545, 545-1.

BULL'S-EYE OR CIRCULAR LEVEL VIAL

Description:	"Reading" surface of vial is perpendicular to the vertical axis.
Tolerance:	Bubble stays within black lines
Affected Parameters:	None

1. Use the Test Instrument's leveling screws to adjust until bubble is centered.

2. Rotate the Test Instrument's about its vertical axis 180° -- observe bubble.

3. Correct one-half the bubble centering error with the vial mounting screws, and the other half with the Test Instrument's leveling screws.

4. Repeat steps 2 and 3 until no error is observed in the vial when the Test Instrument is rotated about its vertical axis.

VERTICAL AXIS BEARING RUNOUT

Description:	Instrument rotates accurately about its vertical axis to describe a horizontal plane.
Tolerance:	5.0 arcseconds
Affected Parameters:	All

Note: In this procedure either an M.T.C. or a line scope can be used as the reference scope; this scope will be referred to as the collimator. If a line scope is used, it must be set to infinity focus.

1. Focus the Test Instrument's telescope at infinity, and using the telescope tangent screw, achieve accurate register between the Test Instrument's horizontal reticle line and the collimator's infinity target.

2. With the Test Instrument's horizontal tangent clamp loosened, gently rotate the Test Instrument about its vertical axis 360° until the collimator is again sighted.

3. Observe any error in register between the horizontal reticle lines of the Test Instrument and collimator.

4. Repeat steps 2 and 3 at least 4 more times. (This assures the individual balls in the vertical axis bearings have all made at least one complete revolution.)

5. If the error in register remains 5 arcseconds or less, results are acceptable. If an error greater than 5 arcseconds is observed, repairs are required and the Test Instrument should be returned to the manufacturer.

RETICLE ORIENTATION

Description:	Horizontal reticle line is perpendicular to the vertical axis.
Tolerance:	± 2.0 arcseconds
Affected Parameters:	Line-of-sight straightness, Coincidence Level Vial

Note: In this procedure either an M.T.C. or a line scope can be used as the reference scope; this scope will be referred to as the collimator. If a line scope is used it must be set to infinity focus.

1. Level the Test Instrument using the Bull's-eye Level.

2. Sight the collimator and focus on the infinity reticle. Bring the Test Instrument's reticle into precise register with the infinity reticle of the collimator using the Test Instrument's tangent screws.

3. Observing a point on the collimator's reticle, use the Test Instrument's horizontal tangent screw and "track" across that point. Notice whether the reticle line stays in register with or deviates from the point.

4. If deviation is observed, note which direction the Test Instrument's reticle is tilted. If error is more than the tolerance, use a drift and small hammer to tap against the adjusting screw heads of the Test Instrument's reticle to rotate the reticle into position. These are the four capstan-head screws farthest from the eyepiece and positioned at 12, 3, 6, and 9 o'clock. When adjusting, tap against opposing screw heads, 12 and 6 or 3 and 9, for even adjustment to the reticle (refer to the picture in the transit section regarding reticle orientation).

5. Repeat steps 1, 2, and 3 until the Test Instrument's reticle line stays in tolerance with the point.

HORIZONTAL LINE-OF-SIGHT STRAIGHTNESS

Description: Line-of-sight is straight throughout the focusing range as measured from the vertical reticle line.

Tolerance: ± .001 inch, or ± 1 arcsecond, whichever is greater.

Affected Parameters: Vertical Line-of-sight straightness, coincidence vial, and reticle orientation

1. Verify that the target reticles in the M.T.C. are all truly positioned on a straight line. This may be done in two ways: 1) Calibrate and adjust the M.T.C. using the procedure given in "Operation Instruction and Maintenance Manual for Model 270-BN Universal Short-Range Calibrator." 2) Use an instrument whose line-of-sight is known to be straight to determine the relative positions of the M.T.C. targets.

2. Focus the Test Instrument's telescope at infinity, and using the horizontal tangent screw, achieve accurate register between the Test Instrument's vertical reticle line and the M.T.C. infinity target (horizontal reticle lines should also be approximately in register.)

3. Focus the Test Instrument's telescope on the 4-ft. M.T.C. target. Make certain the optical micrometer is set precisely at zero. If an out-of-register condition exists, use the lateral slide on the Test Instrument's mounting post to achieve accurate register between the Test Instrument's vertical reticle line and the 4-ft. M.T.C. target. (Again, the horizontal reticle lines should be approximately in register.)

4. Repeat steps 2 and 3 until the Test Instrument's telescope can be focused at either infinity or 4 ft., and the vertical reticle lines remain in register with no manipulation.

5. Without disturbing tangent screws, lateral slide, or precision lift, take readings with the optical micrometer for any out-of-register condition observed at the 16-ft. M.T.C. target, and any other targets deemed necessary or desirable. These readings are the amounts by which the Test Instrument's line-of-sight deviates from a straight line at those distances. If a reading is greater than .001 inch at the 16-ft. target, or 1 arcsecond at the more distant targets, the Test Instrument should be returned to the manufacturer for adjustment.

VERTICAL LINE-OF-SIGHT STRAIGHTNESS

Description:	Line-of-sight is straight throughout the focusing range when measured from the horizontal reticle line.
Tolerance:	± .001 inch or 1 arcsecond, whichever is greater.
Affected Parameters:	Horizontal line-of-sight straightness, coincidence vial, and reticle orientation

1. Turn the optical micrometer to the position suitable for elevation readings.

2. Verify that the target reticles in the M.T.C. are all truly positioned on a straight line. (See step 1 of the procedure for horizontal line-of-sight straightness.

3. Focus the Test Instrument's telescope at infinity, and using the vertical tangent screw, achieve accurate register between the Test Instrument's horizontal reticle line and the M.T.C. infinity target (vertical reticle lines should also be approximately in register.)

4. Focus the Test Instrument's telescope on the 4-ft. M.T.C. target. Make certain the optical micrometer is set precisely at zero. If an out-of-register condition exists, use the precision lift in the Test Instrument's mounting post to achieve accurate register between the Test Instrument's horizontal reticle line and the 4-ft. M.T.C. target. (Again, the vertical reticle lines should be approximately in register.)

5. Repeat steps 3 and 4 until the Test Instrument's telescope can be focused at either infinity or 4 ft., and the horizontal reticle lines remain in register with no manipulation.

6. Without disturbing tangent screws, lateral slide, or precision lift, take readings with the optical micrometer for any out-of-register condition observed at the 16-ft. M.T.C. target, and any other targets deemed necessary or desirable. These readings are the amounts by which the Test Instrument's line-of-sight deviates from a straight line at those distances. If a reading is greater than .001 inch at the 16-ft. target, or 1 arcsecond at the more distant targets, the Test Instrument should be returned to the manufacturer for adjustment.

COINCIDENCE LEVEL VIALS

Brunson model nos. 194, 194-T.

COINCIDENCE LEVEL VIAL

Coincidence level vials are found attached to the telescope barrel on precise levels, jig transits, transit squares, and optical tooling theodolites. This procedure applies to any of these several types of instruments.

Two separate gravity-level references are provided for use with the model 270-BN calibration test stand. One is the model 187-S stride level. The other is the model 287-1 leveling mirror. Procedures for use with both these references are given here.

COINCIDENCE LEVEL VIAL ADJUSTMENT USING THE MODEL 187-S STRIDE LEVEL AS A REFERENCE

NOTE: THE MODEL 187-S STRIDE LEVEL, AND THE COLLIMATOR OR LINE SCOPE ON WHICH IT IS PLACED (HEREAFTER REFERRED TO AS "THE LEVEL-REFERENCE COLLIMATOR") MUST BE IN GOOD ADJUSTMENT TO OBTAIN ACCURATE RESULTS. EITHER THE M.T.C. OR THE MODEL 81 LINE SCOPE MAY BE USED AS THE LEVEL-REFERENCE COLLIMATOR. (SEE "OPERATION INSTRUCTION AND MAINTENANCE MANUAL FOR MODEL 270-BN UNIVERSAL SHORT-RANGE CALIBRATOR" FOR CALIBRATION PROCEDURES.)

1. Verify that the level-reference collimator is in fact accurately leveled using the model 187-S stride level. (See procedures referenced above.) If the model 81 line scope is used, it must also be focused accurately at infinity.

2. Sight the level-reference collimator with the Test Instrument's telescope accurately focused at infinity. Using the telescope tangent screw, achieve accurate register between the Test Instrument's horizontal reticle line and the horizontal reticle line of the level-reference collimator. (The vertical reticle lines should also be in approximate register.)

3. Observe any error in the Test Instrument's coincidence level vial. This error may be corrected using the nuts securing the vial case to its mounting studs. These nuts should be quite tight, and will be easier to tighten or loosen if two adjusting pins are used on one nut at the same time.

4. After any movement of the coincidence vial mounting nuts, re-verify the register of the Test Instrument's horizontal reticle line with that of the level-reference collimator.

5. Repeat steps 2, 3, and 4 until the Test Instrument's coincidence vial shows no error when the horizontal reticle lines are exactly in register.

COINCIDENCE LEVEL VIAL ADJUSTMENT USING THE MODEL 287-1 LEVELING MIRROR

NOTE: THE MODEL 287-1 LEVELING MIRROR MUST BE IN ACCURATE ADJUSTMENT FOR THIS TEST. THIS ADJUSTMENT SHOULD BE ACCOMPLISHED WHILE THE MODEL 287-1 IS IN POSITION ON ITS SHELF ON THE TARGET POST OF THE MODEL 270-BN TEST STAND, NOT ELSEWHERE. (SEE "OPERATION INSTRUCTION AND MAINTENANCE MANUAL FOR MODEL 270-BN UNIVERSAL SHORT-RANGE CALIBRATOR" FOR THIS ADJUSTMENT.) THE MODEL 287-1 MUST BE CHECKED FOR ACCURATE ADJUSTMENT EACH TIME IT IS USED IN ORDER TO MAINTAIN MAXIMUM ACCURACY.

Any Test Instrument to be inspected using this procedure must have autocollimation capability.

1. Verify that the model 287-1 leveling mirror is in fact accurately adjusted. (See procedure referenced above.)

2. With the proper lighting attachment for the Test Instrument in question, sight the Test Instrument at the model 287-1 mirror and achieve accurate autocollimation using the Test Instrument's tangent screws. Pay particular attention to the accuracy of autocollimation of the horizontal reticle line.

3. Observe any error in the Test Instrument's coincidence level vial. This error may be corrected using the nuts securing the vial case to its mounting studs. These nuts should be quite tight, and will be easier to tighten or loosen if two adjusting pins are used on one nut at the same time.

4. After any movement of the coincidence vial mounting nuts, re-verify autocollimation, particularly that of the horizontal reticle line.

5. Repeat steps 2, 3, and 4 until the Test Instrument's coincidence vial shows no error when the horizontal reticle line is perfectly autocollimated.

ALIGNMENT TELESCOPES

Brunson model nos. 81, 83, 381, include models with "-1", or "-M" suffix.

INITIAL SET-UP

In order to mount a line scope or alignment scope on the Test Instrument's mounting post of the model 270-BN, a suitable "vee" mounting base must be used. This unit should provide adequate rigidity, and have tangent screws or some other means of fine angular adjustment. A Brunson model 88 or 88-6 is suggested.

1. Position the mounting base on the Test Instrument's mounting post so that the M.T.C. may be sighted by the Test Instrument.

2. Focus the Test Instrument at infinity and sight the M.T.C. infinity target. Use the tangent screws on the Test Instrument's mounting base to achieve approximate register between the Test Instrument's reticle and the M.T.C. infinity target.

3. Focus the Test Instrument on the 4-ft. M.T.C. target. Use the lateral slide and precision lift in the Test Instrument's mounting post to achieve approximate register between the Test Instrument's reticle and the M.T.C. target. (If the amount of adjustment required is beyond the range of movement of the precision lift, use the handwheel to move the entire mounting post up or down until within the precision lift's range.)

4. Repeat steps 2 and 3 of this procedure until the Test Instrument can be focused at either infinity or 4 ft., and the Test Instrument reticle remains in approximate register with no manipulation. Initial set-up is now accomplished, and calibration may proceed.

NOTE: IN THE CASE OF AN ALIGNMENT TELESCOPE WITH BUILT-IN MICROMETER, THE MICROMETER ACCURACY MUST BE VERIFIED FIRST IN ORDER TO OBTAIN VALID RESULTS IN CALIBRATING THE TELESCOPE. ALIGNMENT TELESCOPE MICROMETERS MAY BE CALIBRATED USING THE PROCEDURES FOR DETACHABLE MICROMETERS FOUND ELSEWHERE IN THIS MANUAL, WITH THE FOLLOWING EXCEPTIONS:

1) FOR THE "ZERO-CENTER" CALIBRATION TEST, THE ENTIRE TELESCOPE MUST BE ROTATED 180°, SINCE THE MICROMETERS ARE INTEGRAL PARTS OF THE SCOPE.

2) THERE IS NO ADJUSTMENT FOR "MICROMETER SCALE ACCURACY". IF A MICROMETER IS IN ERROR DURING THIS TEST, THE ENTIRE INSTRUMENT SHOULD BE RETURNED TO THE MANUFACTURER FOR REPAIR.

COLLIMATION AT INFINITY FOCUS

Description:	The line-of-sight is parallel to the barrel outside diameter at infinity focus.
Tolerance:	± 1 arcsecond
Affected Parameters:	Line-of-sight straightness and centering

Note: In this procedure either an M.T.C. or a line scope can be used as the reference scope; this scope will be referred to as the collimator. If a line scope is used, it must be set to infinity focus.

1. Focus the Test Instrument at infinity and sight the collimator's infinity target.

2. Use the target screws on the Test Instrument's mounting base to achieve accurate register between the Test Instrument's vertical reticle line and the collimator's infinity target. (The Test Instrument's horizontal reticle line should also be in approximate register.)

3. Rotate the Test Instrument 180° about its center line. The vertical reticle line should again be in register. If an out-of-register condition exists, correct half of the observed error using the Test Instrument's reticle adjusting screws. (See page A-16.)

   NOTE: ON THE MODEL 81 AND 381 ALIGNMENT TELESCOPES, THE RETICLE ADJUSTING SCREWS ARE ALLEN-HEAD SET SCREWS LOCATED AT 90° FROM EACH OTHER AROUND THE TELESCOPE BARREL. THE FOUR SCREWS CLOSEST TO THE EYEPIECE ADJUST THE ERECTOR LENS ASSEMBLY, AND THE NEXT SET OF FOUR, JUST FORWARD OF THESE, ARE THE RETICLE ADJUSTING SCREWS. ON THE MODEL 83 ALIGNMENT TELESCOPE, THE RETICLE ADJUSTING SCREWS ARE ALLEN-HEAD SET SCREWS LOCATED UNDER COVER SCREWS IN THE BALL-SHAPED MOUNTING OF THE MICROMETER AND FOCUSING KNOBS, AT THE REAR OF THE BARREL.

4. Repeat steps 2 and 3 of this procedure until no error in register is observed on the vertical reticle line when the Test Instrument is rotated.

5. Rotate the Test Instrument 90° about its centerline. Repeat steps 2, 3, and 4 of this procedure for that reticle line now in the vertical position.

6. Perform steps 2, 3, 4, and 5 of this procedure as necessary until no error in register is observed for either reticle line in the Test Instrument.

Note: the vertical and horizontal reticle line collimation calibrations are presented separately for ease of instruction, but it is advantageous for the operator to do both simultaneously as one affects the other.

COMBINED LINE-OF-SIGHT STRAIGHTNESS AND CENTERING

Description:	Line-of-sight is straight as measured from both the vertical and horizontal reticle lines at all focal distances. The line-of-sight is also concentric to the barrel outside diameter.
Tolerance:	
Straightness:	± .001 inch, or ± 1 arcsecond, whichever is greater
Centering:	± .001 inch
Affected Parameters:	All

NOTE: COLLIMATION AT INFINITY FOCUS MUST BE PROPERLY ADJUSTED BEFORE PERFORMING THIS TEST.

1. Focus the Test Instrument on the 4-ft. M.T.C. target. If the Test Instrument has micrometers, make certain that the Test Instrument's reticle line are exactly parallel to those on the M.T.C. target.

2. Use the tangent screws in the Test Instrument's mounting base to achieve accurate register between the Test Instrument's vertical reticle line and the M.T.C. target. (The Test Instrument's horizontal reticle line should also be approximately in register.)

3. Rotate the Test Instrument 180° about its centerline. Observe any error in register between the Test Instrument's vertical reticle line and the M.T.C. target. (If the Test Instrument has micrometers, measure this error. Otherwise, the error's magnitude must be estimated.)

4. Rotate the Test Instrument 90° about its centerline. Now repeat steps 2 and 3 of this procedure.

5. Focus the Test Instrument on the 16-ft. M.T.C. target. Repeat steps 2, 3, and 4 of this procedure.

6. Repeat steps 2, 3, and 4 of this procedure for any other targets deemed necessary or desirable.

7. For any target, half the error observed at step 3 of this procedure is the actual deviation of the Test Instrument's line-of-sight from a straight line at that focal distance. If the actual error exceeds .001 inch at the 4 or 16-ft. targets, or 1 arcsecond at any target farther away than 17 ft., the Test Instrument should be returned to the manufacturer for repairs.

AUTO-REFLECTION TARGET

Description:	Target is concentric to the outside diameter of the barrel.
Tolerance:	± .001 inch.
Affected Parameters:	None

1. Point the Test Instrument at the model 81 alignment telescope, mounted to the side of the M.T.C. on the model 270-BN target post.

2. Use the model 81 alignment telescope to sight the Test Instrument's auto-reflection target. (A lighting attachment must be used in the Test Instrument) Achieve accurate register between the model 81 alignment telescope reticle and the Test Instrument's auto-reflection target.

3. Rotate the Test Instrument 180° about its centerline. Observe any error in register between the model 81 alignment reticle and the Test Instrument's auto-reflection target. Half the observed error is the actual error which must be corrected to make the auto-reflection target concentric with the Test Instrument's centerline. (NOTE: the distance between line centers of the smallest part of the auto-reflection target pattern is approximately .010 inch.)

4. If the actual error in concentricity of the auto-reflection target exceeds .001 inch, use the target adjusting screws (four allen-head set screws located around the Test Instrument's telescope barrel, farthest from the eyepiece) to move the auto-reflection target in the proper direction.

5. Repeat steps 2, 3, and 4 of this procedure until no error is observed at step 3.

APPENDIXES

"TRANSIT HORIZONTAL AXIS ADJUSTMENT"

"ADJUSTING A TRANSIT STANDARD"

GLOSSARY OF TERMS

LIST OF TOOLS REQUIRED FOR INSTRUMENT ADJUSTMENT

ILLUSTRATIONS

TRANSIT HORIZONTAL AXIS ADJUSTMENT

1. Determine the amount of error in perpendicularity between the Test Instrument's horizontal and vertical axes. Determine also the direction of this error; which end of the horizontal axis is "high" or "low". (See page 35 of the calibration procedures.)

2. If the error is small (20 arcseconds or less), the axis adjusting screw (capstan-head screw located in the standard directly beneath one horizontal axis bearing) may not need to be disturbed. Small errors are generally correctable simply by applying more torque or less torque to the axis bearing cap screws (cap screws securing the horizontal axis bearing caps to the top of the standard. They may be either slotted or allen-head, depending on the instrument's age. Refer to the picture in the calibration section for Plumb Line starting at page 35)

3. Using the appropriate screws, raise or lower an end of the Test Instrument's horizontal axis as necessary. If the axis adjusting screw is used, the axis bearing cap screws must be manipulated in conjunction with the adjusting screw.

   If only the axis bearing cap screws are used, take care to maintain proper torque. Too little torque causes looseness, and all accuracy is lost. Too much torque can damage the axis bearing.

   If an axis bearing cap screw must be loosened for this adjustment, turn it past the desired point, and then re-tighten to proper adjustment.

4. After any adjustment is made, the entire test for relationship of horizontal axis to vertical axis must be performed again.

TRANSIT STANDARD ADJUSTMENT

CAUTION: BEFORE ATTEMPTING THIS ADJUSTMENT, MAKE CERTAIN THAT IT IS REALLY NEEDED. MOVEMENT OF THE STANDARD WILL NOT COMPENSATE FOR A Line-of-sight WHICH IS NOT STRAIGHT. MOST INSTRUMENTS DO NOT REQUIRE THIS ADJUSTMENT UNLESS DAMAGE OR TAMPERING HAVE OCCURRED.

1. Make certain that the Test Instrument's line-of-sight is in fact straight within acceptable tolerances. (See page 28 and 30 of the calibration procedures.)

2. Determine the exact amount by which the line-of-sight is not centered over the instrument's vertical axis. (See page 32 of the calibration procedures.)

3. Mount the Test Instrument on a sturdy, stable base, and make provision for mounting a dial test indicator near enough to contact the base of the Test Instrument's standard. The indicator movement's travel should be parallel to the desired direction of movement.

4. Slightly loosen the allen-head cap screws holding the standard to the plate (refer to the pictures in the Horizontal Centering calibration procedure starting at page 32).

5. With the horizontal tangent clamp tightened and the indicator "zeroed" against the base of the standard, move the entire upper part of the Test Instrument in the proper direction to correct the line-of-sight centering error.

   A. For all models except 79 and 379, this movement is accomplished by turning the allen-head cap screws threaded horizontally into the plate just below the standard. Tightening one of these screws causes the standard to move in the same direction as the screw. (Do not neglect to loosen the adjusting screw in the opposite side.)

   B. For models 79 and 379, use a "soft" hammer (e.g., plastic, rawhide, rubber, etc.) to tap the base of the standard in the proper direction. (Even with the dial indicator there is of necessity more "trial and error" in moving the standards of these instruments, due to the shock effect of using the hammer.)

6. Without disturbing the Test Instrument more than absolutely necessary, re-tighten the cap screws holding the standard to the plate.

7. Re-inspect relationship of horizontal axis to vertical axis, and front-to-back centering--hollow vertical axis.

GLOSSARY OF TERMS AND ABBREVIATIONS

ALIGNMENT TELESCOPE

An optical tooling telescope used to established optical reference lines. Its outer diameter is accurately controlled for precision in mounting, and its line-of-sight is exactly positioned on its mechanical center line. Alignment telescopes may have integral or separate optical micrometers for measuring linear displacement.

AUTOCOLLIMATION

Register of an instrument's reticle with its own reflected image, when the instrument is focused at infinity. Achieved by using a lighting attachment to project an image of the reticle out of the telescope. This image is then reflected from a mirror, back into the telescope, and superimposed on the reticle.

AZIMUTH

A horizontal angle.

COLLINEAR

Literally, "on the same line-of-sight". Two telescopes are collinear when they are physically placed on the same center line. Differs from "collimated" which means "parallel".

COLLIMATE

To make two instruments' lines of sight parallel, when focused at infinity and facing each other. The word collimate, or collimation, always implies infinity focus.

COLLIMATION

The condition of being collimated.

COLLIMATOR

A telescope-like instrument fixed at infinity focus, and having one or more reticles to be sighted as reference targets by the Test Instrument.

DIRECT POSITION

Describes the position of a transit-type instrument in which the telescope is positioned with the focusing knob on the top, and the precise level vial on the bottom.

EYEPIECE

That part of a telescope into which the observer looks. Adjustment is normally provided to allow the eyepiece to be moved in or out so that accurate focus on the plane of the reticle may be achieved.

FOCUSING LENS

That lens contained in the focusing slide inside a telescope barrel. Movement of this lens along the length of the telescope bore allows images of objects at varying distances from the telescope to be focused on the plane of the reticle.

FOCUSING SLIDE

The mechanism by which the focusing lens is held and moved inside the bore of a telescope barrel.

HORIZONTAL AXIS

On transit-type instruments, the mechanical axis by which the telescope barrel mounted in the standards.

HORIZONTAL RETICLE LINE

The line or lines of the reticle which lie horizontally when the Test Instrument is mounted upright.

HORIZONTAL TANGENT CLAMP

The clamp just at the top of the spider which controls instrument rotation about the vertical axis.

HORIZONTAL TANGENT SCREW

Slow-motion or fine adjusting screw found in the horizontal tangent clamp. Used for precise rotation about the vertical axis.

INDIRECT POSITION

Describes the position of a transit-type instrument in which the telescope is positioned with the focusing knob on the bottom, and the precise level vial on the top.

INFINITY FOCUS

The condition of a telescope being focused on an object at an infinite distance (extremely far away) from the telescope. This condition is most easily and accurately achieved by autocollimation using a mirror.

LEVEL

An instrument used for sighting elevations. Differs from a transit in that the telescope of a level cannot be plunged.

LEVELING SCREWS

Screws in the base of an optical tooling or surveying instrument, used to tilt the instrument so that its vertical axis is truly vertical with respect to the earth's center of gravity or a reference plane. Also referred to as foot screws.

LINE SCOPE

Term commonly used to identify an alignment telescope with no micrometers.

M.T.C.

Multiple-target collimator. As used in this manual, refers to the Brunson model 272 collimator mounted in the center of the target post on the model 270-BN collimation test stand.

OBJECTIVE LENS

The "front" lens of a telescope; the light-gathering lens at the end of the telescope pointing toward the object being sighted.

OPTICAL MICROMETER

An attachment on the end of the telescope barrel of an optical tooling or surveying instrument, used to displace the line-of-sight parallel to its zero or center position. A graduated scale measures this displacement in linear units of measure.

OPTICAL PLUMMET (IN A THEODOLITE)

An auxiliary telescope whose line-of-sight is concentric to the instrument's vertical axis, used for sighting below the instrument and centering it over a reference point.

OPTICAL PLUMMET (IN THE MODEL 270-BN TEST STAND)

A collimator and mechanical positioning assembly located in the bottom of the Test Instrument's mounting post on the model 270-BN test stand. It is used for adjustment of optical plummets in theodolites, and for centering the line-of-sight over the vertical axis in optical tooling transits with hollow vertical axis.

PLUNGE

The act of moving the telescope of a transit end over end through an angle of 180° or more. (Rotating the barrel about the horizontal axis.)

PRECISION SIGHT LEVEL

A level with capabilities for transiting the telescope up or down by small amounts for precise leveling and elevation readings.

REGISTER

"Aligned with." The reticle of an instrument is said to be "in register" with a target if it is precisely centered on, or aligned with, that target.

RETICLE
The "cross-hair" or "cross-wire" lines (filars) in an optical instrument telescope.

SPIDER
That part of the base of an instrument having four leveling screws, into which those leveling screws are threaded. Differs from "tribrach" on three-screw leveling bases.

STANDARD
On a transit-type instrument, that framework which holds the telescope and horizontal axis above the vertical axis.

STRIDE LEVEL
A level vial mounted on metal "vees" for use on the outer surface of an alignment telescope or collimator barrel.

VERTICAL TANGENT CLAMP
On a transit-type instrument, the clamp which controls telescope motion about the horizontal axis.

VERTICAL TANGENT SCREW
Slow motion or fine adjustment screw controlling up-and-down tilt of an instrument's telescope.

THEODOLITE
A transit with graduated circles about its mechanical axes for the measurement of horizontal and vertical angles.

TRANSIT (noun)
An optical tooling or surveying instrument with horizontal and vertical axes enabling the telescope to be plunged in a vertical plane, as well as rotated in a horizontal plane.

TRANSIT (verb)
To tilt the telescope of a transit or precision sight level up or down.

TRIBRACH
The base of any optical tooling or surveying instrument having three leveling screws.

VERTICAL AXIS
The mechanical axis about which an instrument may be rotated to sweep a horizontal plane. Also called vertical spindle.

VERTICAL RETICLE LINE

The line or lines of the reticle which lie vertically when the instrument is mounted upright.

ULTRADEX

Trademark of the AA Gauge Company to describe an indexing table capable of turning angles to an accuracy of 1/4 arcsecond. Used in the mounting post of the model 270-BN test stand.

TOOLS REQUIRED FOR INSTRUMENT ADJUSTMENT

1. Screwdrivers: several sizes of standard flat-blade screwdrivers, ranging from 1/8 inch to 3/8 inch in width.

2. Hammers: one soft hammer (plastic, rubber, or rawhide), about 8 - 16 oz., and one small brass or steel hammer, about 1 - 2 oz.

3. Allen wrenches: complete range of American sizes from .028 inch to 3/8 inch. For use on European optical-reading theodolites, metric sizes from 1.5 mm. to about 5 or 6 mm.

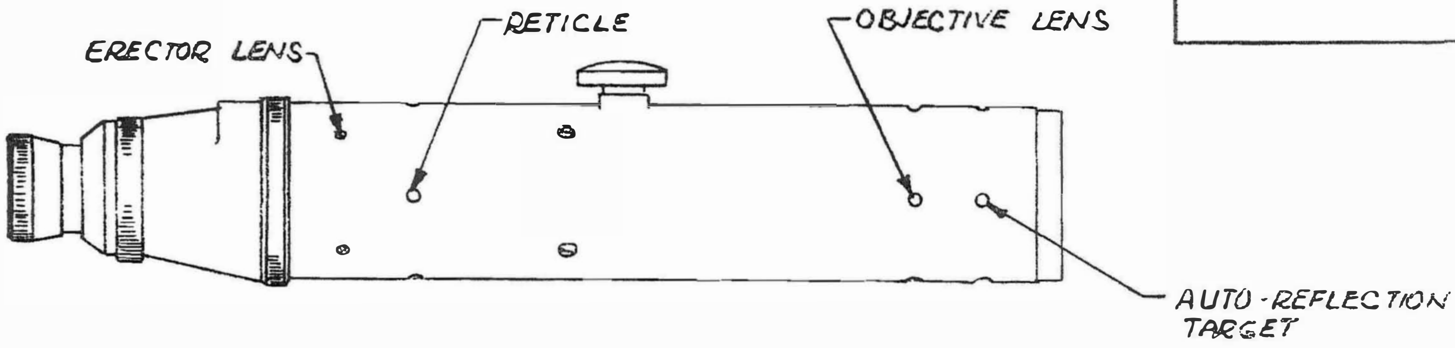
4. Small brass drift: suitable size for applying to heads of reticle adjusting screws for reticle orientation.

5. Adjusting pins: Brunson part nos. 5086 and 70540, or equivalent. Several dozen.

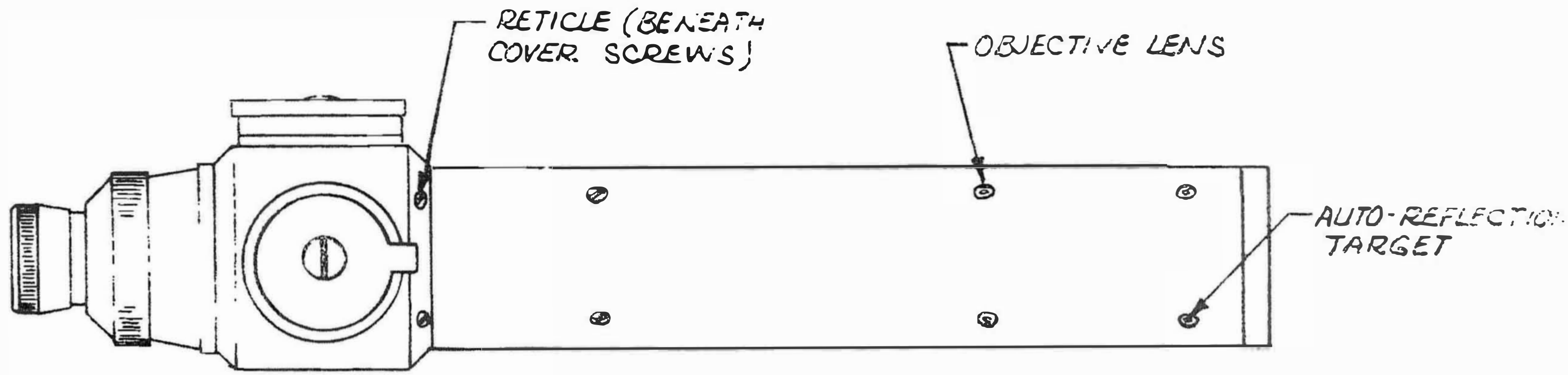
6. End wrenches: American sizes from 1/4 inch to 1/2 inch. Metric sizes from 4 mm. to 10 mm.

ILLUSTRATIONS

CHG.



MODEL 81 ALIGNMENT SCOPE



MODEL 83 ALIGNMENT SCOPE

TOLERANCE DEC. FRAC. ANG.

REV.	DESCRIPTION	DATE	REV.	DESCRIPTION	DATE

REQ'D UNIT | REQ'D. ASSEM. | MAT'L. | FINISH

PART NAME: ADJUSTMENT SCREW LOCATION

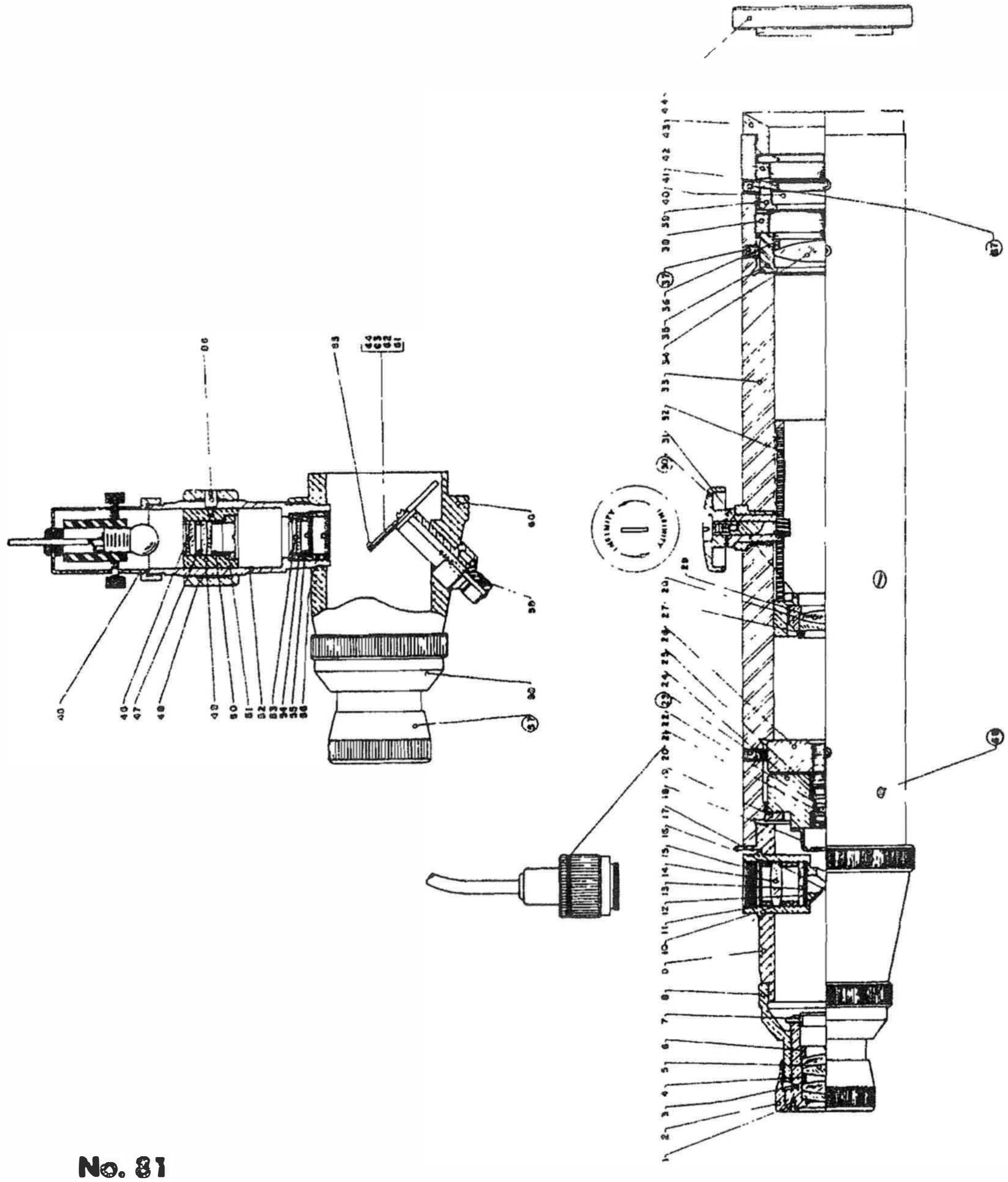
BRUNSON INSTRUMENT CO.
KANSAS CITY, MISSOURI

PROD. NAME: ALIGNMENT SCOPE

DR. M.D.H. | CH.

SCALE NONE | APPR'D.

NEXT ASSEM. —— | CAT. NO. —— | PART NO. —— | CHG

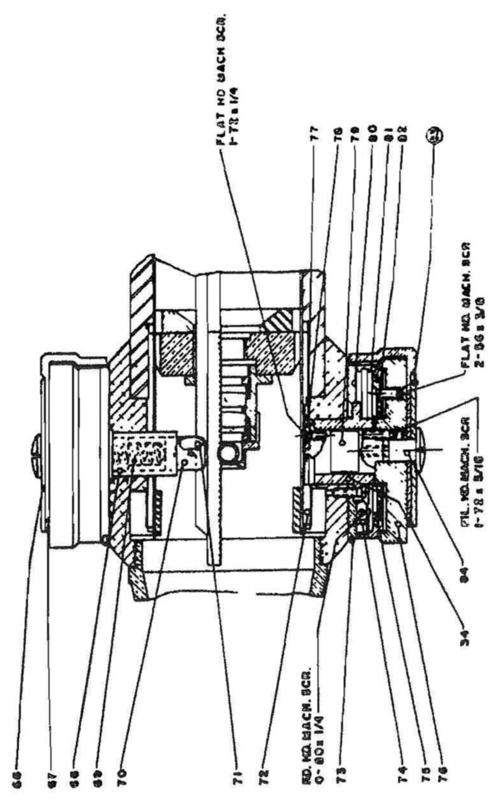


No. 81

MODEL 81 ALIGNMENT SCOPE — PARTS LIST

INDEX	PART NO.	DESCRIPTION
1	2433	Screw, focusing ring lock
2	2430	Ring, eyepiece focusing
3	2428	Mount, eyepiece lens
4	2427	Spacer, eye lens
5	2432	Lens, eye
6	2426	Ring, eye lens retiner
7	2425	Diaphragm, eyepiece
8	2429	Nut, eyepiece focusing
9	2611	Adaptor, straight eyepiece
10	2886	Spacer, lens & diffuser
11	2610	Mount, reflector
12	2635	Spring, diffuser and lens tension
13	2636	Diffuser, light
14	2885	Lens, condenser
15	2638	Retainer, diffuser & Lens
16	2637	Spacer, condenser lens
17	2623	Reflector, light
18	2424	Diaphragm, erector mount
19	2628	Ring, reticle & erector lens mount retainer
20	2630-GI	Light housing assembly w/2672 transformer
21	2431	Lens, erector
22	2423	Spacer, erector lens
23	2614	Screw, erector lens & reticle adjuster
24	2616	Mount, erector lens
25	2422	Ring, erector lens retainer
26	2769-GI	Reticle assembly (Projection)
26	2769-G2	Reticle assembly (Filar-BiFilar)
27	2414	Ring, focusing lens retainer
28	2413	Mount, focusing lens
29	2415	Lens, focusing
30	5051-G2	Pinion assembly
31	2615-G1	Focusing slide assembly (short focus)
32	2726	Rack, focusing slide
33	2632-GI	Model 81 Barrel assembly
34	2406	Lens, objective
35	2602	Mount, objective lens
36	2606	Ring, objective lens retainer
37	2613	Screw, objective lens & target adjuster
38	2604	Ring, objective mount & target mount retainer
39	2603	Mount, auto reflection target
40	2640	Target, auto reflection
41	2605	Ring, auto reflection target retainer
42	2604	Ring, objective mount & target mount retainer
43	2629	Ring, objective end (small)
44	2681	Ring, objective end (large)
45	1719-G3	Light housing assembly
46	5293	Lens, eye
47	1718	Spacer, lens
48	1692	Ring, eyepiece focusing
49	1691	Mount, eye lens
50	1695	Spacer
51	1693	Ring, lens retainer
52	2772-GI	Adaptor, light housing
53	1698	Diffuser, light
54	2719	Mount, light diffuser
55	2720	Ring, light diffuser retainer
56	2721	Ring, light diffuser mount retainer
57	2430	Ring, eyepiece focusing
58	2455-GI	Eyepiece focusing nut & lens mount assembly
59	2716	Knob, reflector index
60	2715	Adaptor, eyepiece & projection attachment
61	5294	Filter, green
62	5295	Reflector, clear
63	5296	Reflector, full mirror
64	5297	Reflector, partial mirror
65	1723-GI	Reflector, mount & reflector assembly
66	1716	Screw, spiral focusing
67	2613	Screw, objective lens & target adjuster
68	2614	Screw, erector lens & reticle adjuster

No. 83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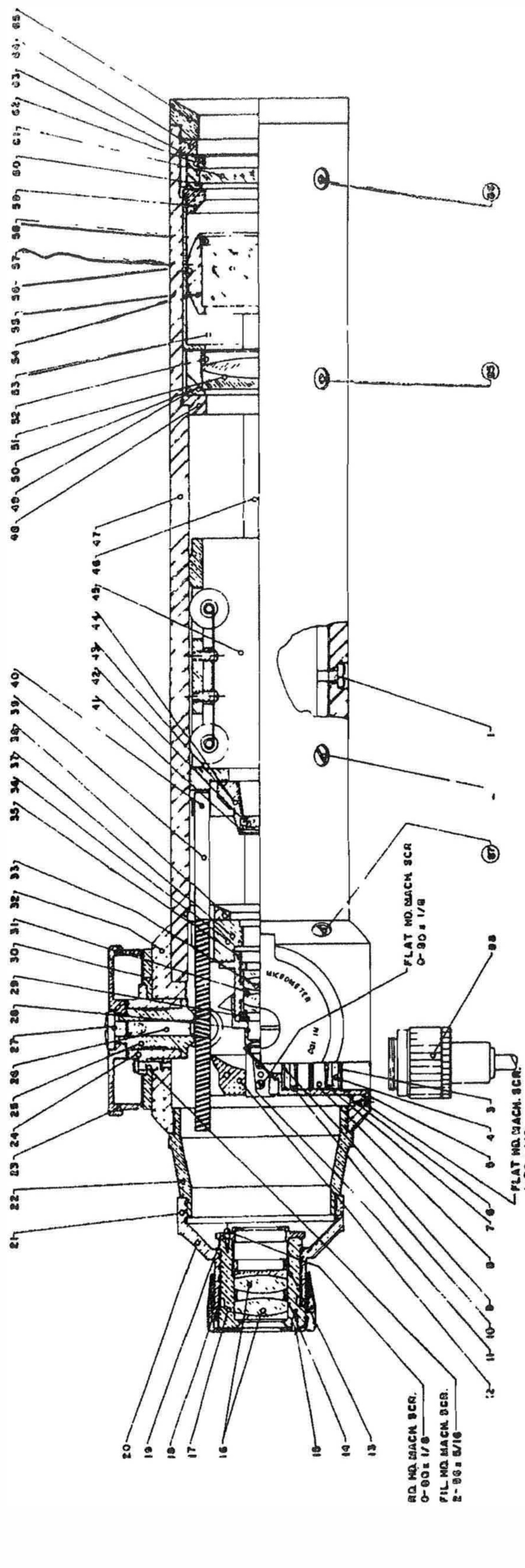
FIL. HD. MACH. SCR. 1-72 x 5/16
RD. HD. MACH. SCR. 0-80 x 1/4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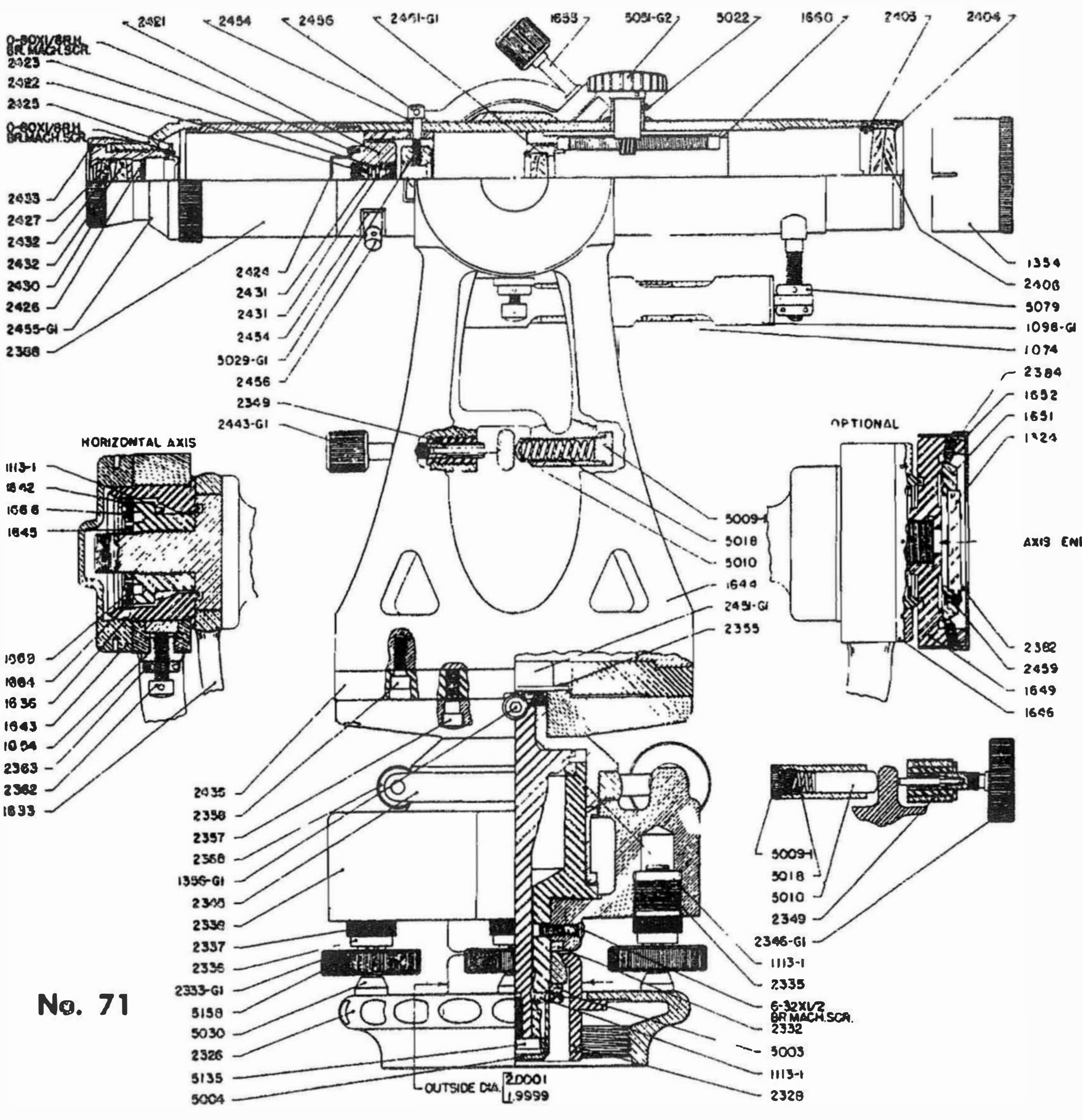
RD. HD. MACH. SCR. 0-80 x 1/8
FIL. HD. MACH. SCR. 2-56 x 5/16
MICROMETER

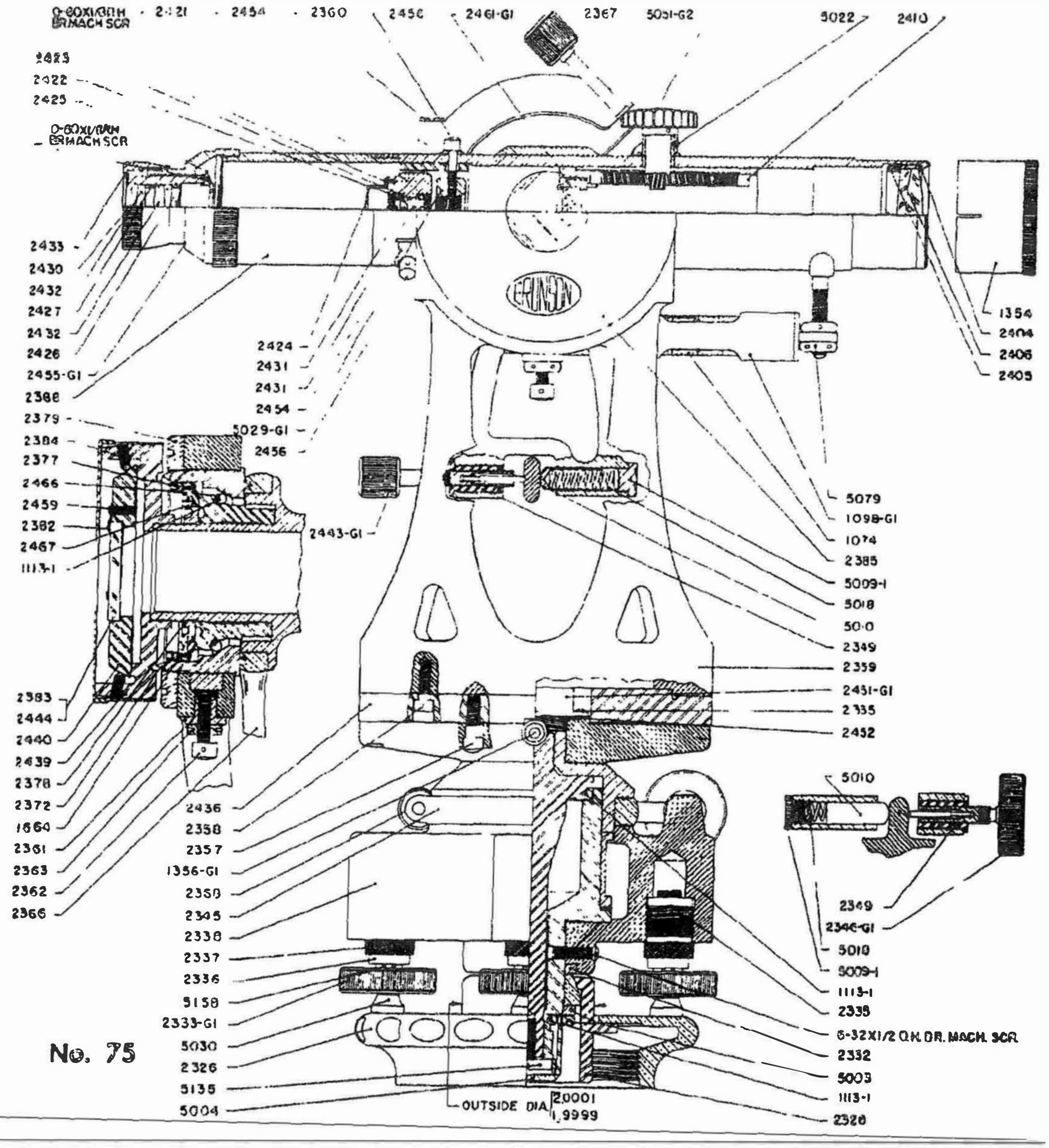
BRUNSON MODEL NO. 83 ALIGNMENT SCOPE PARTS LIST

INDEX	PART NO.	DESCRIPTION
1	2783	Stop, focusing slide
2	2845	Cover, focusing lens adjuster screw
3	2638	Retainer, diffuser & lens
4	2636	Diffuser, light
5	2834	Mount, condenser & reflector
6	2631 GI	Light, reflector & condenser assembly
7	2637	Spacer, lens & diffuser
8	1260	Lens, condenser
9	2635	Spring, diffuser & lens tension
10	2637	Spacer, lens & diffuser
11	2623	Reflector, light
12	2784	Guide, micrometer link
13	2426	Ring, eye lens retainer
14	2427	Spacer, eye lens
15	2433	Screw, focusing ring lock
16	2432	Lens, eye
17	2428	Mount, eye lens
18	2430	Ring, eyepiece focusing
19	2425	Diaphragm, eyepiece
20	2450-G2	Lens & eyepiece assembly (No. 83)
21	2660	Nut, eyepiece focusing
22	2661	Adaptor, straight eyepiece
23	2665	Drum, focusing
24	2662	Bearing, camshaft
25	2777	Bushing, pinion
26	5041	Gear, pinion
27	2846	Screw, focusing drum retainer
28	2669	Diaphragm, erector mount
29	2422	Ring, erector lens retainer
30	2866	Plate, focus index
31	2423	Spacer, erector lens
32	2847	Housing, control
33	2431	Lens, erector
34	2662	Bearing, camshaft
35	2649	Mount, erector lens
36	2865-GI	Reticle assembly
37	2864-GI	Reticle & erector lens assembly
38	2643	Ring, reticle thrust
39	2832-GI	Focusing rack assembly
40	2848	Pin, rack anchor
41	2854	Ring, focusing lens retainer
42	2489	Lens, focusing
43	2678	Mount, focusing lens
44	2863-G1	Focusing lens & Mount assembly
45	2862-G2	Focusing slide assembly
46	2779-G1	Micrometer link assembly
47	2634	Barrel, telescope (83)
48	2644	Ring, objective thrust
49	2861-G1	Objective lens & mount assembly
50	2645	Mount, objective lens
51	2406	Lens, objective
52	2842	Ring, objective lens retainer
53	2658	Housing, micrometer
54	2860-G1	Micrometer block mount
55	2655	Mount, micrometer block
56	2859-G1	Micrometer housing assembly
57	2520	Block, micrometer
58	2840	Ring, micrometer block retainer
59	2659	Ring, micrometer housing cap
60	2858-GI	Auto reflection target & mount assembly
61	2640	Target, auto reflection
62	2839	Mount, auto reflection target
63	2843	Ring, target retainer
64	2841	Ring, target mount retainer
65	2856	Ring, objective end (83)
66	2850	Stop, horizontal tolerance
67	2849	Stop, inner tolerance
68	2652	Sleeve, rack thrust guide
69	2833	Spring, rack roller tension
70	2650	Guide, rack thrust roller
71	2651	Roller, rack thrust
72	2778	Follower, cam
73	2677	Stop, stationary
74	2868-G1	Zero stop assembly
75	2663	Disc, clamp
76	2666	Drum, knurled micrometer
77	2835	Cam, micrometer (right side)
78	2836	Cam, micrometer (left side)
79	2657	Shaft, cam
80	2656	Plate, index
81	2664	Drum, graduated
82	2653	Spring, drum brake
83	2851	Stop, vertical tolerance
84	2844	Screw, micrometer drum retainer
85	2613	Screw, objective lens & target adjuster
86	2613	Screw, objective lens & target adjuster
87	2826	Cover, reticle adjusting screw
88	2630-G1	Light housing assembly w/No. 2672 transformer



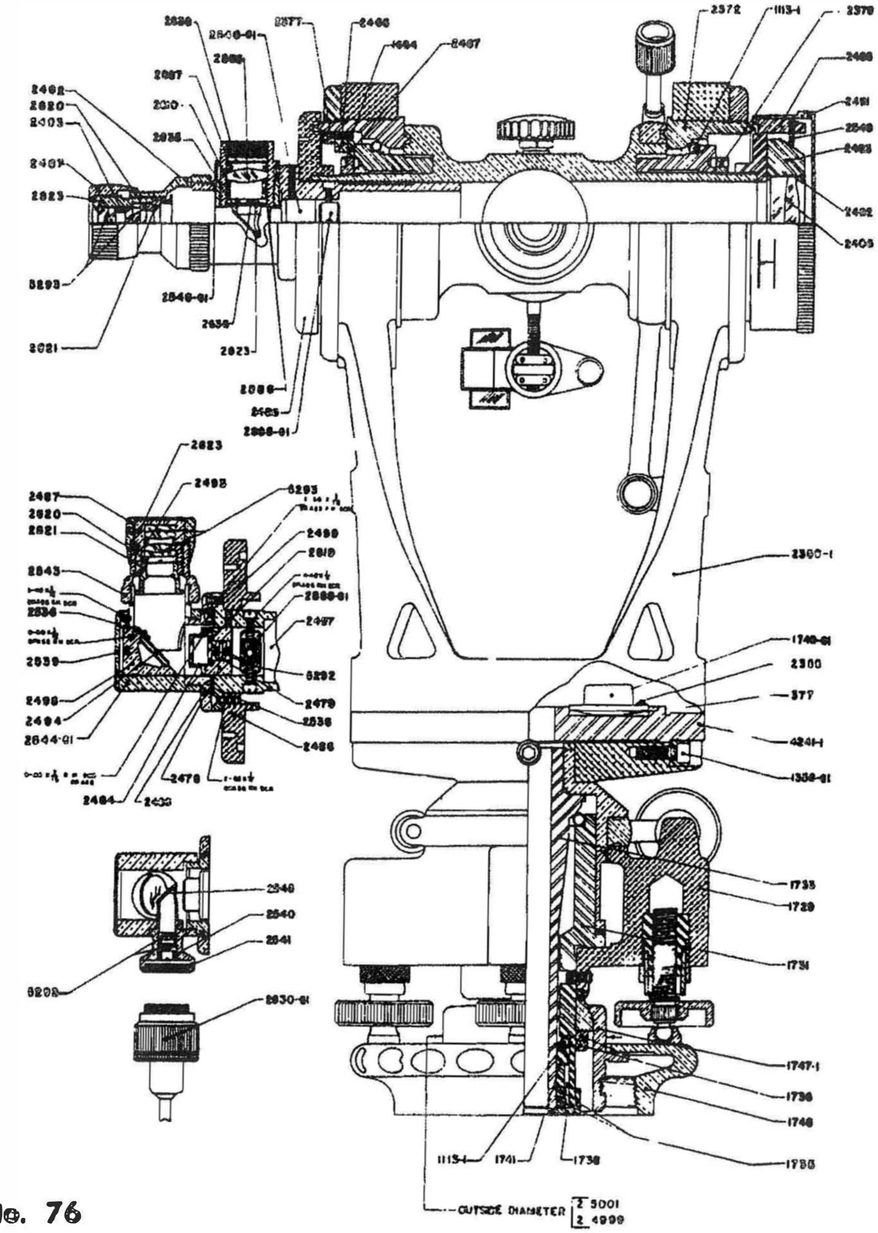
2421
2454
2456
2461-G1
1653
5051-G2
5022
1660
2405
2404
0-80X1/8R.H.
BR.MACH.SCR.
2423
2422
2425
0-80X1/8R.H.
BR.MACH.SCR.
2433
2427
2432
2432
2430
2426
2455-G1
2388
2424
2431
2431
2454
5029-G1
2456
2349
2443-G1
1354
2406
5079
1098-G1
1074
2384
1652
1651
1324
OPTIONAL
AXIS END
HORIZONTAL AXIS
1113-1
1642
1666
1645
5009-1
5018
5010
1644
2451-G1
2355
2382
2459
1649
1646
1669
1664
1636
1643
1064
2363
2362
1633
2435
2358
2357
2368
1356-G1
2346
2339
2337
2336
2333-G1
5158
5030
2326
5135
5004
OUTSIDE DIA. 2.0001 / 1.9999
5009-1
5018
5010
2349
2346-G1
1113-1
2335
6-32X1/2
BR.MACH.SCR.
2332
5003
1113-1
2328

No. 71



2456
2461-GI
2367
5051-G2
5022
2410
2423
2422
0-80XI/8RH
BRMACH SCR
2433
2430
2432
2427
2432
2426
2455-GI
2388
2379
2384
2377
2466
2459
2382
2467
1113-1
2424
2431
2431
2454
5029-GI
2456
2443-GI
1354
2404
2406
2405
5079
1098-GI
1074
2385
5009-1
5018
2349
2359
2451-GI
2452
2383
2444
2440
2439
2378
2372
1664
2361
2363
2362
2366
2436
2358
2357
1356-GI
2345
2338
2337
2336
5158
2333-GI
5030
2326
5135
5004
5010
2349
2346-GI
5010
5009-1
1113-1
6-32X1/2 O.H. BR. MACH. SCR
2332
5003
1113-1
2328
OUTSIDE DIA.
2.0001
1.9999

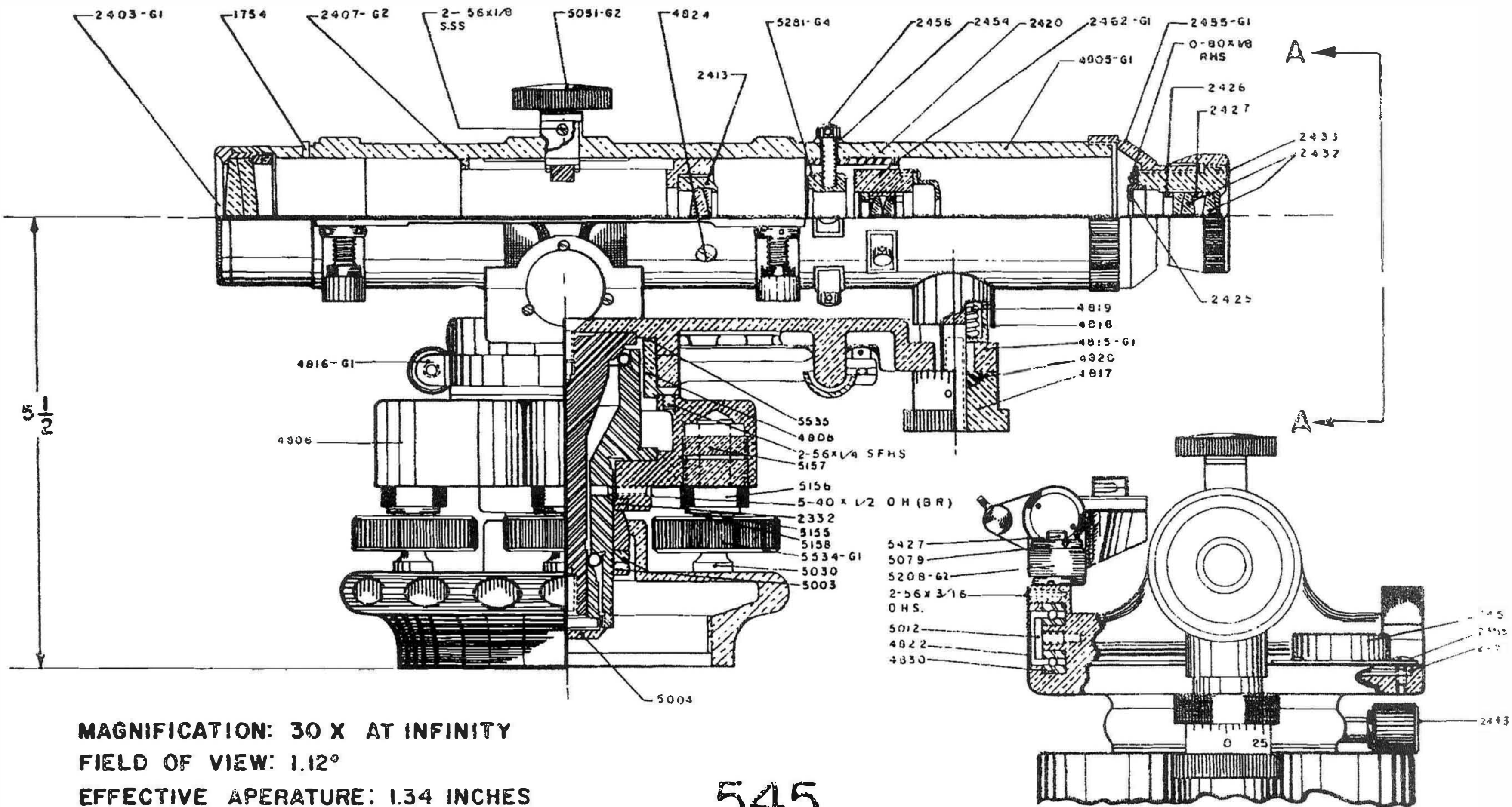
No. 75


2372
1113-1
2370
2466
1664
2467
2877
2648-01
2488
2487
2462
2820
2403
2823
5293
2540-01
2836
2821
2823
2886
2465
2888-01
2823
2498
5293
2487
2820
2821
2843
2836
2839
2496
2494
2844-01
2484
2478
2490
2818
2888-01
2497
5292
2479
2536
2486
2548
2840
2841
5208
2830-01
2461
2549
2483
2482
2405
2390-1
1740-01
2300
377
4241-1
1338-01
1735
1729
1731
1747-1
1736
1746
1738
1113-1
1741
1738
OUTSIDE DIAMETER
2.5001
2.4999

No. 76

MODEL 75 OPTICAL TRANSIT SQUARE, MODEL 76 TELESCOPIC TRANSIT SQUARE AND MODEL 71 JIG TRANSIT

177	Spring, bulls eye vial mount
1074	Vial, telescope level, reversion
1098-G1	Level, telescope, vial & case assembly
1113-1	Balls, steel, 5/32 (set of 59), vertical axis (hollow spindle)
1113-1	Balls, steel, 5/32 (set of 47), Plain vertical axis
1113-1	Balls, steel, 5/32 (set of 45), One side horizontal axis Model 75
1113-1	Balls, steel, 5/32 (set of 26), one side horizontal axis Model 71
1324	Mirror, first surface (full reflecting)
1354	Cap, objective
1356-G1	Screw, base adjusting
1633	Clamp, telescope
1636	Race, outer axis bearing
1642	Nut, brake nut lock
1643	Cap, axis end
1644	Standard
1645	Nut, inner axis race retainer
1646	Nut, standard toe-in
1649	Flange, Mirror
1651	Mount, mirror
1652	Cover, horizontal axis mirror
1654	Bushing, axis adjuster
1655	Screw, telescope clamp
1660	Slide, focusing (finished)
1664	Screw, telescope brake retainer
1668	Nut, brake
1669	Spring, telescope brake
1729	Spider
1731	Socket, spindle (hollow spindle)
1733	Spindle, hollow vertical
1735	Ring, half ball bearing lock
1736	Ring, half ball lock
1738	Cap, spindle
1741	Bearing, half ball
1747-1	Socket, center half ball
1748	Plate, bottom
1749-G1	Bulls eye, vial & case assembly
2326	Plate, bottom
2328	Socket, center half ball (factory fitted)
2332	Bearing, half ball and spider
2333-G1	Screw, leveling assembly
2335	Bushing, leveling screw
2336	Shield, lower, leveling screw
2337	Shield, upper, leveling screw
2338	Spider
2345	Clamp, lower
2346-G1	Screw, lower tangent, assembly
2349	Bushing, tangent screw
2355	Screw, bulls eye vial mount
2357	Screw, standard base to intermediate plate
2358	Screw, intermediate plate to standard
2359	Standard
2359-1	Standard, hollow spindle
2360	Screw, standard top
2361	Bushing, axis adjuster
2362	Screw, axis adjuster
2363	Nut, lock, axis adjuster
2366	Clamp, telescope
2367	Screw, telescope clamp
2368	Screw, lower clamp
2372	Race, outer axis bearing
2377	Nut, brake nut lock
2378	Nut, race retainer
2379	Nut, standard toe-in
2382	Clip, window and mirrow retainer
2383	Window, axis (30% reflecting) (Clamp side)
2384	Screw, window adjuster
2385	Cover, flange
2388	Adaptor, straight eyepiece
2404	Mount, objective
2405	Ring, objective lock
2406	Lens, Objective
2410	Slide focusing (finished)
2421	Mount, erecting lens
2422	Ring, erector lens retainer
2423	Spacer, erector lens
2424	Diaphragm, erector mount
2425	Diaphragm, eyepiece
2426	Ring, eye lens retainer
2427	Spacer, eye lens
2430	Ring, eyepiece focusing
2431	Lens, erector
2432	Lens, eye
2433	Screw, lock, focusing ring
2436	Plate, intermediate
2439	Flange, window
2440	Mount, window
2443-G1	Screw, telescope tangent assembly
2444	Window, axis (low reflecting) (Left side)
2451-G1	Vial, bulls eye and mount assembly
2452	Spring, bulls eye vial mount
2454	Collet, reticle and erector lens
2455-G1	Eyepiece focusing ring and lens mount assembly
2456	Screw, reticle and lens mount adjuster
2459	Screw, clip retainer
2401-G1	Focusing lens and mount assembly
2466	Nut, brake
2467	Spring, telescope brake
2478	Mount, erector lens
2479	Spacer, lens
2482	Nut, eyepiece lock
2483	Mount, objective
2484	Diaphragm, erector
2485	Flange, objective
2486	Flange, axis eyepiece
2487	Cap, eyepiece
2491	Cover, objective flange
2492	Ring, objective lens retainer
2493	Spacer, eye lens
2494	Mirror, (Right angle eyepiece-cross scope)
2496	Ring, right angle eyepiece retainer
2497	Barrel, cross scope, right angle eyepiece
2498	Mount, right angle eyepiece cross scope mirror
2499	Bearing, right angle eyepiece cross scope
2536	Clip, mirror retainer
2538	Spring, right angle eyepiece cross scope
2539	Cover, right angle eyepiece end
2540	Retainer, lens
2541	Mount, right angle eyepiece cross scope reflector
2543	Nut, right angle eyepiece lock
2544-G1	Right angle eyepiece housing assembly
2545	Reflector, light
2546-G1	Cross scope erector lens assembly
2548-G1	Barrel, straight cross scope
2549	Screw, objective adjuster
2610	Mount, straight eyepiece cross scope reflector
2623	Reflector, light
2630-G1	Light housing assembly
2635	Spring, diffuser and lens tension
2636	Diffuser, light
2637	Spacer, condenser lens
2638	Retainer, diffuser & lens
2819	Ring, erector lens retainer
2820	Ring, eye lens retainer
2821	Diaphragm, eyepiece
2823	Mount, eyepiece lens
2885	Lens, condenser
2886	Spacer, lens & diffuser
2888-G1	Cross scope reticle assembly
4241-1	Plate, intermediate
5003	Ring, lock, spindle
5004	Cap, seal
5009-1	Cap, clamp
5010	Plunger, spring
5018	Spring, tangent
5022	Screw, pinion retainer
5029-G1	Reticle assembly (single cross)
5030	Shoe, leveling screw
5051-G2	Pinion assembly
5079	Nut, telescope vial adjuster
5135	Screw, Spindle
5158	Ring, keeper
5292	Lens, erector
5293	Lens, eye

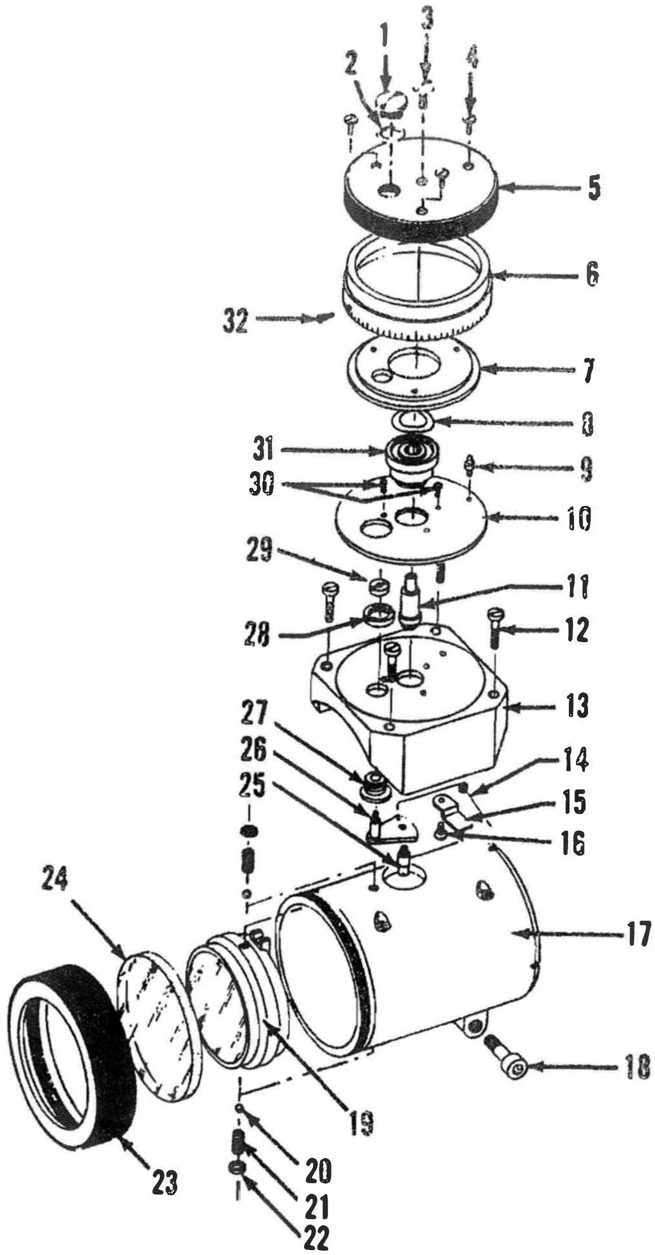


MAGNIFICATION: 30 X AT INFINITY
FIELD OF VIEW: 1.12°
EFFECTIVE APERATURE: 1.34 INCHES
RESOLUTION: 3.9 SECONDS

545

VIEW-A A

LEVELING ACCURACY = 1 SECOND



BRUNSON MODEL # 190 OPTICAL MICROMETER

REF. NO.	DESCRIPTION	PART NO.	QTY. REQ.
1	Adjusting Cap Screw	5995	1
2	Adjusting Screw Washer	2550	1
3	Pinion Screw	2513	1
4	Drum Clamp Screw	2533	3
5	Knurled Drum	2503	1
6	Graduated Drum (Model 190)	2504-1	1
	Graduated Drum (Model 190-50)	2504-2	1
7	Index Disc	2505	1
8	Brake Spring	2525	1
9	Stationary Stop	2518	1
10	Clamp Disc	2506	1
11	Pinion	2511	1
	Support Screw	2527	4
	Support Drum	2502-1	1
14	Anti-Backlash Spring	2529	1
15	Spring Retainer	2530	1
16	Retainer Screw	2534	1
17	Main Body Tube	2501-1	1
18	Clamp Screw	2538	1
19	Window Assembly	Specify Model Number when ordering	1
20	Ball Bearing	1113-2	2
21	Window Screw	2509	2
22	Window Screw Nut	2510	2
23	Glass Retainer	2522	1
24	Cover Glass	2523	1
25	Crank Pin	2508	1
26	Sector	2514	1
27	Sector Bearing	2515	1
28	Sector Bearing Nut	2516	1
29	Sector Retainer Nut	2517	[illegible]
30	Index Disc Screw	2532	
31	Pinion Bearing	2512	[illegible]
32	Movable Stop	2510	1

BRUNSON

USEFUL CONVERSION TABLES

Seconds of arc in terms of thousandths of an inch

	10 Ft.	20 Ft.	30 Ft.	40 Ft.	50 Ft.	100 Ft.
1 Sec.	.0006	.0012	.0018	.0024	.0030	.0060
2 Sec.	.0012	.0024	.0036	.0048	.0060	.0120
3 Sec.	.0018	0036	.0054	.0072	.0090	.0180
4 Sec.	.0024	.0048	.0072	.0096	.0120	.0240
5 Sec.	.0030	.0060	.0090	.0120	.0150	.0300
10 Sec.	.0060	.0120	.0180	.0240	.0300	.0600
15 Sec.	.0090	.0180	.0270	.0360	.0450	.0900
20 Sec.	.0120	.0240	.0360	.0480	.0600	.1200
25 Sec.	.0150	.0300	.0450	.0600	.0750	.1500
30 Sec.	.0180	.0360	.0540	.0720	.0900	.1800
60 Sec.	.0360	.0720	.1080	.1440	.1800	.3600

Angles to linear measurement

Angle	Per Inch	Per 10 Inches	Per Foot
1 Sec.	.000005	.000048	.000058
5 "	.000024	.000242	.000291
10 "	.000048	.000485	.000582
20 "	.000097	.000970	.001163
30 "	.000145	.001454	.001745
1 Min.	.000291	.002909	.003491

Linear measurement to angles

Linear	Per Inch	Per 10 Inches	Per Foot
.000001"	0.206 Sec.	0.021 Sec.	0.017 Sec
.000025"	5.157 "	0.516 "	0.430 "
.00005"	10.3 "	1.03 "	0.86 "
.0001"	20.6 "	2.06 "	1.71 "
.001"	3 Min 26. "	20.6 "	17.2 "
.005"	17 Min 11. "	1 Min 43. "	1 Min 26. "