OPTICAL TOOLING EQUIPMENT

KEUFFEL & ESSER CO.

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K+E

OPTICAL TOOLING EQUIPMENT

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In addition to its long experience in manufacturing surveying instruments, Keuffel & Esser Co. has been a leading factor in the design and manufacture of many types of specialized optical instruments in which the greatest accuracy and precision are essential, including submarine periscopes and optical fire-control instruments.

To these many specialized types K&E has added a line of Optical Tooling Equipment. This is the result of long and thorough research and development in collaboration with leading industrial concerns. Production methods have been greatly advanced by the use of Optical Tooling Equipment.

K&E OPTICS FOR TOOLING

If you build large mock-ups, jigs or structures to close tolerances, optical devices will save you time and money. In fact they may be the *only* practical means of holding the necessary tolerances.

Optics provide essentially a line of sight that is absolutely straight, has no weight, and from which measurements can be made with great accuracy.

There are three basic instruments:

1. The Alignment Telescope
2. The Jig Transit
3. The Precise Level

The *Alignment Telescope* provides permanent reference lines on the jig. The *Jig Transit* establishes an absolutely vertical plane exactly where desired – on line with two marks, or precisely at right angles to any other line of sight. The *Precise Level* establishes a precisely horizontal plane at any desired height.

All three instruments are self-checking. Their accuracy is independent of any master gauge. They can be tested quickly and adjusted exactly.

Two *Optical Micrometers* are built into the *Alignment Telescope*. These move the line of sight parallel to itself left and right and up and down. The *Jig Transit* and *Precise Level* can and should be provided with a *K&E Optical Micrometer*, positioned so as to move the line of sight either left and right or up and down. The motions are controlled by micrometer knobs that show the extent of the movement in thousandths of an inch.

Measurements are made from the line of sight with precision *K&E WYTEFACE* Optical Tooling Scales*. These provide a precision target at every tenth of an inch. The remaining decimal part is measured with the optical micrometer to 0.001 inch.

Optical instruments supplement and usually replace plumb bobs, straightedges, precise steel squares, surface plates, indicator gauges, and shop levels for all large jigs or structures. They produce results so easily and accurately that their operation is incomparably superior to that of the older devices. Their use is so flexible that, with proper ingenuity, they can be applied to almost any type of precision measurement job.

Optical instruments are now an essential part of the aircraft industry. They are used throughout the entire manufacturing process from building mock-ups to checking the alignment of the final product. Present day tolerances cannot be held without optical devices. Attempts to use the older methods are usually slow and expensive and often unsuccessful.

The following pages describe the K&E optical tooling instruments and equipment in some detail and cover some of the fundamental procedures for their use.

A WORD ABOUT OPTICS

The fundamental element of optical tooling is the sighting telescope. It is the basis of the jig alignment telescope, the jig transit, and the precise level. Its purpose is to create a picture for the observer that shows the position of the cross lines on the target with the greatest possible clarity and precision. This purpose is attained by choosing the *combination* of optical qualities best suited to a particular application, by skillful design, and by perfection in manufacture. These qualities include: resolving power, definition, magnification, eye distance, size of pupil and field of view.

Specifications alone can seldom indicate the true qualities of one telescope as compared with another. The most important and, in fact, the only final test for a telescope is a simultaneous comparison under the same conditions with another telescope.

*Trade Mark

May 1953

OPTICAL TERMS

Resolving Power. "Resolving power" is the name given to the ability of a lens to show detail. It is measured by the smallest angular distance, expressed in seconds of arc, between two points that are just far enough apart to be distinguished as separate.

The maximum resolving power of a telescope, that can be theoretically attained when the optical parts are perfectly designed and perfectly placed, depends entirely on the diameter of that part of the objective lens actually used (the effective aperture). The resolving power of the objective lens is entirely independent of magnification. It can be computed as follows:

$$R = 4.6''/D$$

where R is the angle in seconds that can be resolved and D is the diameter of the effective aperture of lens in inches. For example, the objective lens of the K&E Jig Transit has an effective aperture of 1.18 inches in diameter. The resolving power is therefore 3.9 seconds.

On the other hand, the accepted standard for the resolving power of the human eye is limited to 60 seconds. Therefore the resolving power of the telescope has to be brought within the range of the human eye by magnification. For this reason the 3.9 seconds angular distance resolved by the telescope must be magnified by a ratio of 15 to bring it up to the resolving power of the human eye, which is 60 seconds. Accordingly the value of the magnification is computed by the formula $60/R = 15$, so the magnification must be at least 15. But since the eyesight of different observers varies, more magnification is invariably used.

Magnification. The value of *magnification* or *power* is the apparent size of an object viewed through a telescope divided by the size it appears to the unaided eye from the same distance. Magnification varies slightly when the focus of the telescope is changed and therefore is slightly affected by the distance of the object. For any telescope, the greatest magnification occurs at infinite focus. The magnification at infinite focus is usually the value given when the magnification of a telescope is stated.

While in every telescope M, magnification, must be greater than $60/R$, there is a point beyond which it is impossible to increase magnification without sacrificing definition. This point is passed when M becomes greater than two or three times $60/R$. If magnification is increased beyond this point, the quality of the image seen is impaired and the accuracy by which the line of sight and a target can be made to coincide is reduced. Instead, it is much more important to use properly designed targets or scales. See page 4-3.

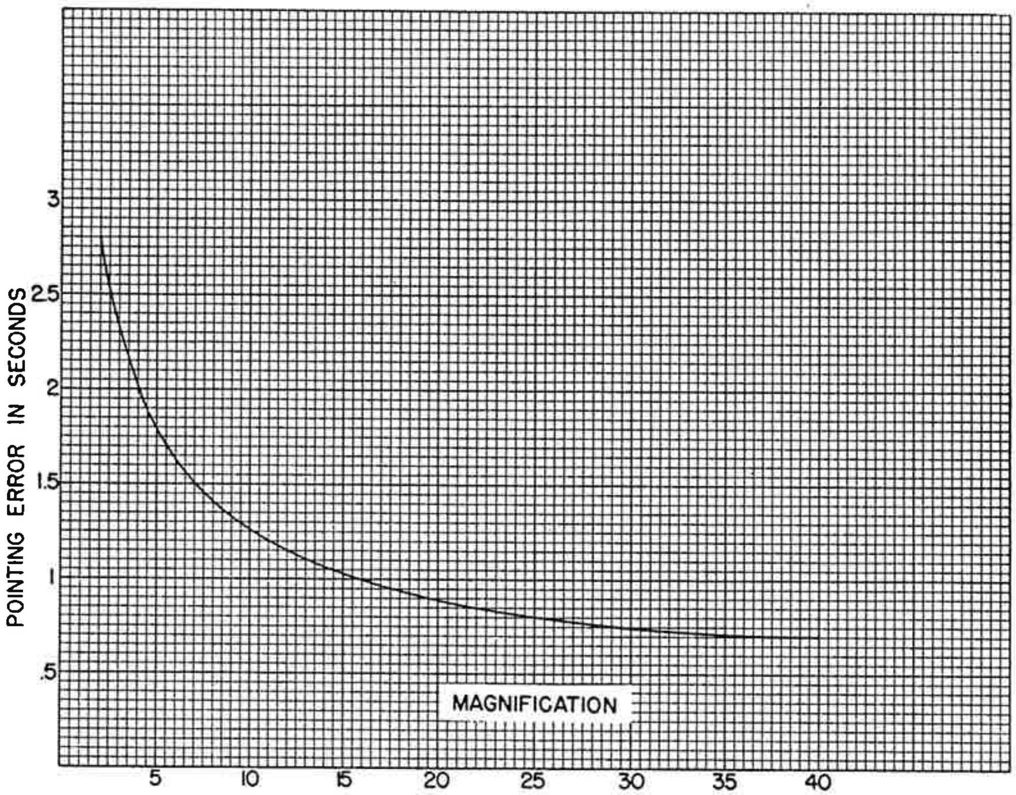
There are certain disadvantages to the use of too high a magnification, even when the objective lens is large enough to give the necessary resolution. With high magnification, the field of view is reduced, and any heat waves, turbulence or vibration cause the image to move over the cross lines too fast for accurate observation.

Definition. Definition is an overall term used to define the results produced by a telescope. The better the definition, the better can objects be seen through the telescope. It depends on a great many optical features and it is the quality that gives the greatest pointing accuracy.

As definition is a relative term, it can be best determined by comparing the appearance of the same object when viewed through the telescope to be tested and a telescope with which the observer is familiar.

Pointing Accuracy. The accuracy of pointing can be defined as the accuracy with which the line of sight can be directed toward a target, or a target can be placed on the line of sight. It depends on magnification, but chiefly on definition, the arrangement of the cross lines, and the design of the target sighted.

It has been found that the best target is a white space between two black lines or areas. The ob-



server places the cross line in the center of the white space. He can do this much more accurately than he can place the cross line on a single black line. When he is judging the center of the white space, he sees a long, narrow strip of white each side of the cross line and he regulates the aim of the telescope until the two white strips are equal in width. It has been found that an observer can do this with great accuracy even when the white space is quite wide. It is essential, however, that the two white strips be fairly long and uniform in width.

Pointing accuracy is greatest when the white strips are as narrow as possible but still wide enough to be seen clearly. Accordingly, a target should be designed so that it presents a series of narrow white spaces of different widths so that the best width for any length of sight can be chosen.

The series of paired black lines (or areas) on a K&E target are spaced so that, at whatever distance the target is observed, at least one white space will be of such a width that it subtends an angle of between 8 and 21 seconds of arc. The error of pointing within this range of sizes is exceedingly small. Careful tests have shown that, with a good telescope, when the white space is in the range of 8 to 21 seconds wide, the error of pointing is less than 0.5 second of arc in 19 out of 20 observations.

Pointing Accuracy versus Resolution. The question is often raised, "How can the error of pointing be so much less than the value of the resolution?" The two depend on entirely different human visual abilities. Pointing depends on the ability to balance two white spaces; resolution depends on the ability to distinguish the separation between closely spaced lines. Resolution is important in pointing only as a measure of how small a white space on each side of the cross line can be clearly seen.

While the design of K&E targets is based on very careful tests of actual targets, it is possible to prove from the theory involved that the 8 second minimum width gives white spaces that can be clearly seen and therefore accurately bisected.

According to the U. S. Bureau of Standards specifications, the resolution of a telescope is tested by observing sets of parallel lines at different spacings. In each set the spacing is uniform and the black lines have the same width as the spaces between them. The observer chooses the set with smallest spacing in which he can distinguish lines rather than a gray color. The angular separation between the centerlines of adjacent black lines on that pattern is the value of the resolution.

According to this test, for example, the K&E Jig Transit has a resolution of 4.5 seconds, somewhat poorer than the value of 3.9 seconds derived theoretically. Since the angular separation between the centerlines of the black lines in this case is 4.5 seconds, the width of the white spaces is 2.25 seconds.

On most instruments the cross line has a width of between 2.5 and 3.0 seconds. On a target with a white space of 8 seconds, the remaining 5 to 6 seconds is divided between the two white spaces, which must therefore be 2.5 to 3.0 seconds in width. Since a white space of 2.25 seconds can be distinguished, a space having a width of 2.5 to 3.0 seconds can easily be seen.

Thus, with an instrument having a resolution of 4.5 seconds, an observer can easily see white lines on each side of the cross line when the target has a white space of only 8 seconds. It is certainly not difficult to believe that he can place the cross line so that the two spaces are balanced better than to 2.5 seconds on one side and 3.5 seconds on the other. If he can do this his error is less than 0.5 second.

Pointing Accuracy versus Magnification. Magnification increases pointing accuracy very much at first, but as the magnification is increased this effect is less. The chart shows the general relationship between the two. For any combination of telescope and target, the curve would have a similar shape but not exactly the same values.

FEATURES OF K&E INSTRUMENTS

The features and qualities of K&E Surveying Instruments are well known to the engineering and surveying professions. These same features and qualities are carried into this line of Optical Tooling equipment. A few of these K&E features which should be particularly noted, are: high resolving power and excellent definition, leveling screws and tangent screws that have threads which are made to the tolerances of micrometer screws; draw tubes and centers that are chrome plated; telescopes that are completely sealed against dust and moisture; level tubes that are kinematically supported.

THE IMPORTANCE OF CORRECT FOCUSING

It is particularly important when using telescopes in optical tooling to eliminate any parallax that might result from faulty focusing of either the eyepiece or the objective.

The objective lens of a telescope should form a small inverted image on the plane of the cross lines. The eyepiece is a microscope that magnifies this image along with the cross lines. It usually erects the image as well. It is essential that the image be exactly focused on the plane of the cross lines. If it is not, when the eye is moved slightly up and down or left and right, the cross lines will apparently move over the image and thus destroy the accuracy of the sight. This condition indicates *parallax* between the cross lines and the image.

The eyepiece is first adjusted according to the natural focus of the eye of the observer until the cross lines appear sharp and clear. While making this adjustment, the observer should hold a white card in front of the telescope, slanted so that it throws light into the lens.

The instrument is then aimed at the object to be sighted and the main focus is regulated until parallax is eliminated. Turning the focusing knob actually moves the image back and forth in the telescope. If, when the parallax is eliminated, the image is not clear, the observer has changed the focus of his eye. The eyepiece should then be slightly refocused.

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ALIGNMENT TELESCOPES

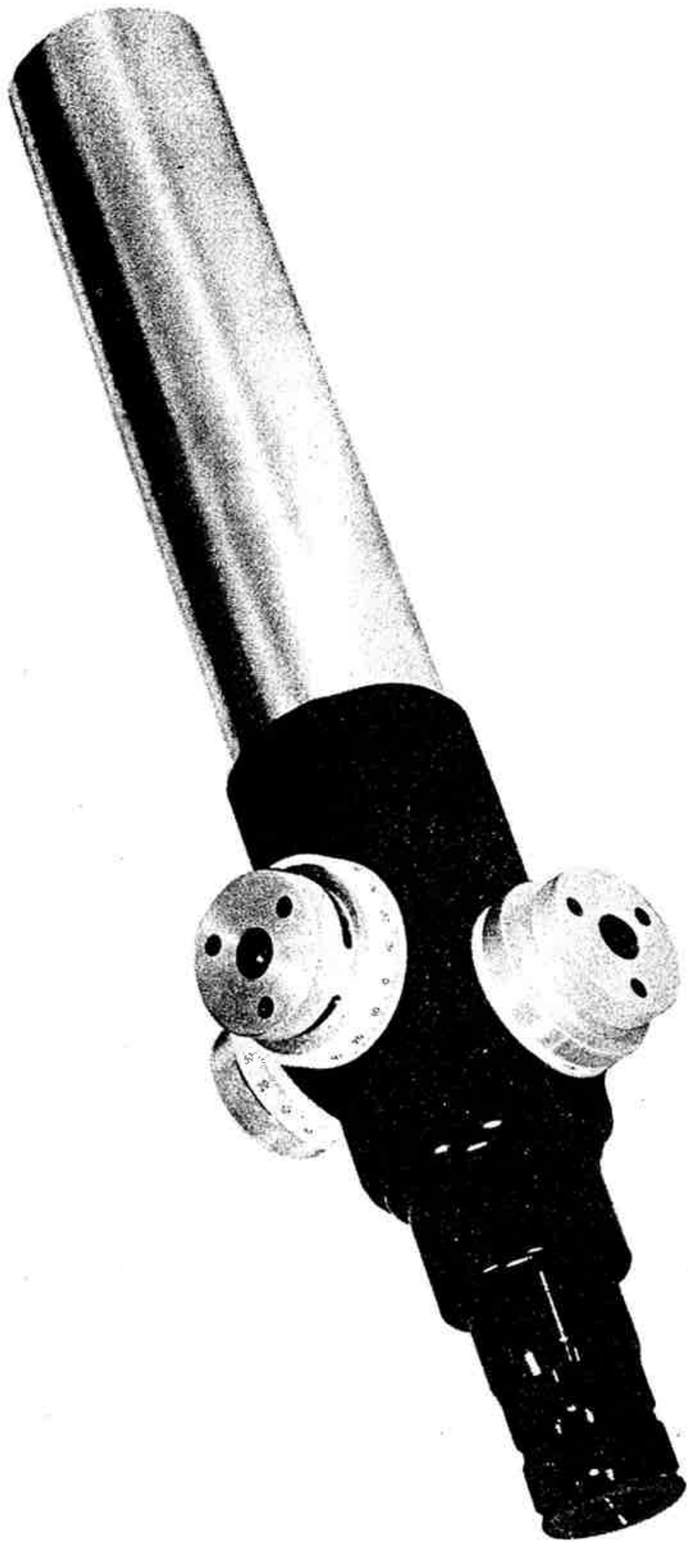


Fig. 1. **The K&E Jig Alignment Telescope (without sphere). Built-in optical micrometers, which provide vertical and horizontal parallel displacements of the line of sight. The heavy walled telescope barrel is made of hardened stabilized tool steel with a hard chrome surface. An auto-reflection target pattern is on the rear surface of the objective lens. An eyepiece with a built-in auto-collimation illumination unit can be provided.**

K+E

JIG ALIGNMENT TELESCOPES

No. 9092-2	(Without Sphere)
No. C9092-2*	(Without Sphere, with built-in Auto-Collimation Illumination Unit)
No. N9092-2*	(Without Sphere, with built-in Auto-Reflection Target)
No. CN9092-2	(Without Sphere, with built-in Auto-Reflection Target, with built-in Auto-Collimation Illumination Unit)
No. 9092-2½	(With Sphere permanently attached)
No. C9092-2½*	(With Sphere permanently attached, with built-in Auto-Collimation Illumination Unit)
No. N9092-2½*	(With Sphere permanently attached, with built-in Auto-Reflection Target)
No. CN9092-2½	(With Sphere permanently attached, with built-in Auto Reflection Target, with built-in Auto-Collimation Illumination Unit)

The K&E Alignment Telescope (see Fig. 1), specially developed for Optical Tooling, has several unusual features.

It, of course, conforms to the standards of the Aircraft Industry Association. These include: accuracy, concentricity of line of collimation, outside diameter of the telescope and size of sphere.

The optical system is based on an entirely new K&E design, for which a patent is pending. The telescope can be focused all the way from infinity back to a point *actually in contact with the front end of the telescope.* This means that it can be mounted with the minimum space requirement. It can usually be mounted directly within the jig frame—a safer and more stable position and one that involves less floor space. Moreover, it is never necessary to interchange the positions of the target and the instrument.

The optical micrometers (horizontal and vertical) are built right into the telescope.

The image is especially bright and clear with excellent definition. Coated optics are used throughout.

Other optical features include:

Field of view about 30 minutes at infinity focus.

Resolving power 3.4 seconds (according to the Bureau of Standards' test procedure).

Magnification varies automatically from approximately 4 power at zero focus to 46 power at infinity focus.

Open cross line pattern for reticule.

90° prismatic eyepiece attachment that can be rotated through 360°.

The field of view increases in angular value as the point focused is moved toward the instrument, so that the actual size of the field of view is approximately the same at all working distances. This makes it easier to place a target in the field of view near the instrument.

The telescope barrel is made of hardened stabilized tool steel with a hard chrome surface. It is cylindrical in shape for a length of 9-3/16" from the front end to a shoulder. The entire instrument is about 17-3/4" long when the eyepiece is fully extended.

The instrument is furnished either without the sphere so that it can be used in special fixtures, or with the sphere permanently attached so that there is no possibility of introducing strain. The centerline of the sphere is 7-1/8" from the shoulder.

For the Jig Alignment telescope that has no sphere, K&E supplies a spherical adapter that slides over the telescope tube. It is held in any position desired by a contracting ring that does not change the centering. It gives greater flexibility than the permanently attached sphere for positioning the telescope to clear jig parts. For further description see page 7-3.

* To order only.

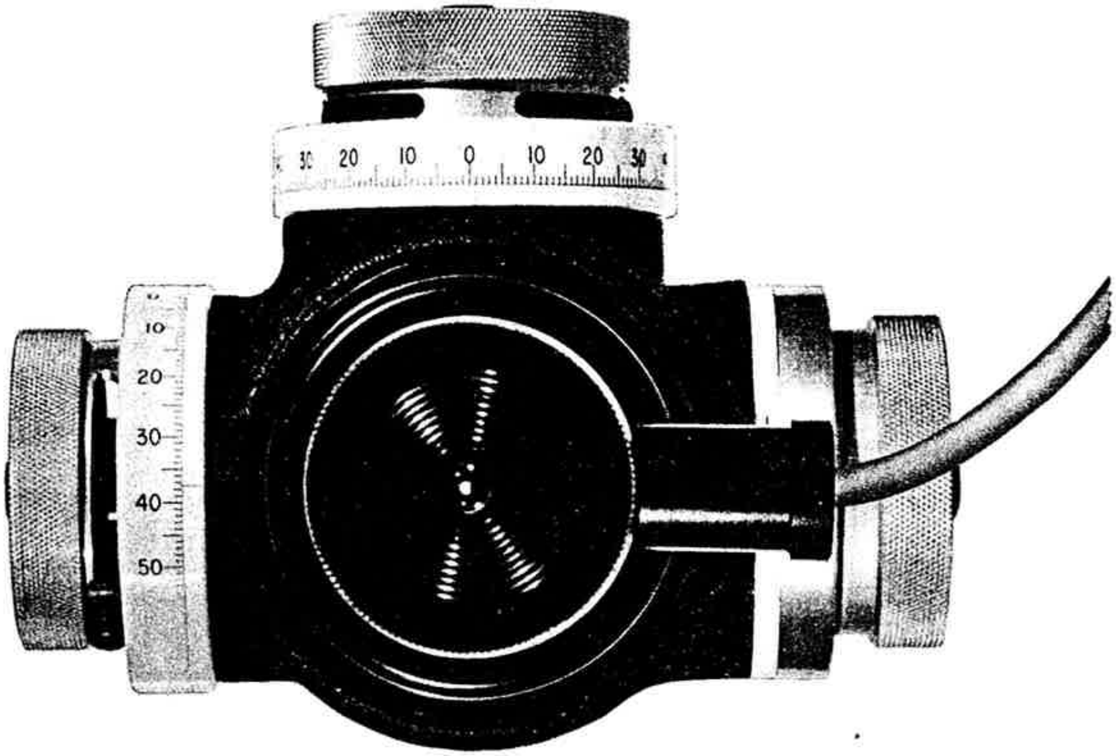


Fig. 2. What the operator sees. The upper knob raises and lowers the line of sight. The left hand knob moves it left and right. The scales give the movement in thousands of an inch. The right hand knob (slightly nearer the eyepiece) focuses the instrument.

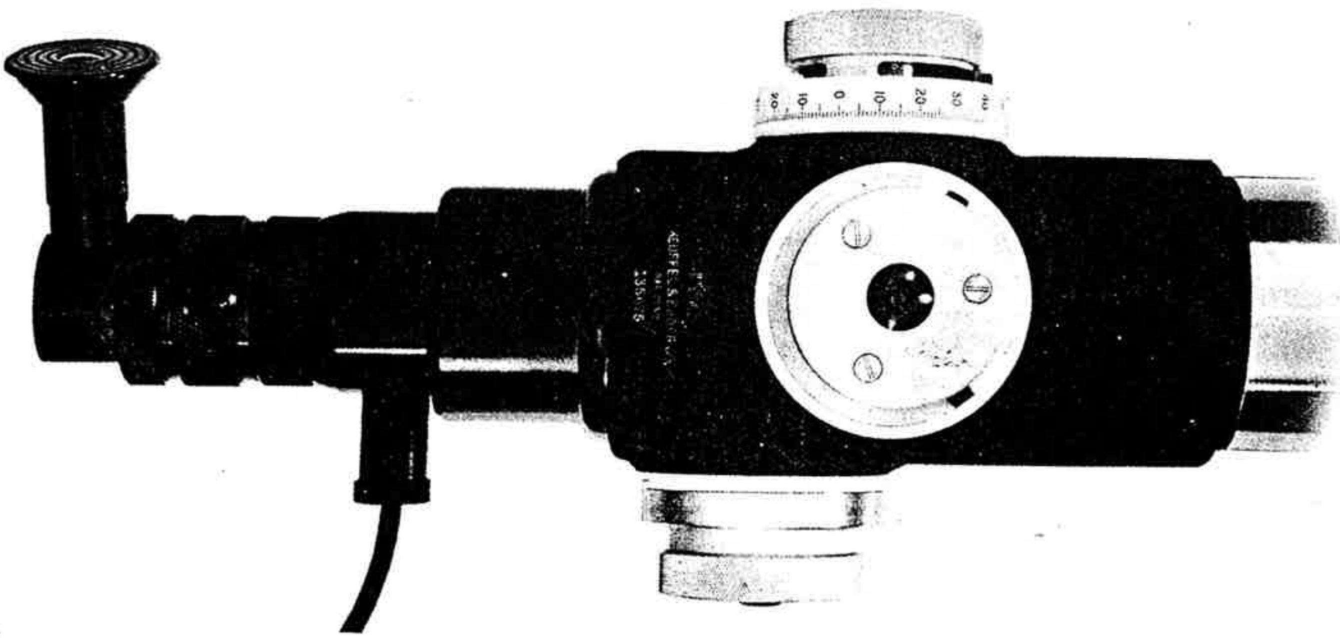


Fig. 3. The Jig Alignment Telescope fitted with a right angle eyepiece attachment arranged so that the operator can look sideways into the instrument. The attachment can be rotated through 360°. The rear knurled ring is for attaching the right angle eyepiece to the telescope. The middle ring is for focusing the eyepiece. The forward ring locks the eyepiece focusing mechanism in place. The auto-collimation illumination unit is shown inserted in the eyepiece.

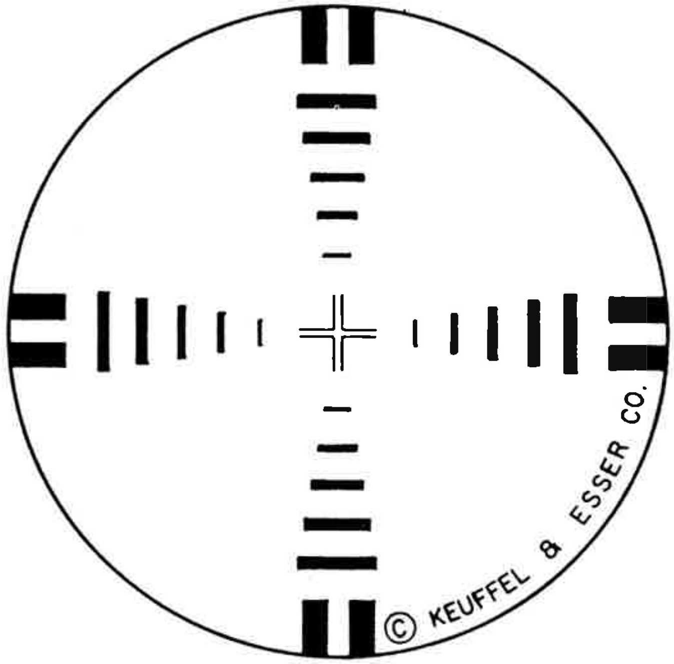


Fig. 3a. **Bar Pattern of built-in Auto-Reflection Target.**

The micrometer hand knobs are located so that their axes are vertical and horizontal, that is, in line with the cross lines on the reticule. There is never any doubt as to which to use. The micrometer drums are graduated to read to 0.001 inch and they read from 0 to plus and minus 50 thousandths of an inch. Adjustable tolerance stops are provided. See Fig. 2. The greatest allowable overall error in the run of the micrometer from -0.050 to +0.050 is ±0.0002 inch. The maximum permissible backlash in the micrometer is 0.0001 inch.

The focusing knob is set back away from the optical micrometer knobs for the observer's convenience and to avoid confusion with the other knobs.

The right angle eyepiece attachment, see Fig. 3, makes it possible to mount the instrument at floor level or with the eyepiece almost against a wall or other obstruction. The eyepiece focusing mechanism is equipped with a lock ring so that the focus adjustment will not be disturbed as the right angle eyepiece attachment is rotated.

Built-In Auto-Reflection Target and Auto-Collimation Illumination Unit. The instrument is also regularly furnished with an auto-reflection target built in, and with a built-in Auto-Collimation Illumination Unit. The target is on the inside surface of the objective lens. The Illumination Unit is built into the eyepiece. The light source, which may be removed when desired, is operated on any 110 volt circuit. With this combination the instrument is designated: Alignment Telescope CN9092-2 (or CN9092-2½ if the sphere is permanently attached). The purposes of auto-reflection and auto-collimation are described on page 1-9.

The instrument may also be furnished to order with only the built-in Auto-Reflection Target (N9092-2 or N9092-2½), or with only the built-in Auto-Collimation Unit (C9092-2 or CN9092-2½).

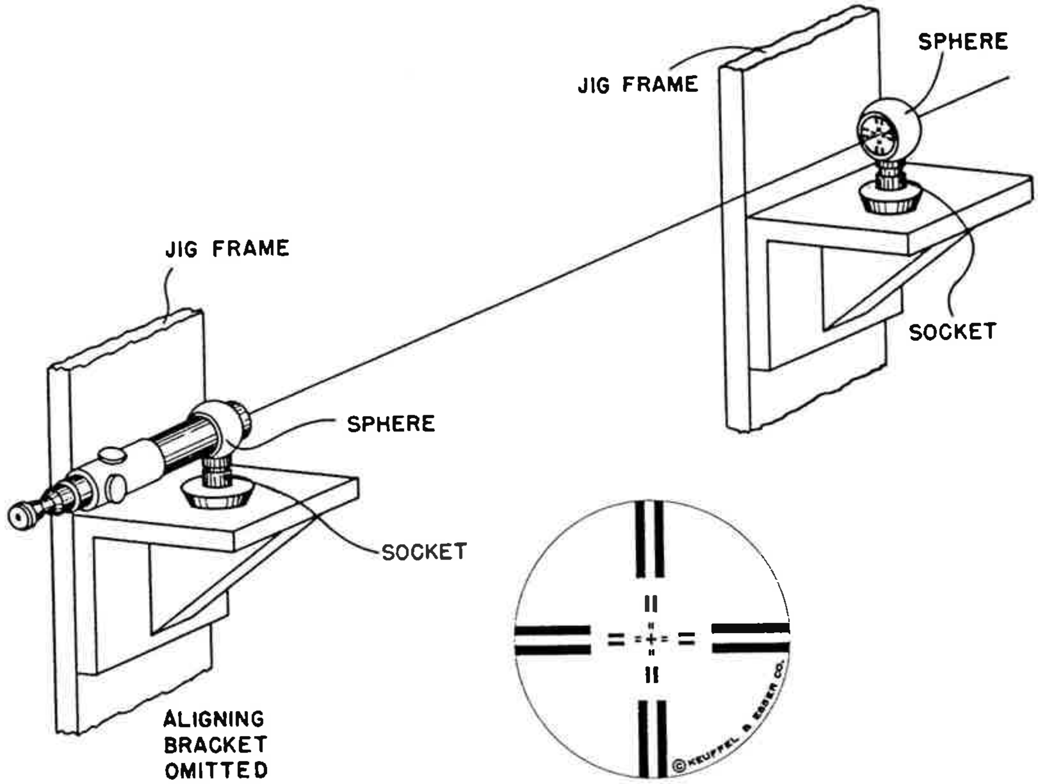


Fig. 4. **The alignment telescope and target establish a long, permanent absolutely straight reference line. Since the sockets are attached permanently, the telescope and target can be removed and replaced repeatedly, but the reference line remains in the same position.**

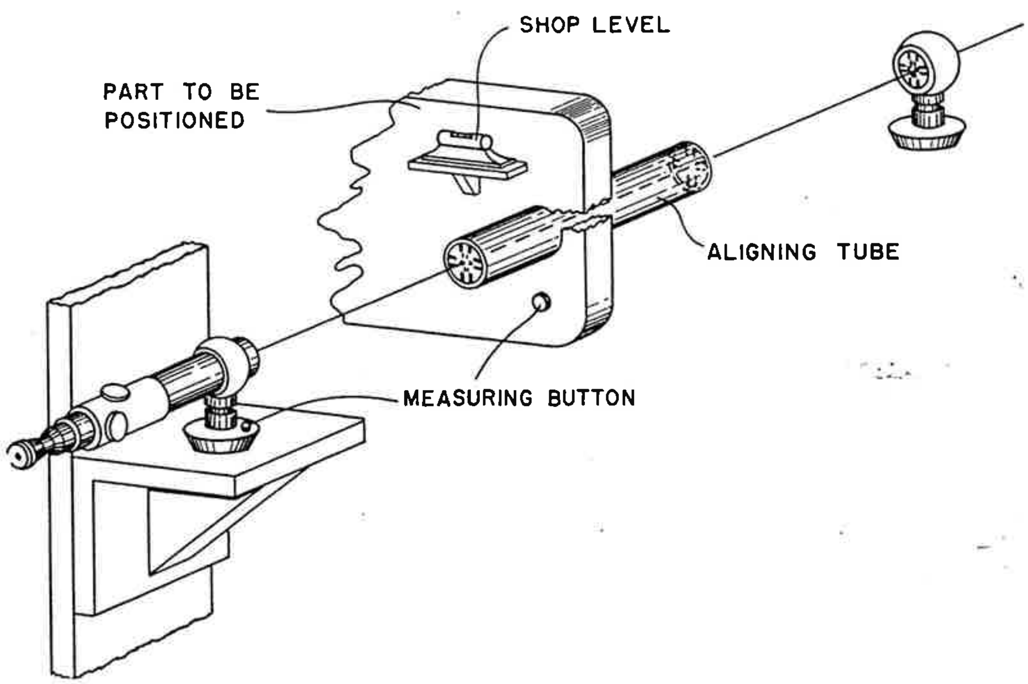


Fig. 5. **Positioning by two targets in line and a shop level.**

USE OF JIG ALIGNMENT TELESCOPE

Principle: The jig alignment telescope provides a long, straight, *permanent* optical reference line of great accuracy on a jig or on any structure where measurements are to be made. A bracket to support a socket mounting base is built at each end of the jig. The telescope, mounted in a sphere, is held in one socket, and a target, centered in another sphere, is held in the other. A special device with adjusting screws, called an aligning bracket, is provided for aiming the telescope. When the cross lines of the telescope are brought on the target, the optical reference line is established. See Fig. 4. As long as the sockets remain on the jig this line can be reestablished whenever desired.

The sockets have adjustable mounts by which the line of sight is originally positioned. Accurate positioning is necessary only when more than one line of sight is to be used or the line of sight is to be level.

It is usually convenient to set the line of sight exactly level. A sphere with a target is placed in each socket and one of the sockets is adjusted until the two targets are at exactly the same elevation. The relative elevation is determined with a precise level. See the description of the K&E Tilting Level P5022. One of these targets is then replaced with the jig alignment telescope, which is tilted until the other target appears to coincide with the reticule of the jig alignment telescope, when the micrometers are set at zero. The line of sight is usually placed so as to establish a waterline or a centerline, or a line parallel to them.

The line of sight is picked up wherever desired by targets. A target consists of a glass circle mounted in a steel ring ground to a given diameter. On the glass is a design that marks the center of the ring and sometimes contains scales that give distances from the center. It is usually illuminated from behind. Station positions (distances parallel to the line of sight) are measured with a tape, or an inside micrometer with measuring rods from a reference button (usually on the socket support) to a reference button on the part to be positioned.

TO POSITION A PART

Two Targets in Line: When a small jig part is to be positioned on or near the line of sight, it is built with a bracket to hold a square-setting aligning tube, which has two targets at different stations along the line of sight, also with a bracket to hold a shop level perpendicular to the line of sight, and a button to give the correct station. See Fig. 5. The part is positioned by adjusting it until the two targets are both on line, the shop level bubble will center when placed on the bracket, and the button is at the correct station. When the part is off the line of sight and sometimes for other reasons, a special *facility gauge* is made to hold the targets so that the part is correctly positioned.

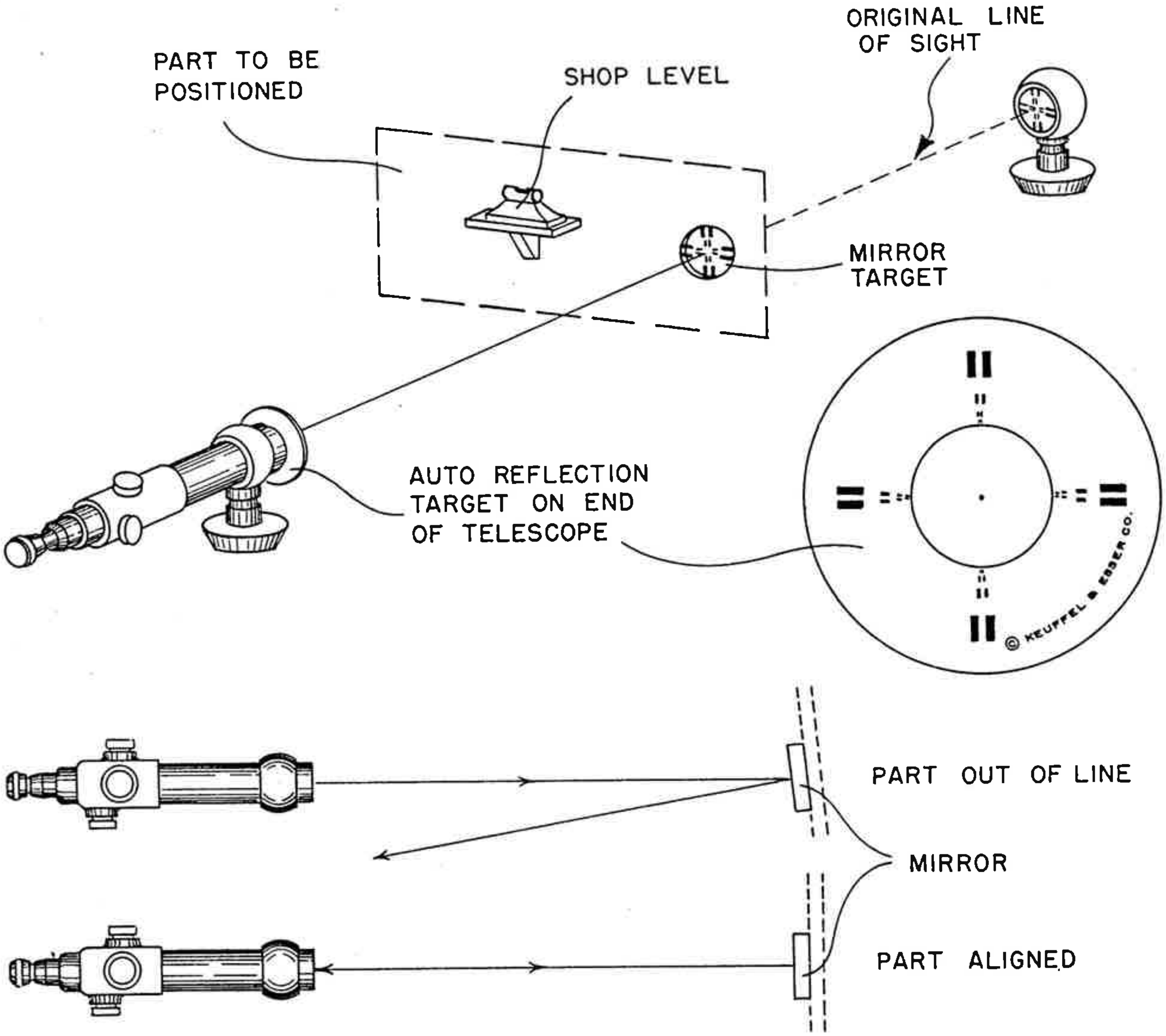


Fig. 6. **Positioning by auto-reflection and a shop level.**

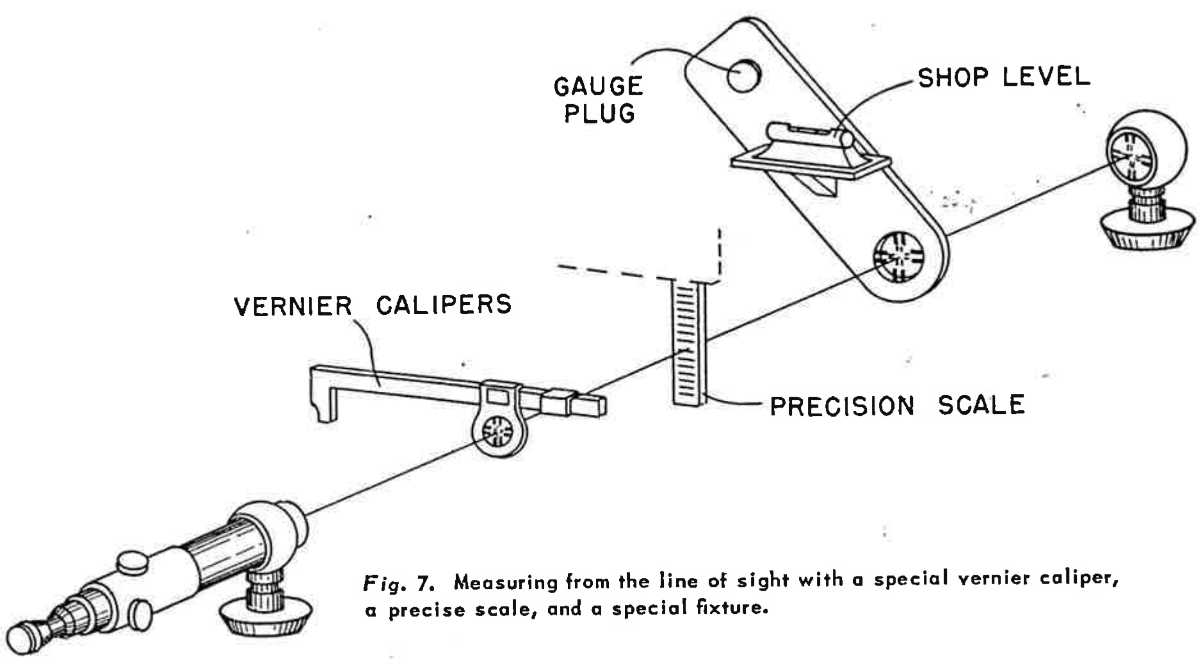


Fig. 7. **Measuring from the line of sight with a special vernier caliper, a precise scale, and a special fixture.**

Auto-Reflection: When greater angular accuracy is necessary, an optically flat target-mirror is mounted on the part to be positioned so that its reflecting surface is parallel to the proper reference plane on the part and where it will be in the line of sight of the alignment telescope. The part is positioned by placing the target-mirror on line and the button at the proper station and then turning and tilting the part until the cross lines in the alignment telescope appear to coincide with the image of a target mounted on the end of the telescope, or on the inside surface of the objective (see page 1-5), reflected back through the telescope from the target-mirror. See Fig. 6.

When several points must be set at some distance off the line of sight, an optical plane must be established at a known station at right angles to the line of sight. This is accomplished by auto-reflection with a jig transit or a device based on a pentaprism, called an optical square (see pages 2-3 and 15-2).

Auto-Collimation. Auto-collimation is similar to auto-reflection but more accurate. In auto-reflection the line of sight is aimed at the reflection of a target. In auto-collimation the line of sight is aimed at the reflection of the cross lines of the telescope itself. To use an instrument in this way, it is necessary only to direct a small amount of light on the cross lines. The telescope is focused at infinity so that its reflection is really a collimator. And, since the telescope is focused at infinity, the cross lines of the collimator are in focus. When the mirror is adjusted so that the reflection of the cross lines falls on the cross lines themselves, its surface must be perpendicular to the line of sight. When a target is used in auto-reflection, there is always the possibility that it may not be exactly centered on the line of sight and thus may introduce a slight error. Moreover, as auto-reflection is used to establish a series of parallel planes, a slight error may be introduced if there is any curvature in the line of sight of the sighting telescope when it is focused at different distances. In auto-collimation, the sighting telescope is always focused at infinity and therefore there can be no curvature in the line of sight due to focusing.

To Measure from the Line of Sight: When the optical micrometer knobs of the Jig Alignment Telescope are turned the line of sight is moved parallel to itself by the number of thousandths of an inch shown on the graduated drums. On the K&E instrument, horizontal motion results when the knob with the horizontal axis is turned. Vertical motion occurs when the knob with the vertical axis is turned. Thus, there is little chance of confusing the knobs. Optical micrometers are used to measure distances to thousandths of an inch. They are often used to measure any error in positioning a target and thus to check against tolerances. Tolerance stops are provided for repeated checking of the same tolerance. Under most circumstances, measurements of distances greater than the range covered by the micrometers should be made from the line of sight with a K&E precision scale.

Measurements can also be made from the line of sight with a special vernier caliper or a special height gauge that has a target attached to the movable section. Sometimes a target is placed on the line of sight and the measurements are made with an inside micrometer and measuring rods. Often a special device is built with a target at one end, a measuring button on the other end at a predetermined distance from the target center, and with a bracket to hold a shop level. The bracket that holds the shop level can be placed so that the measurement will be made vertically, horizontally or at any desired angle in a plane perpendicular to the line of sight. See Fig. 7.

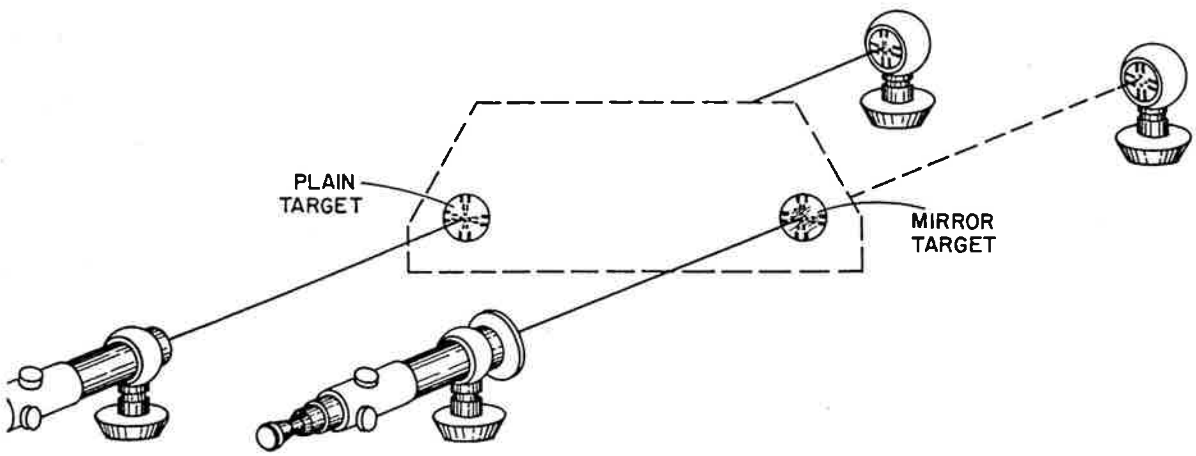
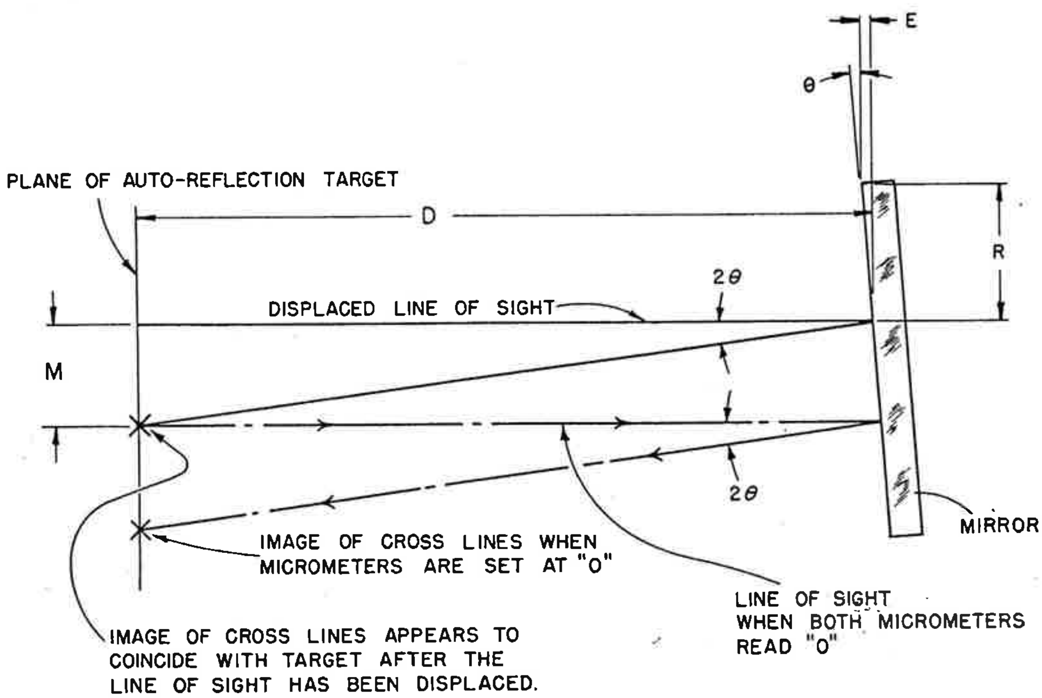


Fig. 8. **Positioning by two lines of sight, a mirror target and a plain target.**



$$\text{TAN. } 2\theta = \frac{M}{D}$$

$$\text{TAN. } \theta = \frac{M}{2D}$$

$$\text{BUT TAN } \theta = \frac{E}{R}$$

$$\therefore \frac{E}{R} = \frac{M}{2D}$$

$$\text{AND } E = \frac{RM}{2D}$$

Fig. 9. **Theory of measuring station error by optical micrometer when auto-reflection is used.**

Two Lines of Sight: Frequently two lines of sight are used. This eliminates the need for a shop level. Each part is provided with two target positions, one for each line of sight. One mirror-target and one ordinary target are used. The mirror-target establishes the angular relationship with respect to the line of sight by auto-reflection. The two targets together establish the transverse positioning of the part and its angular position in the plane perpendicular to the two lines of sight. See Fig. 8.

The lines of sight must be carefully set parallel to each other and at exactly the required separation. Sometimes they are placed vertically above and below each other but more often they are placed at the same elevation. Usually a special gauge is made with two targets to space the lines. These targets can be placed in line above and below each other with a jig transit and they can be made level with each other with a precise level. See Fig. 9.

When auto-reflection is used, the micrometers will measure the station error E of a point at a distance R from the line of sight. See Fig. 9

$$\text{Error} = \frac{R}{2D} M$$

where R is the distance in inches of the point from the line of sight,

D is the distance in inches from the station of the reflecting surface of the mirror to the station of the telescope target of the telescope,

M is the micrometer reading in inches, or the amount the line of sight is displaced.

The following two examples illustrate the practical utility of this formula:

1. If it is required that each point on a part be positioned to a given station tolerance, the station error of each point can be determined by the above formula and compared with the tolerance. Of course this procedure requires that the part itself be accurately made.

2. If a part is correctly located along the line of sight, but is inclined to the perpendicular plane, the above formula can be used to calculate how much a point on the part of the axis should be moved in order to tilt the part to bring it into its proper position. The angular position of the part may then be rechecked by looking through the alignment telescope with the micrometers reading zero and if necessary, the procedure can be repeated to further correct the angular position of the part.

On page 1-12 is a table which shows how the built-in Auto-Reflection Target can be used to check whether the tilt of a part is within tolerance.

USE OF BUILT-IN AUTO-REFLECTION TARGET, BLOCK PATTERN AS TOLERANCE TARGET

TARGET LINE NUMBER \ LENGTH OF SIGHT ✱	TILT OF PART (MIRROR) IN INCHES PER FOOT WHEN CROSS-LINE IS ALIGNED WITH EDGE OF TARGET LINE AT A DISTANCE OF 5'	10'	20'	40'	60'	80'	100'	150'
1	.0012	.0006	.0003					
2	.0023	.0012	.0006	.0003				
3	.0059	.0030	.0015	.0007	.0005	.0004	.0003	.0002
4	.0356	.0178	.0089	.0045	.0030	.0022	.0017	.0012
5	.0474	.0237	.0118	.0059	.0040	.0030	.0023	.0016
6	.0534	.0267	.0134	.0067	.0045	.0034	.0027	.0018
7	.0653	.0326	.0163	.0082	.0054	.0041	.0033	.0021
8	.0712	.0356	.0177	.0089	.0059	.0045	.0036	.0023
WITH MICROM. AT .050" & CROSS-LINES CENTERED ON AUTO REFLECTION TARGET, THE TILT WOULD BE IN INCHES PER FOOT	±.0051	±.0026	±.0013	±.0006	±.0004	±.0003	±.00026	±.00017

EXAMPLE: WITH PART 10' FROM OBJECTIVE, MICROMETER AT .030" & CROSS-LINE CENTERED ON TARGET, TILT WOULD BE $\frac{.030}{.050}$ x .0026"=.0016"/FT.

TILT OF PART (MIRROR) IN INCHES PER FT. CAN BE OBTAINED FOR ANY DISTANCE FROM THE FOLLOWING FORMULAS:
D = DISTANCE FROM OBJECTIVE TO MIRROR

LINE 1 TILT = $\frac{.0059}{D}$

LINE 2 TILT = $\frac{.0118}{D}$

LINE 3 TILT = $\frac{.0297}{D}$

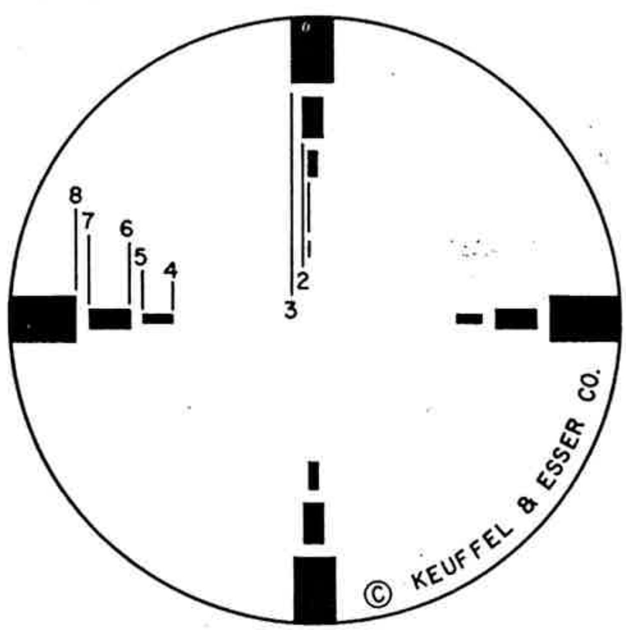
LINE 4 TILT = $\frac{.1780}{D}$

LINE 5 TILT = $\frac{.2372}{D}$

LINE 6 TILT = $\frac{.2672}{D}$

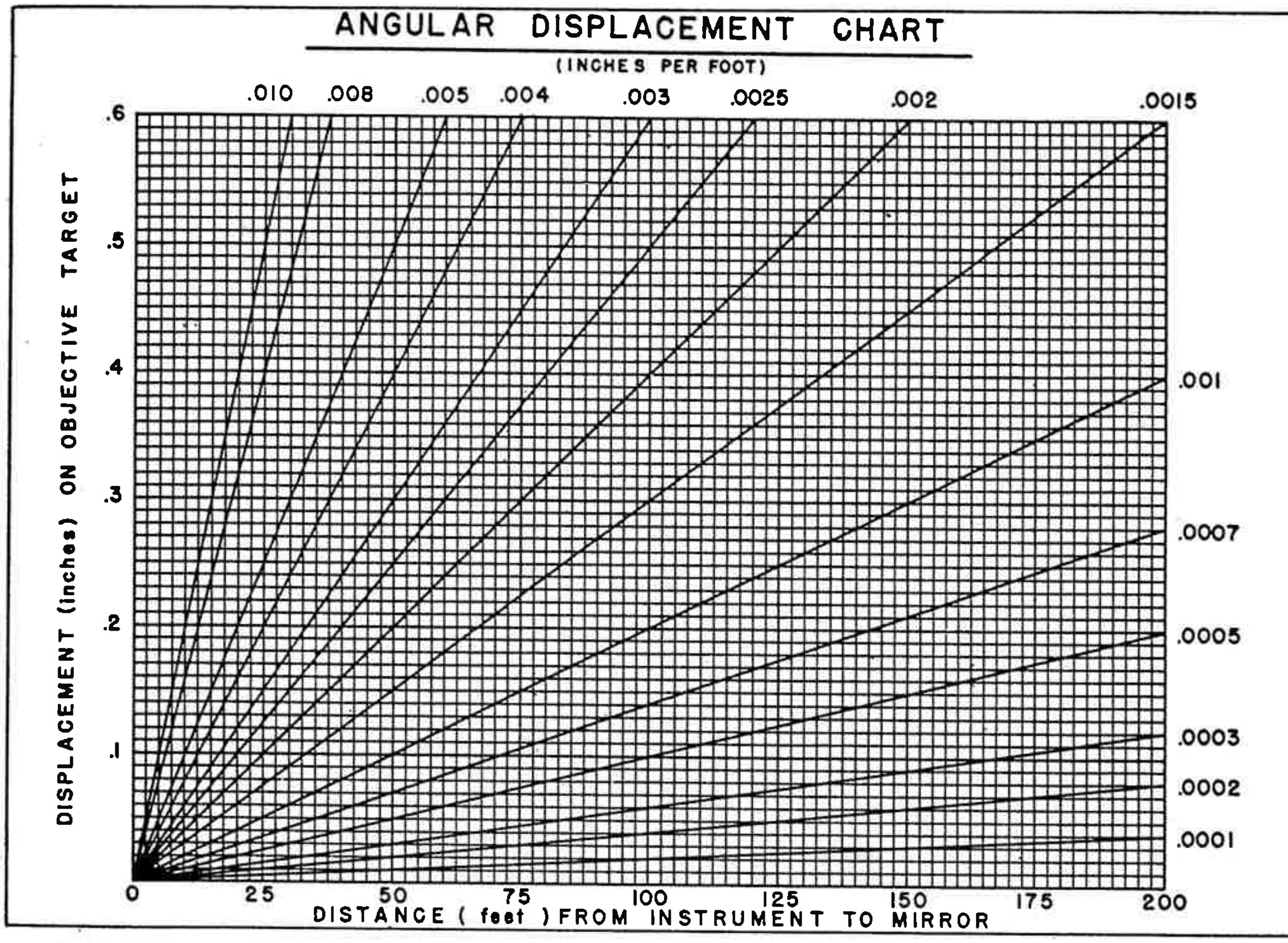
LINE 7 TILT = $\frac{.3264}{D}$

LINE 8 TILT = $\frac{.3560}{D}$



✱ DISTANCE FROM INSTRUMENT TO MIRROR

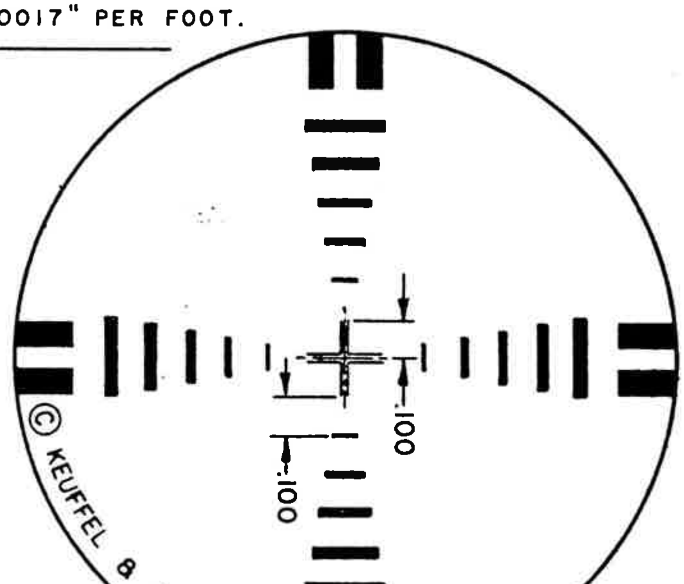
USE OF BUILT-IN AUTO-REFLECTION TARGET, BAR PATTERN, AS TOLERANCE TARGET.



EXAMPLE: IF THE DISPLACEMENT READ ON THE TARGET AND MICROMETER IS .250" AND THE DISTANCE FROM THE INSTRUMENT TO THE MIRROR SURFACE IS 75', THE TILT OF THE MIRROR TO A LINE 90° TO THE LINE OF SIGHT IS .0017" PER FOOT.

TARGET PATTERN

ALL LINES ON THE TARGET ARE SPACED .100" CENTER TO CENTER. THUS, DISPLACEMENT FROM THE CENTER CAN BE DETERMINED TO .001" OVER A RANGE OF ± .600" BY USING THE TARGET PATTERN AND MICROMETERS OF THE INSTRUMENT.



K+E

JIG TRANSIT

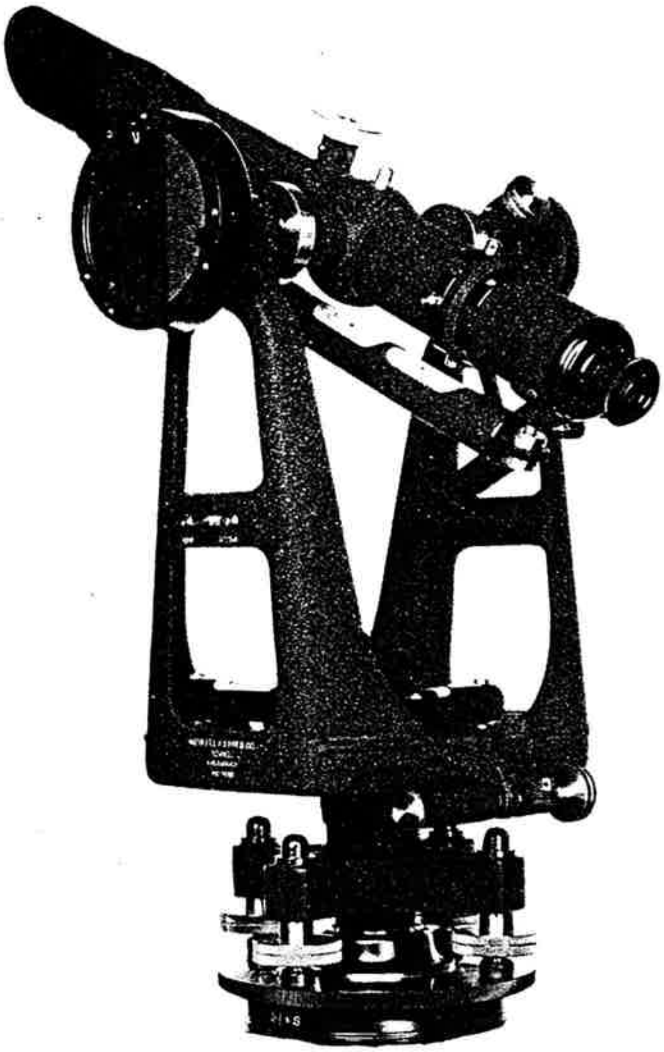


Fig. 21. **The K&E Jig Transit. The axle mirror is in position at left. Note the measuring button (optional at additional charge) on the cross bar of the standard. U. S. standard 3½ x 8 thread base.**

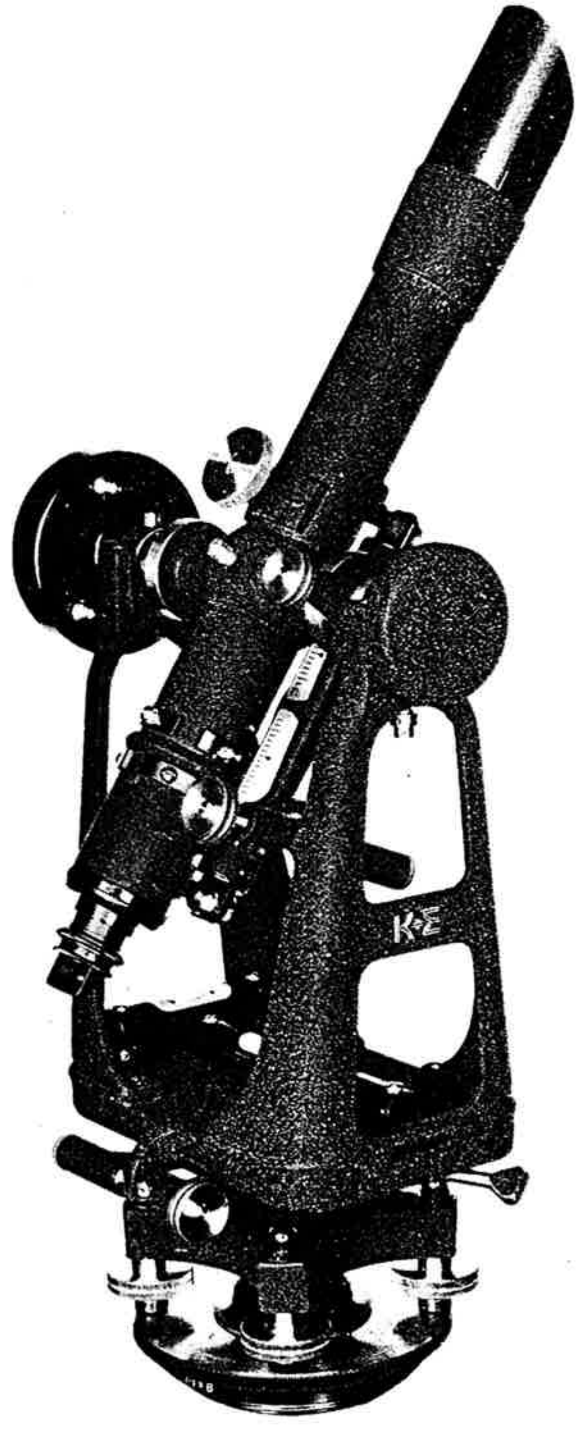


Fig. 22. **The right-hand side of the Jig Transit showing the counterweight. The prismatic eyepiece is arranged for high-angle sights.**

K+E

JIG TRANSIT
9092-1

The K&E *Jig Transit* is designed especially for optical tooling. (See Fig. 21). Its basic operation and functions are those of a transit, but it has a number of special features essential to optical tooling. These are described below.

1. ***Precise Plate Level.*** The instrument has two plate levels for quick set-ups. The plate level that is perpendicular to the telescope is as long and as sensitive as the usual transit telescope level. See Fig. 22. When its bubble is centered, the vertical plane established by the line of sight is vertical. With this arrangement, the slow process of leveling with the telescope level is eliminated. Since an instrument must be leveled many times while it is being bucked in, this is a great time-saver.

2. ***Special Telescope.*** The telescope has a minimum focus of 3 feet from the instrument center, instead of the usual 5 feet for transits, and it has the great advantage of an erecting eyepiece.

The specifications for the telescope are as follows:

Magnification	24 x
Resolving Power*	4.5 seconds
Effective Aperture	1.18 inch
Field (at infinity focus)	1° 10'

*According to Bureau of Standards Test procedures.

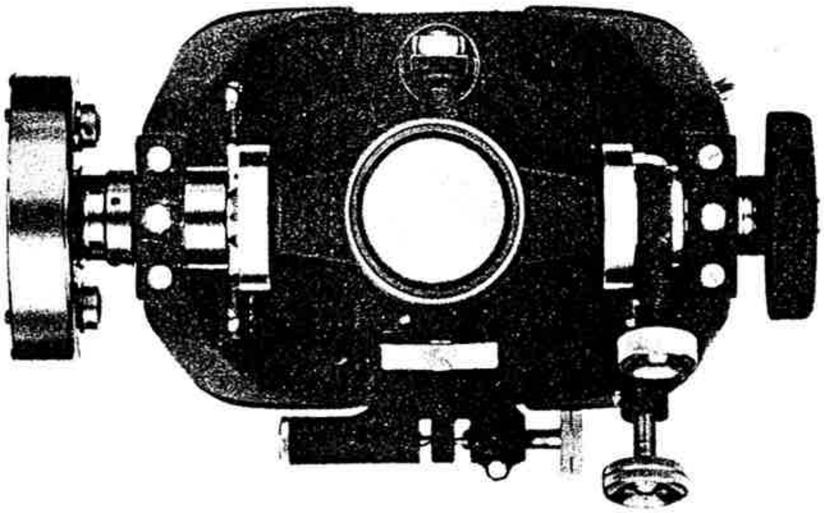


Fig. 23. Top view of the Jig Transit. Note the large objective and the collars for the striding level.

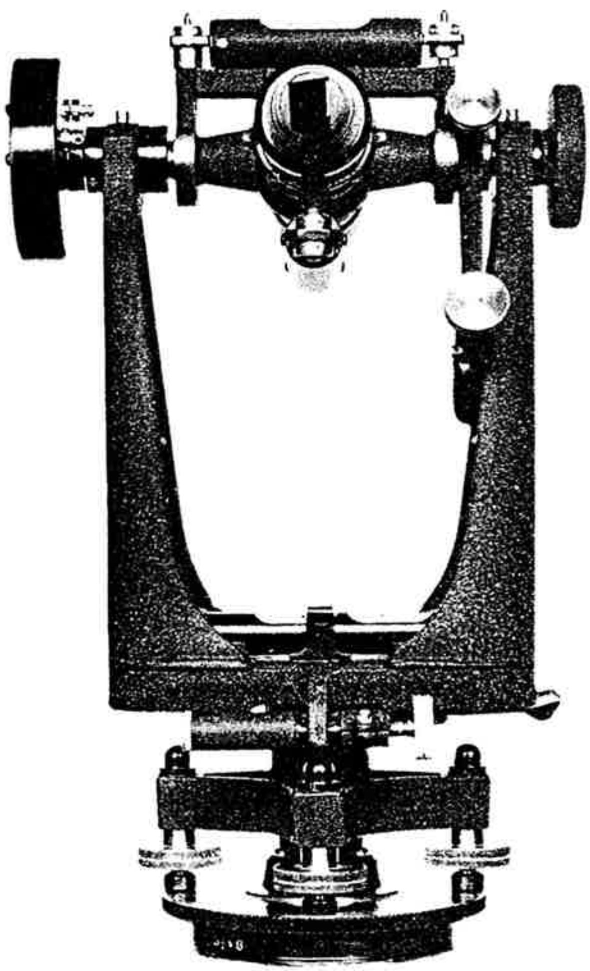


Fig. 24. The Jig Transit with the striding level in place. Note the finder sights on the striding level for setting the instrument approximately perpendicular to the line of sight of the alignment telescope.

3. ***Adjustable Line of Sight.*** The plane of the line of sight of the Jig Transit can be adjusted laterally to cause it to coincide with the vertical axis. This makes it possible to reverse the instrument in azimuth without shifting the vertical plane horizontally.

4. ***Measuring Buttons**** A measuring button may be provided on each side. It is mounted on the standard 2½ inches below the center of the mirror. Its face is exactly 3.250 inches from the vertical axis of the instrument and therefore 3.250 inches from the vertical plane of its line of sight. The position of the plane of the line of sight can thus be determined with measuring rods and inside micrometer. See Fig. 21.

5. ***A Prismatic Eyepiece*** is included. This facilitates sighting to points at high angles above the instrument. See Fig. 22. It may be rotated through 360° so that the instrument can be used with the eyepiece near any obstruction.

ATTACHMENTS

1. The ***Optical Micrometer with Counterweight*** is an important attachment for the Jig Transit. It will very materially reduce the time of set-up when bucking in, and it can be used to measure the actual position of any part of the jig, both vertically and horizontally in any plane perpendicular to its line of sight. See Fig. 27.

The micrometer is provided with two keyways which fit over a key on the objective end of the telescope of the Jig Transit. These hold the micrometer in the correct position for either vertical or horizontal measurement.

2. ***Striding Level and Collars.*** Collars are provided on the telescope axle for a striding level. The striding level is supplied at a small extra cost. See Fig. 24. This device will give a final check on the verticality of the plane of the line of sight independent of any instrument adjustment. If the bubble remains in the same position in its vial when the striding level is reversed, the plane is vertical. The sensitivity is 45 seconds per 2 mm.

3. ***Finder Sights*** are provided on the striding level to assist in positioning the Jig Transit at right angles to the line of sight of the alignment telescope.

*Optional at additional charge.

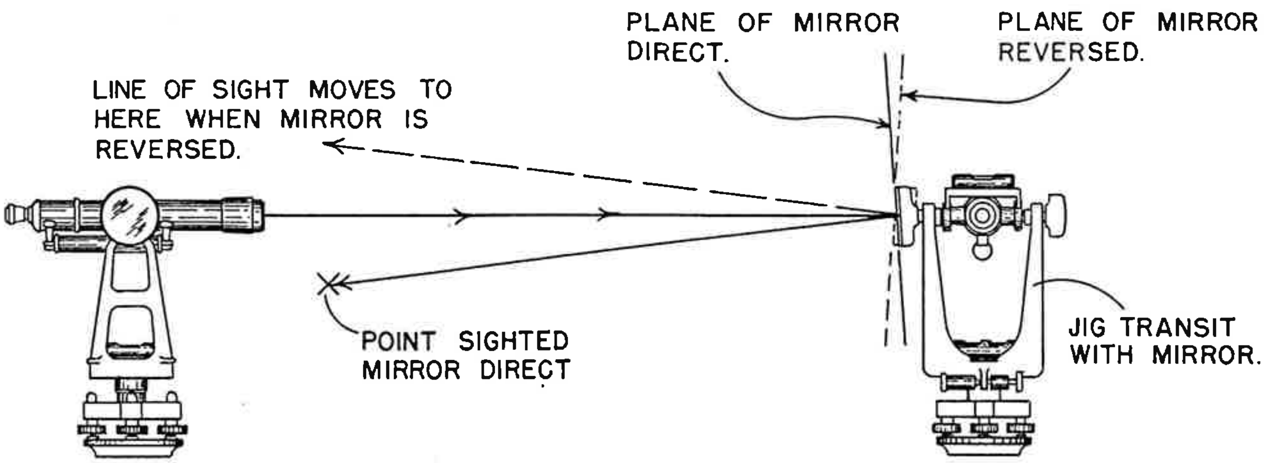


Fig. 25. **When the mirror is not perpendicular to the telescope axle, the reflection of a point sighted through another transit will move off the line of sight when the Jig Transit telescope is plunged.**

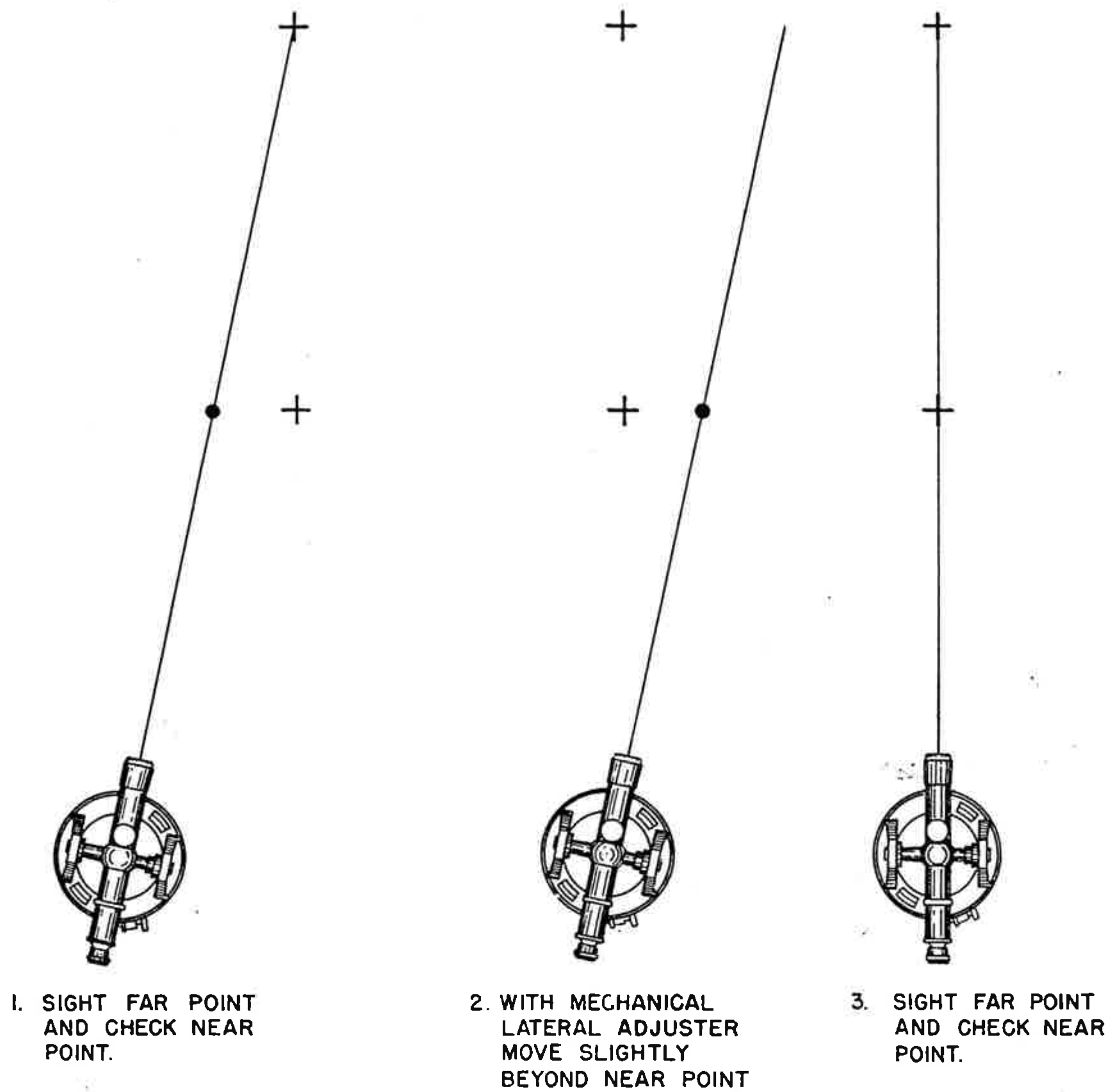


Fig. 26. **Bucking-in. (This operation is much easier with an optical micrometer).**

4. ***The Telescope Axle Mirrors.*** Two types of optically flat front surface mirrors can be screwed on either or both ends of the telescope axle. One is circular, 2-5/16" in diameter, other is rectangular, 2¼ x 4". With either, the plane of the line of sight of the Jig Transit can be set perpendicular to any optical line of sight by auto-reflection. For example, when an alignment telescope is in position, the Jig Transit is set up, so that the mirror is approximately move. The mirror is adjusted by two screws in its support. See page A-8.

When the rectangular mirror is used, the accuracy of the setting of the jig alignment telescope on its distant target can be checked whenever desired. The point of attachment of the mirror is near one end of the mirror. When the transit telescope is in its normal position, the mirror is entirely be-

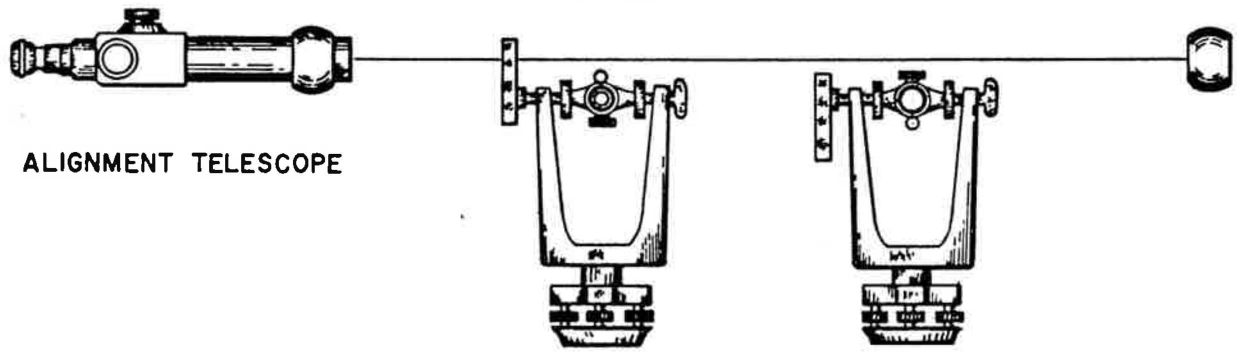


Fig. 26a. When the Rectangular Axle Mirror is used, the setting of the alignment telescope on the target can be checked.

centered with the line of sight of the alignment telescope. The Jig Transit is then turned about its vertical axis until the reflection in the mirror of the auto-reflection target of the alignment telescope appears centered on the alignment telescope cross lines. When this is established, the mirror, and hence the desired plane established by the line of sight of the Jig Transit, must be perpendicular to the optical line of sight of the alignment telescope.

The test for the adjustment of the mirror is extremely simple. See Fig. 25. A transit is aimed into the mirror at the reflection of any well defined point. The telescope of the Jig Transit is then plunged about the telescope axle, thus rotating the mirror. If the mirror reflecting surface is exactly perpendicular to the telescope axle of the Jig Transit, no change occurs in the position of the point as seen in the mirror through the transit. The reflection of the point will remain on the cross lines of the transit. If the mirror surface is not perpendicular, its angle with the transit line of sight will change and the reflection of the point will

low the top of the transit. When the telescope is reversed, the mirror extends upward above the transit. Thus, the Jig Transit is set up and aligned with the telescope reversed, and the mirror is up, and whenever the aim of the alignment telescope is to be checked, the telescope is turned to its normal position so that the mirror is turned down out of the way.

When the Rectangular Axle Mirror is screwed onto the telescope axle of the Jig Transit, it should be set so that its longitudinal axis is approximately vertical when the Jig Transit telescope is horizontal. Its position can be regulated by adjusting a bushing held by a screw on the back of the mirror housing.

5. ***Two Axle Mirrors.*** If desired, the accuracy of the plane established by the Jig Transit can be checked independent of any adjustments of the Jig Transit by using two mirrors, one on each end of the telescope axle. The various points dependent on the plane are set when the Jig Transit has been aligned with one mirror and then checked after the transit has been turned 180 degrees in azimuth and

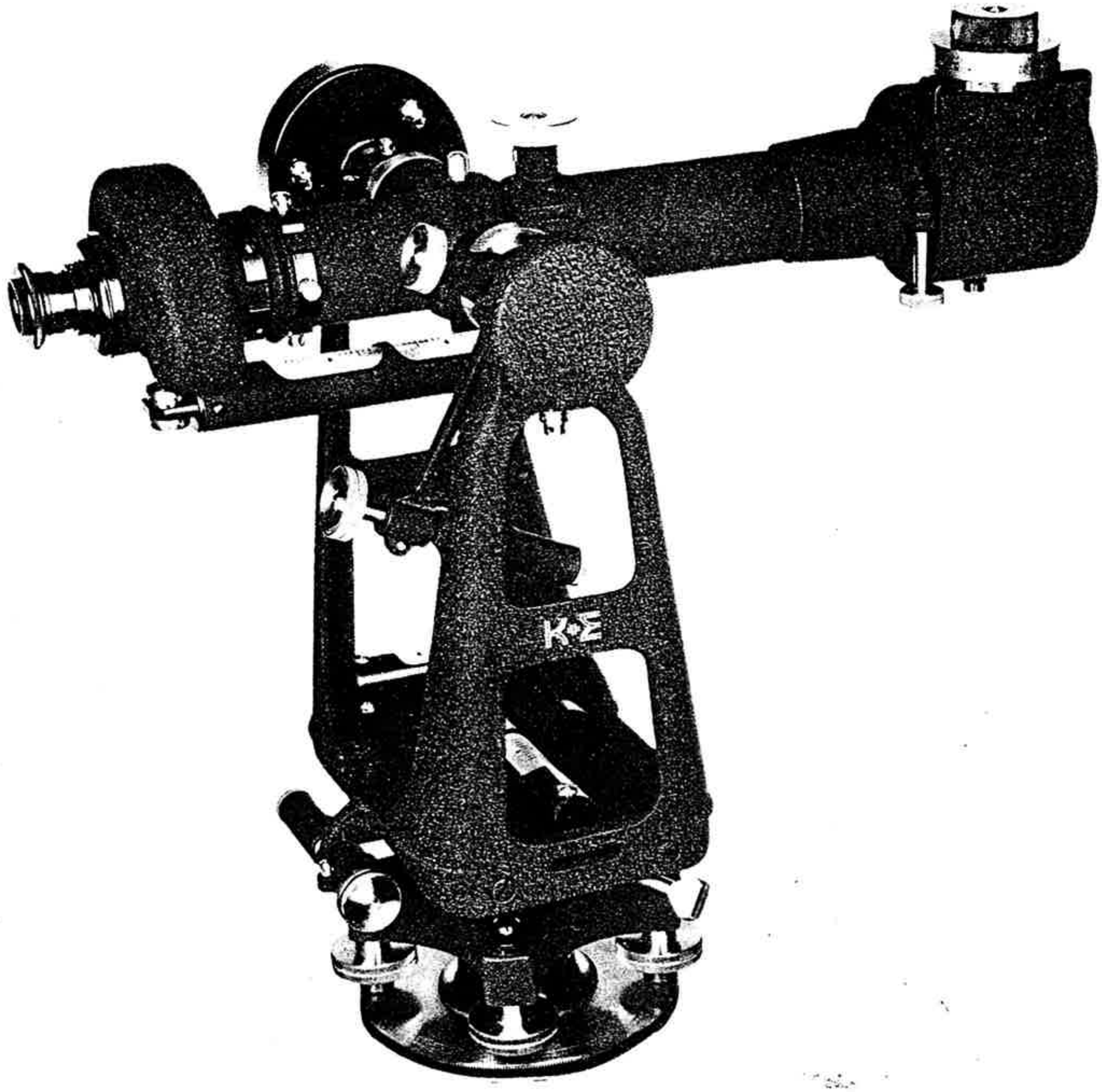


Fig. 27. The Jig Transit with the optical micrometer and its counterweight in position for lateral movement. When used for leveling, the optical micrometer is rotated 90°.

aligned with the other mirror. If any difference is found, the true position is half-way between the two.

ADDITIONAL SPECIFICATIONS

The Jig Transit has a telescope level for ordinary level measurements. If desired, a reversion type level may be had at a slight additional cost. This makes it possible to use the instrument as a level when the telescope is reversed and the level vial is on top. The instrument has four leveling screws which eliminate the possibility of a slight rotational movement of the instrument after it has been clamped. Three-screw instruments are subject to this if the leveling screws become worn. Four screws also maintain a constant height for the line of sight. The instrument has a U.S. standard 3½ x 8 thread base. Its overall size is about 12½" high, about 7" wide. The telescope is about 11¾" long. The telescope has a magnification of about 24x. 32x is optional at an additional charge.

USE OF THE JIG TRANSIT

Purpose. The Jig Transit is designed to establish a precise vertical plane wherever desired. It will also serve as a level when the accuracy of a precise level is not required.

The instrument is used for a wide variety of purposes both in original layouts and for precise control.

Mounting and Accessories. The Jig Transit should be mounted on a mechanical lateral adjuster (K&E No. 9099-71, page 14-1) supported on an instrument stand (K&E No. 9092-20, page 13-1). An optical micrometer greatly facilitates the use of the instrument.

When the micrometer is not used, the sunshade should always be placed on the telescope, particularly in dark locations. It cuts down the unfocused light that tends to dim the image.

Operation. Essentially the Jig Transit must be placed so that the telescope axle is exactly horizontal and the line of sight is in the desired plane. When in this position, the line of sight will sweep out the vertical plane required, so that any point in that plane can be readily located.

To Buck-in. Usually the desired vertical plane is marked by two scribed points. The instrument is placed in line with them by a process called ***bucking-in.*** After the instrument is set up in line as judged by eye, proceed as follows:

1. Loosen a pair of adjacent leveling screws and rotate the leveling head until a pair of opposite leveling screws is in line with the vertical plane to be established.

2. Center the two plate bubbles.

3. Aim at the far point.

4. Aim at the near point without turning the instrument about its vertical axis, and note where the line of sight falls.

5. Move the instrument with the mechanical lateral adjuster until the line of sight has moved in the direction of, and slightly beyond the near point. See Fig. 26.

6. Center the plate bubbles.

7. Aim at the far point.

8. Check at the near point.

Continue until the line of sight will check on both points. Level the instrument each time it is moved. However, if the optical micrometer is used, this operation is much quicker and simpler. (See later paragraphs).

To Use the Striding Level for Bucking-in. When the striding level is used, the telescope axle of the instrument is made exactly horizontal independently of the adjustment of the instrument. (If the instrument is kept in adjustment, there is no advantage in using the striding level.) After the instrument is nearly in line and carefully leveled, proceed as follows:

1. Place the striding level on the collars on the telescope axle. If the bubble does not center, note its exact position and the end of the striding level toward which it stands.

2. Lift off the striding level, turn it end for end and replace it on the collars. If the bubble comes to rest at the same position and toward the same end of the striding level, the horizontal axis is horizontal. If it does not, move the bubble half way toward its original position with the appropriate leveling screws.

Repeat the above steps until the bubble does come to rest in the same position when the striding level is turned end for end.

3. Note this reading of the bubble. (If the striding level is in adjustment the bubble will be centered). This is the reading to use for leveling the intrument.

Note: In handling the striding level do not allow the fingers to touch the vial, and do not hold the level in the hand any longer than necessary. Body heat may disturb the accuracy of the instrument for 10 to 15 minutes of time.

4. Now continue to buck-in the instrument but level with the striding level (using the reading established under 3) instead of with the long plate level.

5. When the instrument is in its final position, the striding level should be turned end for end for a check.

To use the Optical Micrometer* for Bucking-in: Install the counterweight and place the Optical Micrometer on the end of the telescope. See Fig. 27. Rotate the Optical Micrometer about its axis until the axis of rotation of the tilting plate is vertical. While this should be done carefully, an error of 5^{o} will introduce an error of less than 0.0004 inch in a 1/10 inch reading of the micrometer. To test the installation, aim at some well defined point as near the instrument as possible. Turn the micrometer drum through its entire range. One cross line should remain on the point while the other moves away from it. Clamp the Optical Micrometer when the test is satisfactory. Set the micrometer at zero.

Begin the procedure for bucking-in the instrument and continue until the line of sight is within 0.1 inch of the near point. Then proceed as follows:

1. Level the Jig Transit precisely.

2. Sight the far point with the Jig Transit horizontal tangent screw.

3. Sight the near point.

4. Move the line of sight with the micrometer in the direction of, and slightly beyond the near point. This will not disturb the level of the instrument.

5. Repeat the process until the line of sight falls on both points.

6. Note the reading of the optical micrometer. This is the correction that must be applied to every measurement to or from the line of sight of the Jig Transit.

*See the description of this instrument

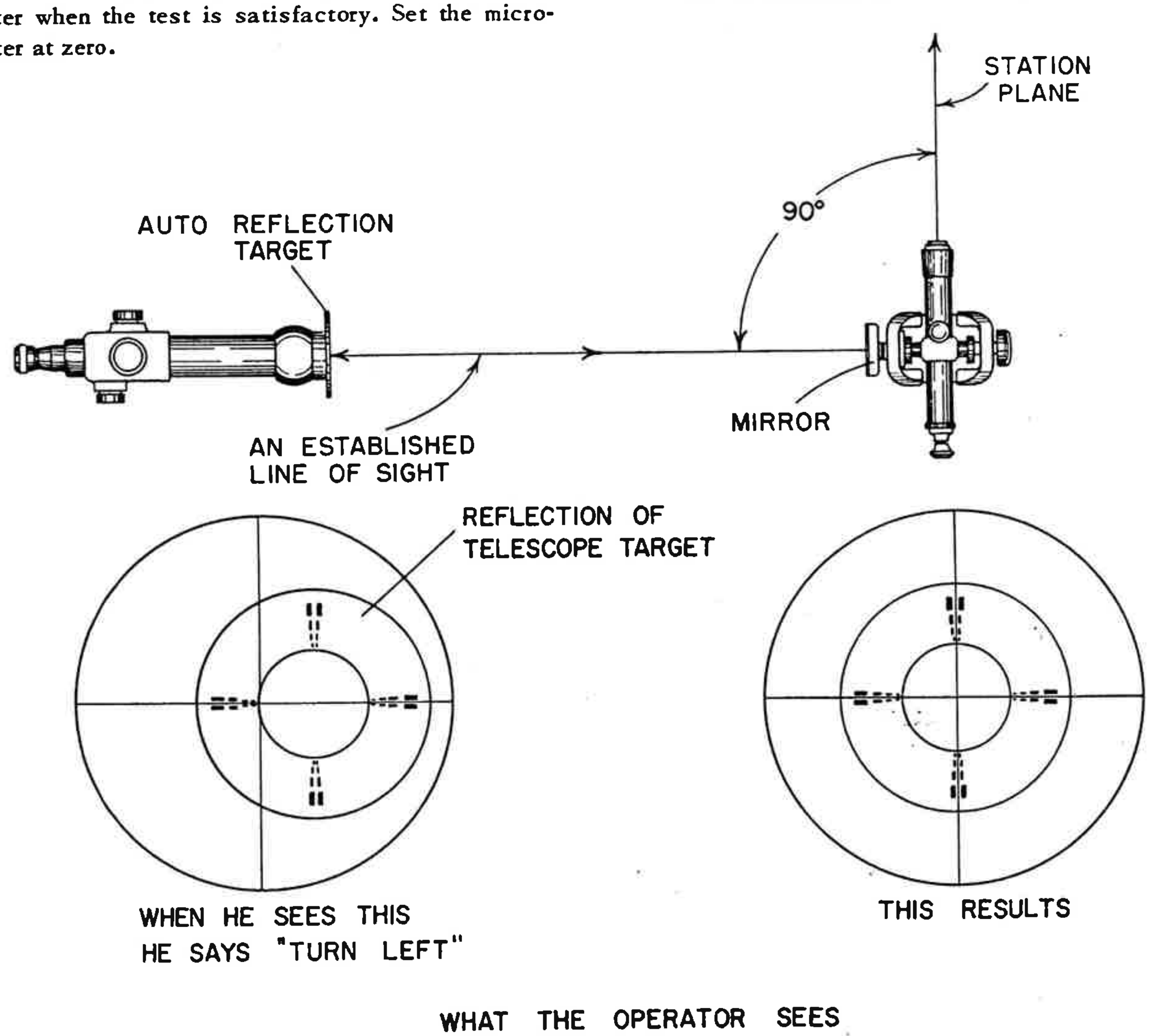


Fig. 28. **To establish a plane perpendicular to the line of sight of the alignment telescope with a Jig Transit. The operator sees the reflection of the target mounted on the end of the alignment telescope. The Jig Transit is turned until the reflection of the target appears on the cross lines of the alignment telescope.**

To Set Up the Jig Transit Perpendicular to the Horizontal Line of Sight of the Jig Alignment Telescope by Auto-Reflection. Make sure the Jig Alignment Telescope Optical Micrometers are set at zero and the alignment telescope is aimed at its target.

1. Set up the Jig Transit approximately in position with the mechanical lateral adjuster perpendicular to the line of sight of the alignment telescope. See Fig. 28.

2. Loosen two adjacent leveling screws and turn the leveling head until a pair of opposite leveling screws is in line with the line of sight of the alignment telescope.

3. Level the Jig Transit approximately.

4. Turn the telescope so that the mirror faces the alignment telescope.

5. Move the instrument vertically by the elevation mount and horizontally by the mechanical lateral adjuster until the center of the mirror is approximately in the line of sight of the alignment telescope.

6. Level the Jig Transit accurately. Tighten the horizontal clamp. If a striding level is available, install it and aim the finder sights at the alignment telescope.

7. By rotating the horizontal tangent screw, turn the Jig Transit slowly left and right until the alignment telescope observer can focus in the mirror of the Jig Transit the reflection of the alignment telescope target. At his direction turn the tangent screw until the reflection of the alignment telescope target is on the vertical cross line of the alignment telescope. If all adjustments are correct, the target will also appear on the horizontal cross line.

To Set Up the Jig Transit when the Reference Line Slopes. The Jig Transit can be set up to sweep a plane perpendicular to the line of sight of the alignment telescope, even when this line slopes at an angle.

The procedure is the same except that a white cord with a weight attached should be held below the alignment telescope if it slopes downward, or above it if it slopes upward, to aid in finding the reflection in the mirror.

The Jig Transit is turned slowly left and right until the reflection from the mirror of the white cord appears on the vertical cross line of the alignment telescope.

Then, by using the pair of opposite leveling screws of the Jig Transit that are on line with the alignment telescope, the operator tilts the Jig Transit until the reflection of the horizontal centering marks on the alignment telescope target appears on the horizontal cross line of the alignment telescope.

The final adjustment is made with the horizontal tangent screw and the pair of leveling screws designated above.

To Eliminate the Effect of Errors of Adjustment. The K&E Jig Transit is designed so that, by proper manipulation, any error in its adjustment can be quickly discovered and its effect eliminated while the instrument is in actual use.

1. *To Use the Plate Levels.* Level the instrument. Turn it 180° in a horizontal plane. The bubble in each plate level should center. If it does not, a point halfway between its new position and the center position is the proper setting. Thereafter level to this setting. The bubble will remain at this setting in whatever direction the instrument is pointed.

2. *To Set a Point in the Line of Sight.* Align the telescope in the usual way, by aiming at a target or by auto-reflection. Set a temporary point in the line of sight. Turn the telescope upside down, rotate the instrument 180° and align the telescope as before. The cross lines should fall on the temporary point. If they do not, the true point is halfway between the temporary point and the cross lines.

3. *To Use the Mirrors.* If a mirror is out of adjustment, the auto-reflection target will appear to move in a circle when the Jig Transit telescope is rotated on its horizontal axis (See page 2-7, Telescope Axle Mirror). Adjust the Jig Transit, as described above, so that the cross lines appear at the center of the circle.

To Set a Point at Right Angles. The instrument can be equipped with two mirrors to make this operation self-checking. When an instrument is so equipped, and a point has been set at right angles to a line of sight by auto-reflection, repeat the operation with the telescope reversed, using the second mirror. The cross lines should fall on the point. If they do not, the true point is halfway between the first point and the cross lines.

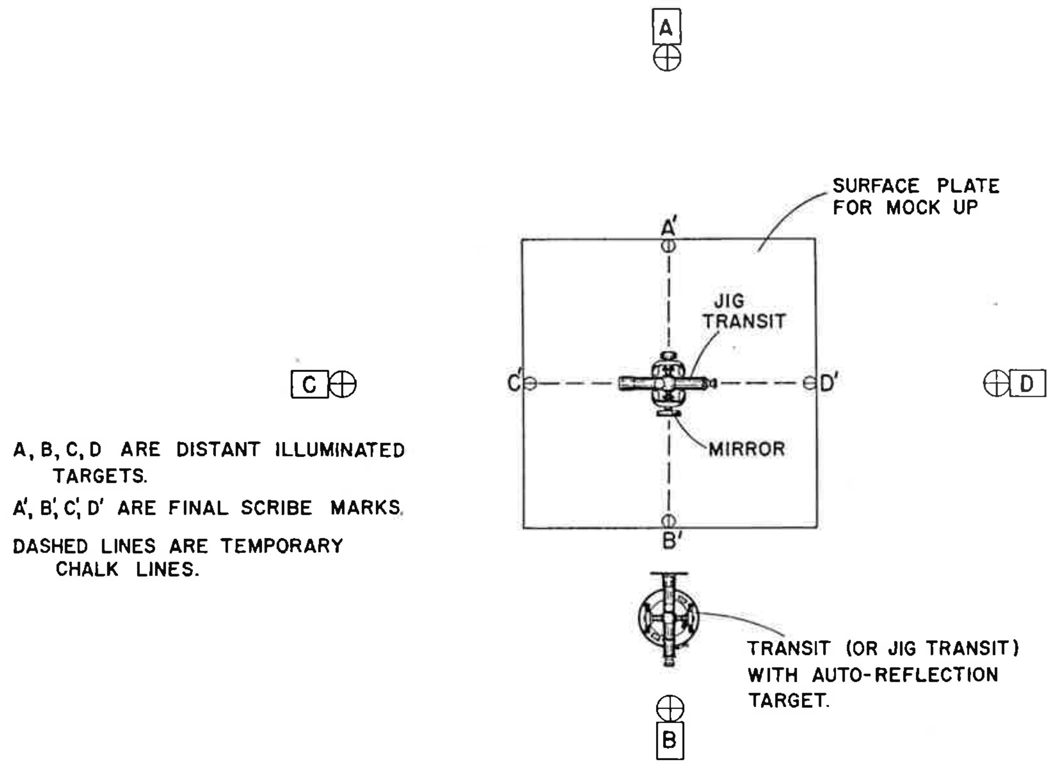


Fig. 29. **The recommended method of establishing the center lines for a mock-up. These will be permanent, precise lines at exactly 90°.**

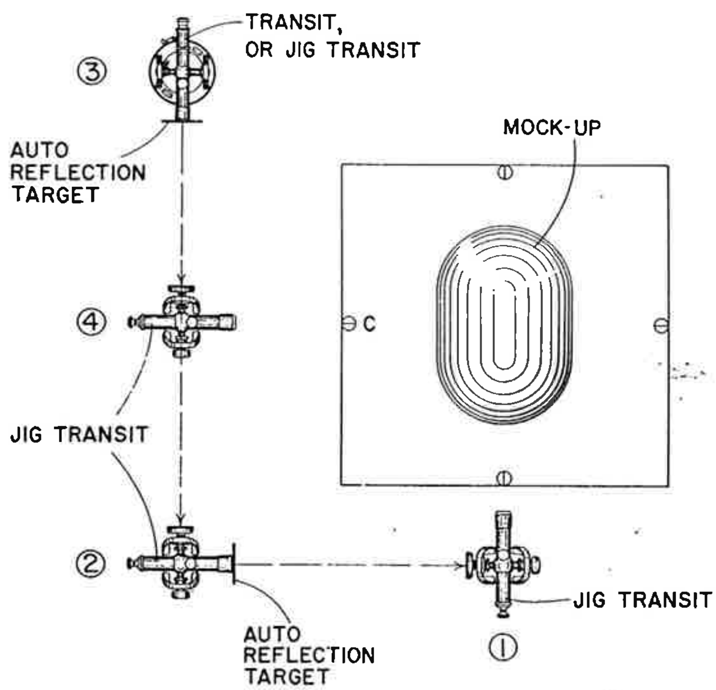


Fig. 30. **To re-check the right angle between the center lines of a partially constructed mock-up.**

To Establish the Center Lines for a Mock-Up with a Jig Transit. A second Jig Transit or an ordinary transit is required. It should be equipped with an auto-reflection target.

Fig. 29 shows the operation. The centerlines are marked approximately on the surface plate with chalk lines or otherwise.

1. Buck-in the transit at position 1 approximately on the chalk line A' B'. Set a distant illuminated target at A. Sight A exactly and place a scribe mark at A' and B' and set a second distant illuminated target at B.

2. Set up the Jig Transit approximately on the intersection of the chalk lines. Turn it until its mirror reflects the auto-reflection target at 1 onto the instrument cross lines at 1.

3. Set C, C', D and D' exactly on line.

To Re-check the Right Angle Between the Center Lines of a Partially Constructed Mock-Up. Two Jig Transits and an ordinary Transit (or a third Jig Transit) are required*. One Jig Transit and the ordinary Transit must be equipped with auto-reflection targets. Fig. 30 shows the procedure.

1. Buck-in a Jig Transit at position 1 on the mock-up centerline.

2. Set up the second Jig Transit at position 2 and adjust its line of sight perpendicular to that of the Jig Transit at position 1 by auto-reflection.

3. Set up the transit at position 3 and adjust its line of sight perpendicular to that of the Jig Transit at position 2 by auto-reflection.

4. Transfer the Jig Transit at position 2 to position 4. Buck-in so that point C is in line when the line of sight is perpendicular to that of the transit at position 3, as determined by auto-reflection.

The foregoing describes only a limited number of applications of the K&E Jig Transit. There are, of course, many more that will be developed by the resourceful user to meet the individual requirements of his problems.

*The same result could be accomplished through the use of only two Jig Transits. This procedure is not recommended however, because after the completion of set-up 3, unless three instruments are used it is not possible to check the set-up of all three instruments to make sure that the lines of sight of the instruments at 1 and 3 are parallel.

K+E GLASS RETICULE

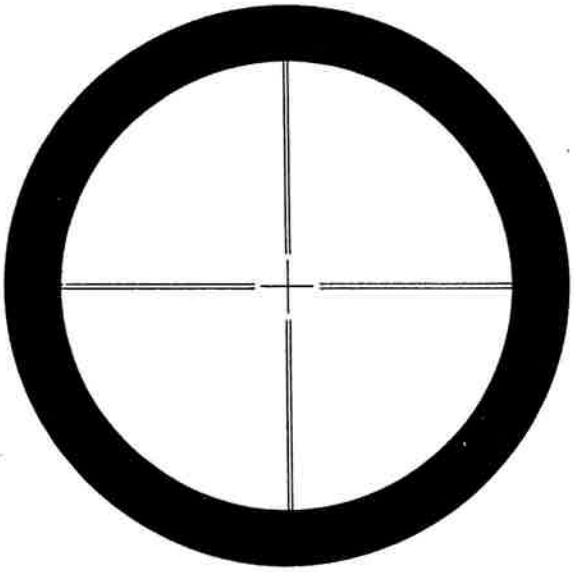


Fig. 31. Glass Reticule No. 5097-49KG used in the K&E Jig Transit, and recommended for K&E Paragon Tilting Level No. P5022 when used for Optical Tooling. It combines a paired line and a single line pattern for use with either single or paired line targets and scales. The thickness of these lines, in angular measure, as they appear on the object sighted is 2½-3 seconds of arc and the paired lines are separated by 20-30 seconds of arc.

K+E TWO-SPEED DIFFERENTIAL TANGENT SCREW*

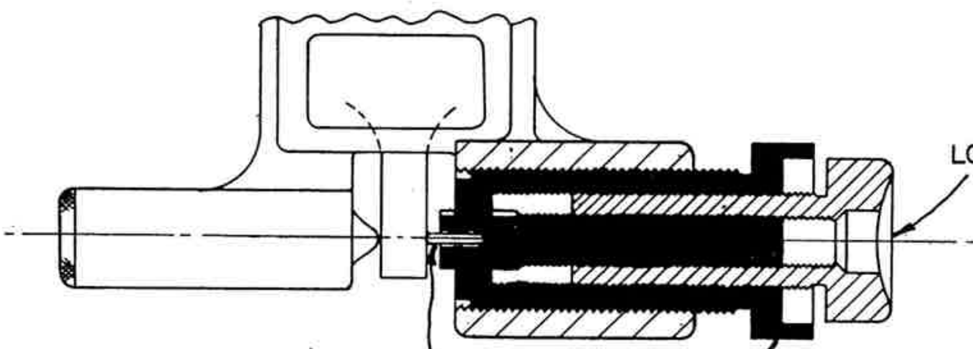


Fig. 32. The K&E Two-Speed Differential Tangent Screw.

The K&E Two-Speed Differential Tangent Screw. The accuracy with which the aim of the K&E Jig Transit can be determined by the auto-reflection method has brought about the development of a new type of tangent screw that makes it possible to point the instrument with great accuracy.

Fig. 32 shows a cross section of the new tangent screw. When the larger knurled head is turned, the whole assembly advances about two-thirds again as fast as most tangent screws. When the smaller knurled head is turned, it advances at about 1/19th of the usual rate.

*Optional at additional charge.

K+E

OPTICAL MICROMETERS

Fig. 40. **The Optical Micrometer. The instrument is shown as it would appear from the direction of the operator when installed on a Jig Transit. The lower right hand screw clamps the instrument in position. The upper knob and drum control the planoparallel plate. The plate is shown tilted sideways so that it would move the line of sight 0.081 inch to the right, as shown by the reading on the drum.**

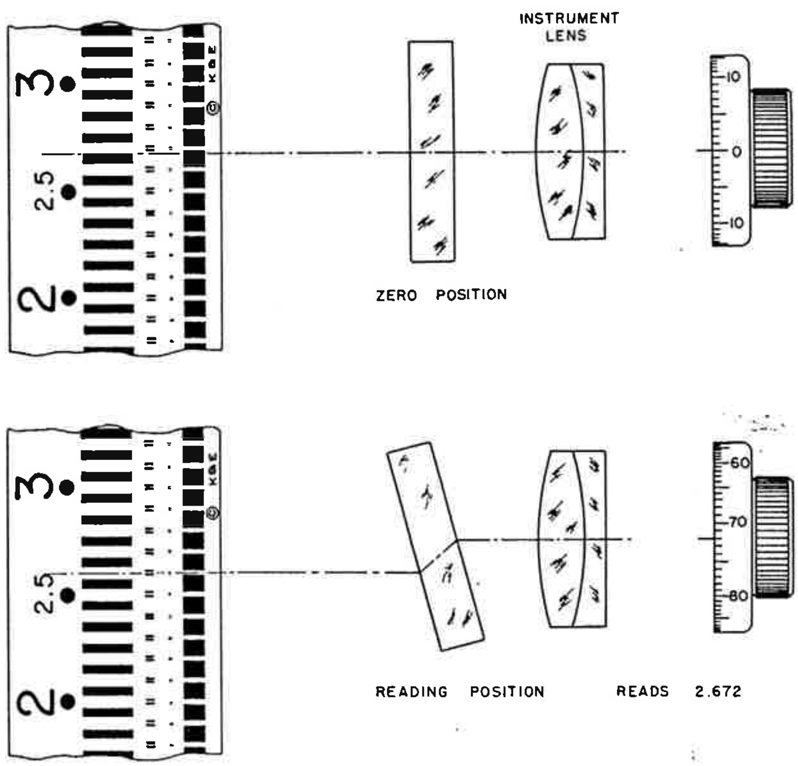


Fig. 41. **The principle of the Optical Micrometer.**

K+E

OPTICAL MICROMETERS

THE OPTICAL MICROMETER

K&E Optical Micrometers are attachments for levels and transits to be used for very precise leveling and very precise alignment. With them, measurements can be made to 0.001 inch.

SIMPLE IN DESIGN AND OPERATION

Essentially, an Optical Micrometer may consist of a disc of optical glass with flat parallel faces called a planoparallel plate. It is arranged so that it can be precisely tilted by the movement of a graduated drum. See Fig. 40. The device is mounted on the instrument in place of the sunshade so that the plate is in front of the objective (main) lens. When the plate is tilted, the line of sight is moved parallel to itself. The device can be installed so that the line of sight moves up and down for leveling or left and right for lateral displacement.

The drum is graduated so that it records the shift of the line of sight to 0.001 inch.

APPLICATION TO MEASURING VERTICAL DISTANCES

Fig. 41 illustrates schematically how an optical micrometer is used for measuring vertical distances. The sights are taken on a steel scale graduated to tenths of an inch. The upper figure shows the line of sight in its zero or normal position. The micrometer drum is graduated in both directions from zero to 100. To avoid using the wrong direction the drum should first be turned to zero. The drum is then turned so that the line of sight moves toward the graduation on the steel scale with the lesser value of the two graduations between which it falls. In this case this is 2.6 inches, as shown in the lower figure. The drum always records how far the line of sight has moved from its zero position, in this case 72.0 thousandths of an inch. Thus the reading is 2.6 + 72.0 thousandths or 2.672.

If these directions are followed, a steel scale that is used to measure downward will also be read without error. The micrometer drum is set at zero and the line of sight is moved toward the zero end of the steel scale. An additive reading will be obtained, regardless of whether the steel scale is up, down, left or right.

DETAILS

Optical Micrometers, graduated by thousandths of an inch 0 to ± 0.100.

No.	Fits
9092-5	K&E Levels P5003, P5010
9092-5 with Adapter 9092-5B	K&E Level P5026
9092-7	K&E Level P5022

Optical micrometers, graduated by thousandths of an inch 0 to ±0.100, and counterweight.

No.	Fits
9092-5 with Adapter 9092-5A*	K&E Transits P5060, P5085
9092-9 †	K&E Jig Transit 9092-1

*If ordered with Adapter for use on a transit, order with counterweight.
†Specify serial number for which wanted, if ordered separately.

K+E

WYTEFACE®
OPTICAL TOOLING
SCALES & STEEL TAPES

•

SCALE LEVEL

•

SCALE HOLDING MAGNETS

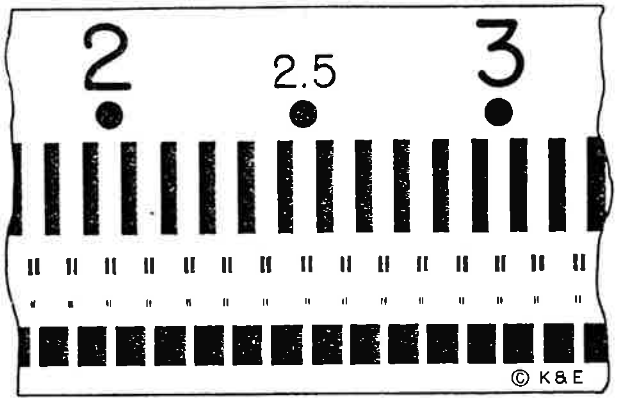


Fig. 60. The Precise Scale. An enlarged section is shown. The different types of graduations are used for different lengths of sight.

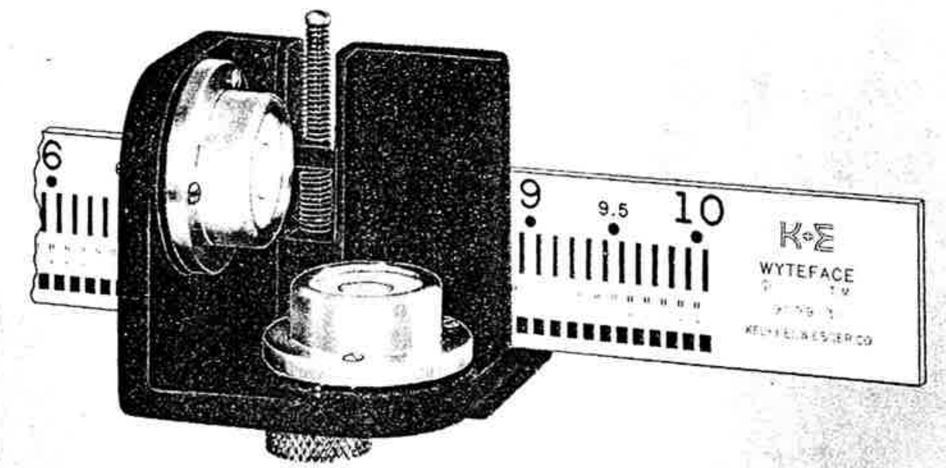


Fig. 61. The K&E Scale Level.

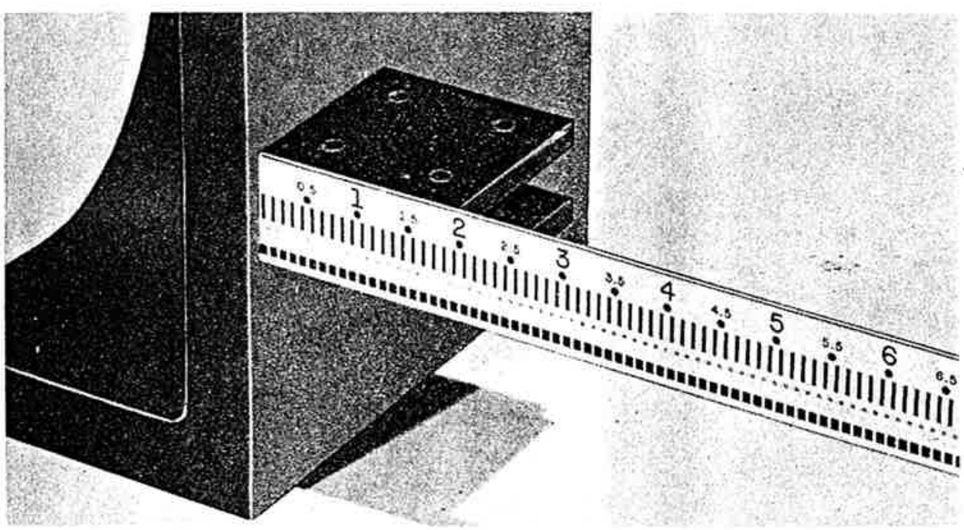


Fig. 62. The K&E Scale Holding Magnet.

K+E

WYTEFACE* OPTICAL TOOLING SCALES

No. 9099-30 (10 in.) No. 9099-32 (20 in.) No. 9099-34 (40 in.)
No. 9099-35 MAHOGANY Box to hold set of three scales

K&E has developed a new type of scale to be used with optical micrometers. These scales are based on a long series of tests, made as part of a research program at Princeton University, to determine the pattern that gives the greatest pointing accuracy. The new K&E WYTEFACE scales are 10, 20 and 40 inches long and are made of hardened tool steel with a white plastic matte surface. The graduations are black, to provide maximum contrast. Each 1/10 inch graduation or separation is positioned correctly to within ±0.001 inch at 68°F. The 10 and 20 inch scales are graduated throughout their entire length, while the 40 inch scale has the first 19½ inches blank and the last 20½ inches graduated.

An ordinary machinist's steel scale has graduations that are slightly irregular and have very little contrast. It nearly always reflects a highlight. The highlight introduces what is known as *"phase"*. This induces the observer to believe that the mark is slightly offset toward the brightest part.

The most accurate setting of a cross line can be made between two black lines on a white surface, provided the white areas between the lines and the cross line are the optimum width. †Accordingly, for a given width of cross line, a certain spacing of lines will serve over a certain range of distances.

Cross lines in good sighting telescopes vary in size from 2 to 3 seconds of arc. When cross lines of this width are used, a white space within the range of 8 to 21 seconds between two graduations on a scale gives a probable pointing error of 0.15 seconds or less. This means that not more than 2½% of the pointings will be in error by more than 0.50 seconds.

The K&E scales are divided to tenths of an inch. At each tenth of an inch, there are four pairs of lines with different separations for sights of different lengths. The separations are the following:

0.004 inch for sights up to about 7 ft.
0.010 inch for sights of from 7 to 20 ft.
0.025 inch for sights of from 20 to 50 ft.
0.060 inch for sights of from 50 to 130 ft.

Fig. 41 shows an enlarged section of a scale.

*Trade Mark

†The principle of paired lines for a target has been in use for many years by the U. S. Coast & Geodetic Survey for first order work.

K+E SCALE LEVEL 9099-29

The K&E Scale Level. This instrument can be attached to any steel scale up to 1/8 inch in thickness and between 1 inch and 1-1/2 inch in width. It has two protected circular bubbles, one is used to keep the scale vertical and the other to keep it horizontal.

The scale level is so constructed that the scale may be inserted with its face upright as shown in the illustration, or it may be tilted at about 45°. In order to check whether a scale held horizontally is not only level but also not inclined toward or away from the line of sight, the scale should be inserted in the level in the tilted position. In this position, if the scale is inclined toward or away from the line of sight, the vertical cross line of the sighting telescope will appear to cut diagonally across the graduation pattern on the scale. The vial has a sensitivity of 10 minutes per 2 mm.

K+E SCALE HOLDING MAGNET 9099-36

The K&E Scale Holding Magnet. The Scale Holding Magnet will hold a tooling scale at right angles to any finished surface of magnetic metal. It has many uses and often will free a man for other work.

The Scale Holding Magnet consists of two square plates 2" x 2", mounting on the poles of an Alnico magnet. The outside surfaces of the plates are parallel and one inch apart. The magnet exerts a pull of 30 lbs.

K+E

WYTEFACE®
OPTICAL TOOLING STEEL TAPES
9099-39

K&E manufactures to order a WYTEFACE measuring tape for optical tooling that is held to a very high standard of accuracy. The tape consists of a steel ribbon 3/8 inch wide and 0.008 inch thick. It can be made to any desired length up to 300 feet. Fine black lines, about 0.006 inch wide, are cut on the tape in a dividing engine, usually at intervals of 10 inches throughout its length. They are clearly readable under the magnification of a transit. Bold black inch numbers are printed beside them.

With each tape, K&E furnishes a report covering a comparison of the tape's graduations with the graduations of the K&E master steel tape which has been certified by the National Bureau of Standards. The comparison is made with both tapes supported on 1/8 inch diameter rollers at intervals of 30 inches, and these, in turn, supported on a smooth horizontal surface, and with the tapes under a tension of 10.00 pounds for tapes up to 1200 inches long and a tension of 20.00 pounds for longer tapes. Under these conditions, at 68 degrees F. (20 degrees C.), no graduation will vary more than 0.005 inch from its true position, and no 10 inch length will vary more than 0.003 inch.

While a temperature correction should be applied to determine an exact distance, this is not necessary when the tape is used on a steel jig, since the jig will expand or contract with the tape.

It has been found that, if a WYTEFACE Optical Tooling Tape under tension is supported throughout its length on a smooth surface, the friction between the tape and the supporting surface may affect the accuracy of the measurements made with it. It is, therefore, recommended that the tape be supported on small rollers about 1/8 inch in diameter at intervals not greater than five feet.

The tape can be mounted along the upper surface of a tooling bar, supported on rollers as described above. With this arrangement the tape can be observed directly with the Optical Tooling Square 9092-14 (See page 15-2) mounted on the Alignment Telescope. The position of the Optical Tooling Square can then be adjusted along the tape to any 10 inch position by means of the longitudinal adjusting screw on the Y Bracket 9099-58 (See page 19-1). In this position, when the Optical Tooling Square is rotated, the line of sight will sweep a plane perpendicular to the tooling bar reference line of sight and exactly at the 10 inch station position. Measurements can be made from this plane to jig positions with an Optical Tooling Scale.

The tape may also be mounted along the jig parallel with the basic line of sight. A Jig Transit with the telescope axle mirror in place is bucked-in so that its line of sight is perpendicular to the basic line of sight and so that it strikes a ten inch mark on the tape. The line of sight of the Jig Transit will then sweep the plane of a given station position. Measurements to any desired station within 10 inches are then made with a scale. See page 4-3.

K+E

PARAGON®
TILTING LEVEL
5022

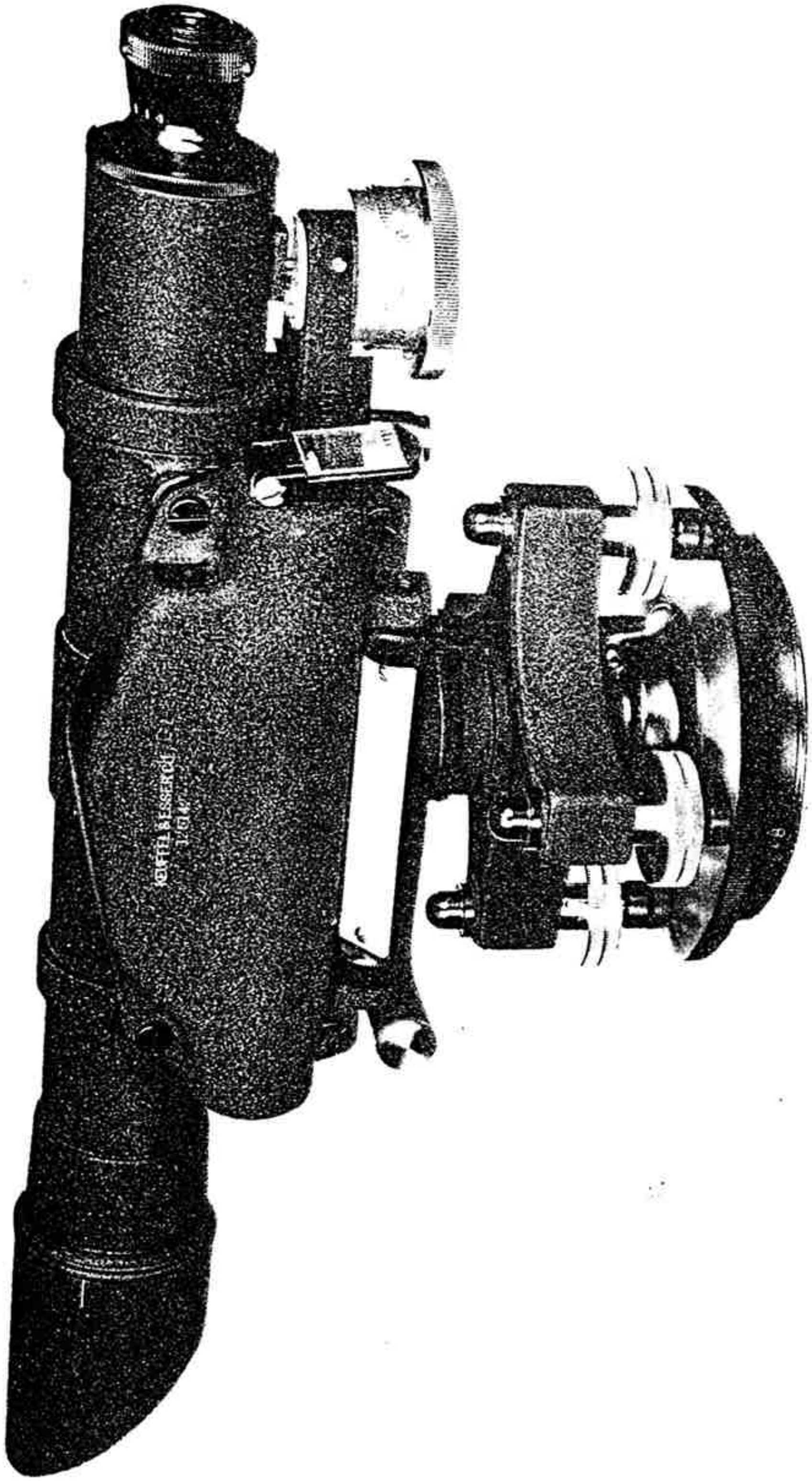


Fig. 80. **The Tilting Level. Note that the level vial is entirely enclosed. The instrument has four screw leveling, an erecting telescope, a coincidence reading bubble, a telescope axle located at mechanical center, and a large, easily operated, precise tilting wheel.**

K+E

PARAGON®
TILTING LEVEL
5022

The K&E Tilting Dumpy Level, as made today, (See Fig. 80) incorporates important improvements, which are the result of years of research. It has a number of features that make it an exceptionally accurate instrument for precise leveling in optical tooling. For this type of work an Optical Micrometer (9092-7) should be available for use with it when desired. Some of the important features of the Tilting Dumpy Level are listed in the following paragraphs.

Brilliant Optics. This instrument has an exceptionally fine optical system. It ensures high accuracy for every sight.

Erect Image. The instrument gives an erected view of the object sighted. This is a great time-saver whenever the levelman must direct the placing of a part. He is not subject to mistakes in direction.

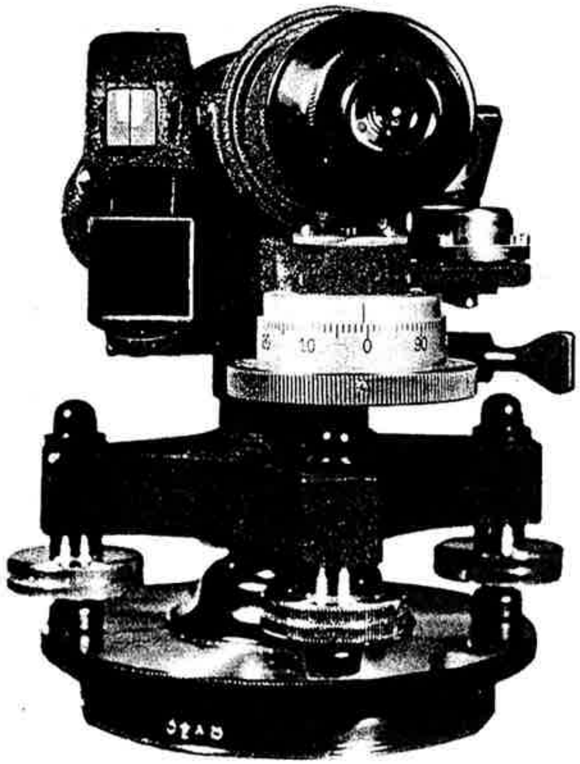


Fig. 81. What the operator sees. The window at the upper left shows the two ends of the bubble. They are brought into coincidence with the tilting wheel in the foreground. The mirror for the circular bubble is partly visible at the right.

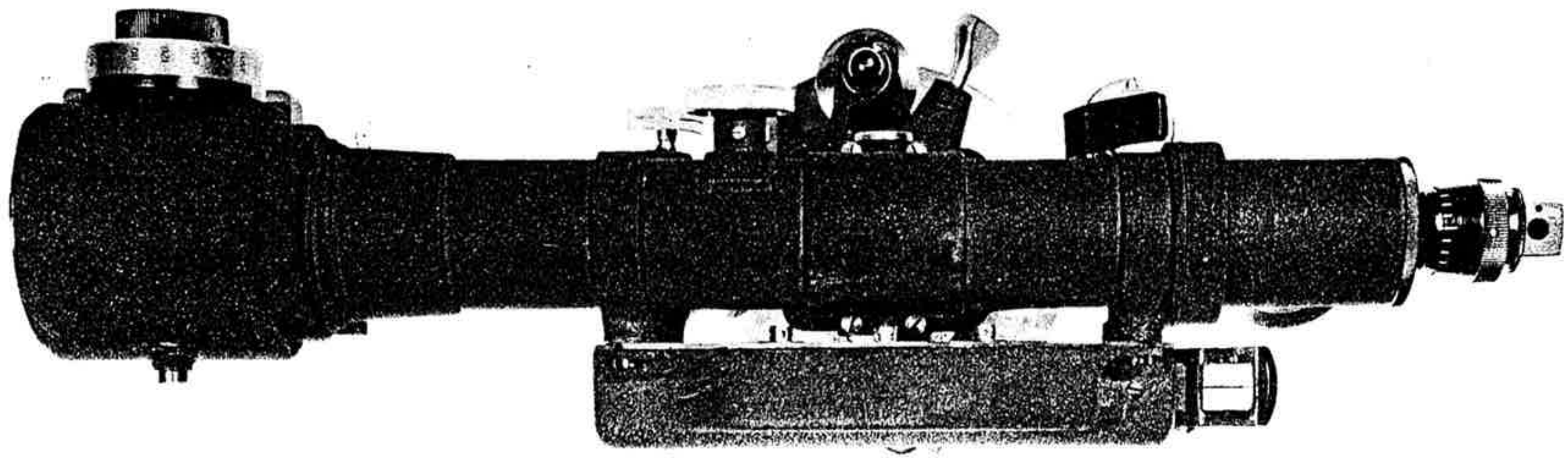
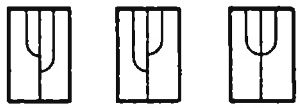


Fig. 82. The top view of the Tilting Level. The Optical Micrometer is shown in place. The instrument is arranged for a low set-up. The operator looks down into the mirror at the right to view the coincidence. He observes through the prismatic eyepiece.

Coincidence Bubble. The high accuracy of a coincidence bubble is well known. The instrument has a small window about an inch to the left of the eyepiece where the two ends of the bubble can be seen simultaneously through a set of optical parts. See Fig. 81. The two ends may appear as shown below.



1 2 3

When the tilting wheel is turned the ends move with respect to each other. When the wheel is regulated so that they appear as shown in 3, the line of sight is level.

Since when one end moves up the other moves down, the precision of setting is doubled. A tilt of one second of arc (approximately 0.0015 inch at 25 ft.) is plainly visible. Tests show that the combined error of reading the scale and setting the bubble is less than one second in 95% of the observations.

Four Screw Leveling. Four screw leveling prevents the instrument from changing height when the leveling screws are turned. This eliminates the error that frequently occurs with a three screw instrument. If, after a sight is taken, one screw of a three screw instrument is moved, the next sight will be in error.

At the lower end of the center of a four screw instrument is a half-ball that is forced upward by the leveling screws into the socket of the footplate. The height of the socket cannot change, the whole instrument merely pivots around the center of the half-ball.

Telescope Axle at Vertical Axis. The K&E Tilting Level has an outstanding advantage in that the telescope is pivoted about a horizontal axis, which intersects the vertical axis of the instrument. Because of this, the height of the telescope axle above the ground does not change as the telescope is rotated, even if the center spindle is not vertical. Since the height of the telescope axle is fixed, and does not change when the telescope is precisely leveled, the horizontal plane swept by the precisely leveled line of sight is always the same distance above the ground.

In conventional Tilting Levels the telescope is frequently pivoted about a horizontal axis which does not intersect the vertical axis of the instrument. In these instruments, as the telescope is turned, if the center spindle is not vertical, the telescope axle moves in a plane which is not horizontal. It rises and falls. Because the horizontal plane swept by the line of sight of the precisely leveled telescope rises and falls with the telescope axle, the height of the instrument changes, and errors are introduced.

Fully Enclosed Vial. The vial is fully protected from drafts and virtually protected from radiant energy. Even the light that illuminates the bubble must pass through a special infra-red absorbing glass tnat tends to filter out most of the heat rays. This is an important item, as even the slight heat generated by the beam of a flashlight can cause the bubble to move.

Right Angle Mirror, 9099-8. A right angle mirror that swings into position and shows the bubble coincindence can be permanently attached to the instrument at slight extra cost. This, with a prismatic eyepiece, makes it possible to use the instrument conveniently even with very low set-ups. A clip-on mirror, 9099-9, is available for older instruments.

More Speed and Accuracy with a Tilting Level. The advantages of a tilting level are evident when its operation is considered. To level the instrument and take a sight the steps are the following:

1. *With the four leveling screws, center the circular bubble.* This is accomplished without walking around the instrument or turning the instrument itself. Merely observe the bubble in the mirror to the right of the eyepiece. The bubble is not sensitive, no time is wasted by unnecessary accuracy.

2. *Focus on the target.*

3. *Set the coincidence.* The tilting wheel used to regulate the main bubble operates a screw that is as accurately made as the screw of a micrometer. Its operation is smooth and fast.

4. *Take the reading.*

5. *Focus on the second point.*

6. *Set the coincidence.*

and so on.

The line of sight is precisely leveled for each sight. No time is wasted attempting to make the vertical axis vertical. The time is spent taking accurate readings – as it should be.

Optical Micrometer. The instrument should be equipped with a K&E Optical Micrometer 9092-7. Fig. 82 shows the instrument with the Optical Micrometer in place.

Auto-Collimation Attachment. The instrument can be equipped with an Auto-Collimation Attachment 9099-20.

K+E

PARAGON® LEVELING OUTFIT
9092-22

This outfit provides the basic minimum equipment required for precise Optical Tooling Leveling. It consists of a case containing the following:

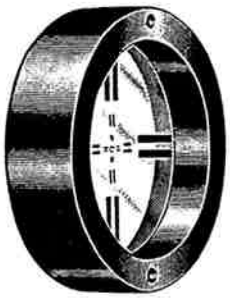
P5022	K&E PARAGON TILTING LEVEL, equipped with Optical Tooling Reticule No. 5097-49KG.
9099-8	RIGHT ANGLE MIRROR for Level Vial Housing.
5097-46A	DETACHABLE PRISMATIC EYEPIECE.
9092-7	OPTICAL MICROMETER. (Can be carried in the case attached to No. P5022.)
9099-29	SCALE LEVEL.
9099-30	WYTEFACE OPTICAL TOOLING SCALE, 10 in.
9099-36	SCALE HOLDING MAGNET.

The case is polished hardwood, lock corner, with corner braces and four large rubber supports. Contains also: Telescope cap, sunshade, adjusting pin, center key, waterproof cover.

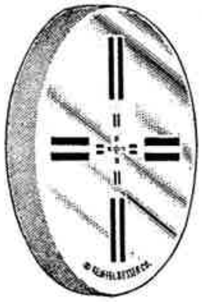
K+E

OPTICAL TOOLING TARGETS AND MIRRORS

February 1954



9099-40



9099-40U

9099-40½U

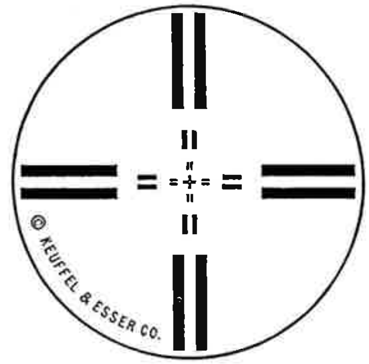


Fig. 90. Alignment Targets.

9099-41

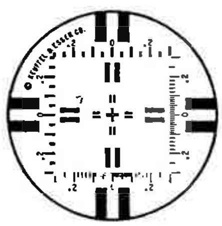


Fig. 91. Displacement Target.

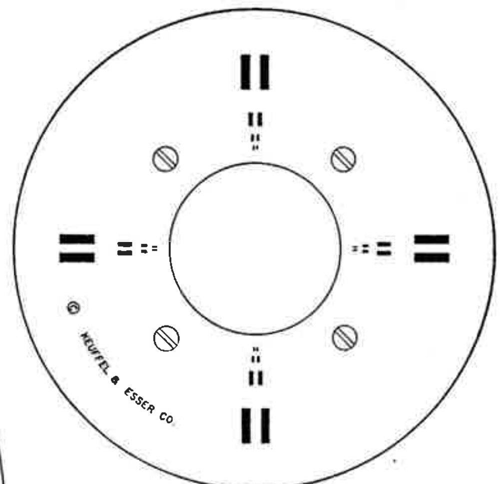
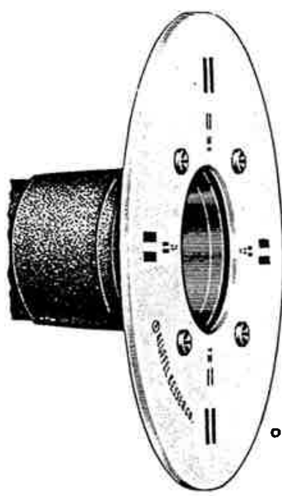


Fig. 92. Auto-Reflection Target.



9099-17
on end of P5022

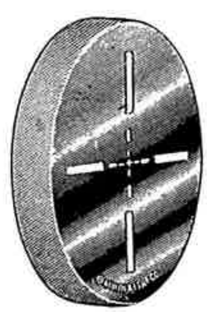


Fig. 93. Mirror Target.

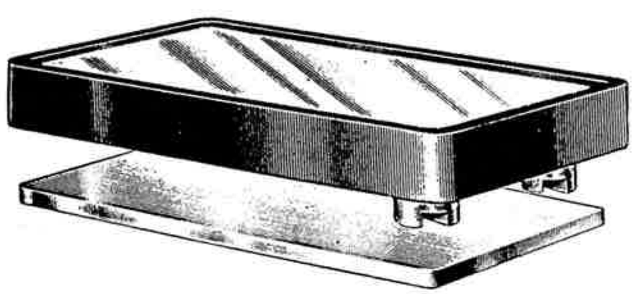


Fig. 94. Magnet Back Mirror.

K+E

OPTICAL TOOLING TARGETS AND MIRRORS

K&E makes four types of targets; Alignment Targets, a Displacement Target, Auto-Reflection Targets, and a Mirror Target. The Alignment Targets give a point of reference. The Displacement Target gives a point of reference and also has horizontal and vertical scales to measure displacements from the line of sight up to 0.3 inch. The Auto-Reflection Targets are placed on the front of a sighting telescope to give a reference point on the line of sight for auto-reflection. The Mirror Target consists of an alignment target pattern cut in the silvering of a front surface mirror. It is used to give a point of reference and also, by auto-reflection or auto-collimation, to control the tilt of the part on which it is mounted.

The patterns used on these targets are based on tests at Princeton University that are mentioned on page 4-3 in connection with Optical Tooling Scales. On Alignment and Displacement Targets, the spacings between the paired lines are the same as on the Wyteface Optical Tooling Scales. The pattern on the Auto-Reflection Target is based on a somewhat wider series of spacings. As pointed out, this pattern ensures a probable error of not more than 0.15 seconds of arc. The pattern used on the Auto-Reflection Mirror is similar to that of the Alignment Target but is necessarily modified because it consists of lines cut in the mirror surface. It is illuminated from the back and it therefore presents lines of light color against a dark background.

To complete the equipment for auto-reflection, in addition to the mirrors for the Jig Transit and the Mirror Target, K&E makes a plain mirror backed by magnets which ensures good contact with steel parts.

Alignment Targets. (Fig. 90) Three kinds of alignment targets are available. No. **9099-40** is made of 1/10 inch optical glass mounted in a hardened stabilized steel ring ground to 2¼ inch diameter. No. **9099-40U** is made of ¼ inch optical glass unmounted and ground to 2¼ inch diameter. Both can be mounted on the part to be positioned or used in the Spherical Adapter No. 9099-50. When they are mounted in the Spherical Adapter against Target Stop Ring No. 9099-51, the center of the pattern is at the center of the sphere. Thus mounted they can be used as a point of aim as described on page 1-7.

No. **9099-40½U** is unmounted and the same as No. 9099-40U except that its outside diameter is 1½ inch.

Displacement Target No. 9099-41. Fig. 91 shows the Displacement Target. It is made of 1/10 inch optical glass mounted in a hardened stabilized steel ring ground to 1½ inch diameter. It is usually mounted on the part to be positioned. As the part is brought into position, the telescope cross lines cut the scales at the point that gives the error of position. The scales are divided into different intervals as shown. The smallest divisions are 0.01 inch, the largest are 0.05 inch. When the optical micrometer is not used, displacements can be estimated with these scales.

Auto-Reflection Targets. Fig. 92 shows the appearance of the Auto-Reflection Targets. They are mounted on a sighting telescope, if it is not equipped with a built-in Auto-Reflection Target, when a mirror is to be used for auto-reflection or auto-collimation. The mounting collars are made in five sizes to fit various telescopes as follows:

Auto-Reflection Target No.	Instrument
9099-15	K&E Jig Alignment Telescopes 9092-2 and 9092-2½, etc.
9099-16	K&E Jig Transit 9092-1
9099-17	K&E PARAGON Tilting Level P5022
9099-18	K&E PARAGON Transits P5060 and P5085C
9099-19	K&E PARAGON Levels P5003 and P5010

Mirror Target No. 9099-65. Fig. 93 shows the Mirror Target. It is a front surface mirror, flat to 1 wave length of light, on ¼ inch optical glass unmounted and ground to 2¼ inch diameter. The back surface is frosted. The target pattern is cut in the silvering. When it is illuminated from behind, the pattern becomes luminous. It is used both to position a part and to control its tilt by auto-reflection and auto-collimation. When the illumination is turned off and the alignment telescope is focused on the reflection of the target at the telescope, the mirror target pattern disappears. Its use is further described on page 1-8.

Magnet Back Mirror Nos. 9099-60 and 9099-61. Fig. 94 shows the Magnet Back Mirror No. 9099-60. It is a front surface mirror flat to 1 wave length of light. Three magnetic feet are permanently cemented to the back. They are ground so that they define a surface that is parallel to the mirror surface within 3 seconds of arc. The mirror is 2¼ x 4 inches with edges protected by a band. A cover for the mirror and a steel plate to protect the ground surfaces of the magnets are furnished.

No. 9099-61 is a circular front surface mirror flat to 1 wave length of light. A large magnetic foot is permanently cemented to the back and is ground so that it defines a surface parallel to the mirror surface within 3 seconds of arc. The mirror is 2½ inches in diameter, with protected edges. A cover for the mirror and a steel plate to protect the ground surface of the magnet are furnished.

K+E

SPHERICAL ADAPTERS

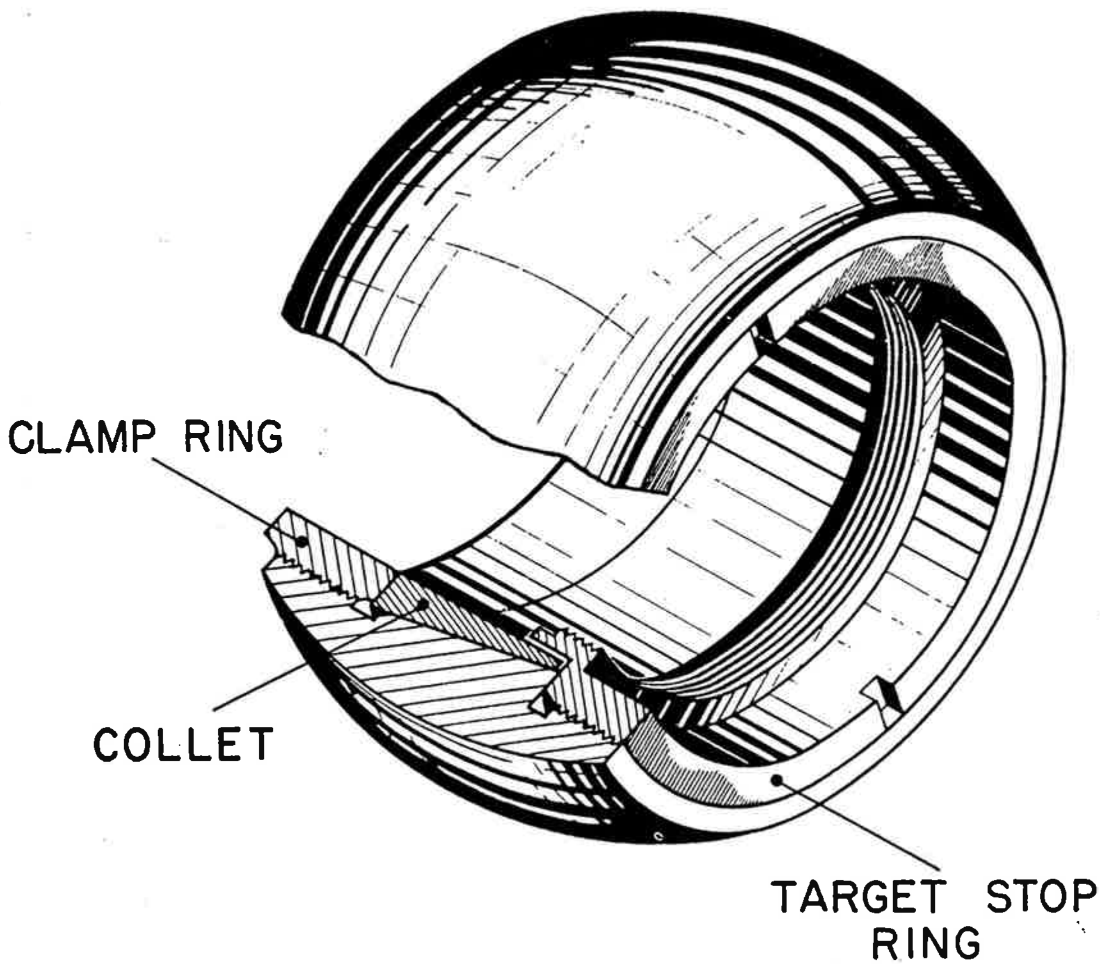


Fig. 100. Spherical Adapter and Target Stop Ring.

K+E

SPHERICAL ADAPTERS

No. 9099-50
No. 9099-53

K&E supplies the Jig Alignment Telescope with or without a sphere permanently attached. Some users prefer a movable sphere that may be positioned anywhere along the telescope tube to provide greater flexibility for clearing jig parts. Either a fixed or a movable sphere is required for most aligning brackets.

Fig. 100 shows the Spherical Adapter No. 9099-50. It provides a movable spherical mount for alignment telescopes not fitted with a fixed sphere, and for alignment targets. It can be clamped in place on the telescope tube wherever desired without disturbing the centering, by tightening the collet with the clamp ring.

When it is used to support an alignment target, Target Stop Ring No. 9099-51 is required. It positions the target correctly in the Spherical Adapter. K&E Spanner Wrench No. 9099-52 is used to turn the Clamp and Target Stop Rings.

The K&E Spherical Adapter is built to the following tolerances:

Displacement from the center of the sphere to the center of the target pattern:

Along the line of sight ±0.009 inch.

Perpendicular to the line of sight ±0.0005 inch.

Although the tolerance along the line of sight, 0.009 inch, may seem large, it affects the direction of the line of sight only if the surface of the target in the sphere is tilted at an angle to the line of sight. The target would have to be tilted at an angle of over 6^{o} to create an error of 0.001 inch. A tilt of 6^{o} is readily detected by eye.

Available also is a plain, unhardened chrome plated steel spherical adapter which is designed to carry any tube or target 2-1/4 inches in diameter. Three set screws are provided, two of them offset from the center of the sphere, to accomodate unmounted targets 3/8 in. or 1/2 in. wide. It is designated as K&E Spherical Adapter without collet No. 9099-53. A set screw is provided to clamp the item carried.

K+E

CROSS LEVEL

K+E

CROSS LEVEL
9099-14

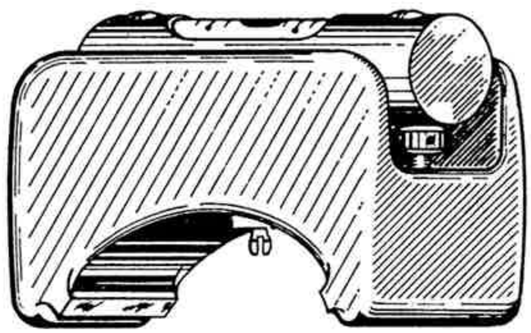


Fig. 101. The Cross Level for the Alignment Telescopes and Collimators.

Fig. 101 shows an accessory auxiliary device called a *Cross Level,* to be used with the K&E Alignment Telescopes and Collimators. It is placed on the telescope tube and positioned by a locating hole in the body of the telescope. When the level bubble is centered, the cross lines of the telescope will be vertical and horizontal. The cross level can be reversed on the tube to check its adjustment. Any targets sighted can then be rotated until they are aligned with the cross lines of the telescope. When a target is in this position, displacements will be measured along exactly vertical or horizontal lines.

K+E

TRIVET

August 1953

K+E TRIVET 9099-70

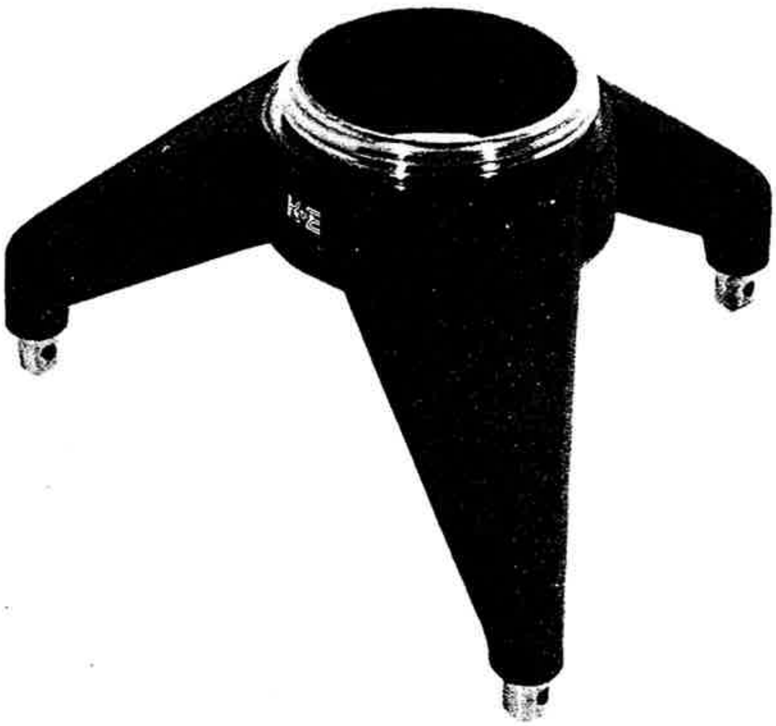


Fig. 102

The Trivet is a special device for supporting a Jig Transit, Transit or a Level near the floor or at any position where the line of sight must be low. The Trivet is very rigid in construction and is mounted on removable, hardened, steel pointed shoes. The steel shoes may be removed and the Trivet bolted directly to a jig or some other fixture. It is fitted with the standard 3-1/2"x 8 thread.

Height: 5-5/8"
Radius: 4-1/4"
Weight: 4-1/4 lbs.

K+E

AUTO-REFLECTION ANGLE MIRROR

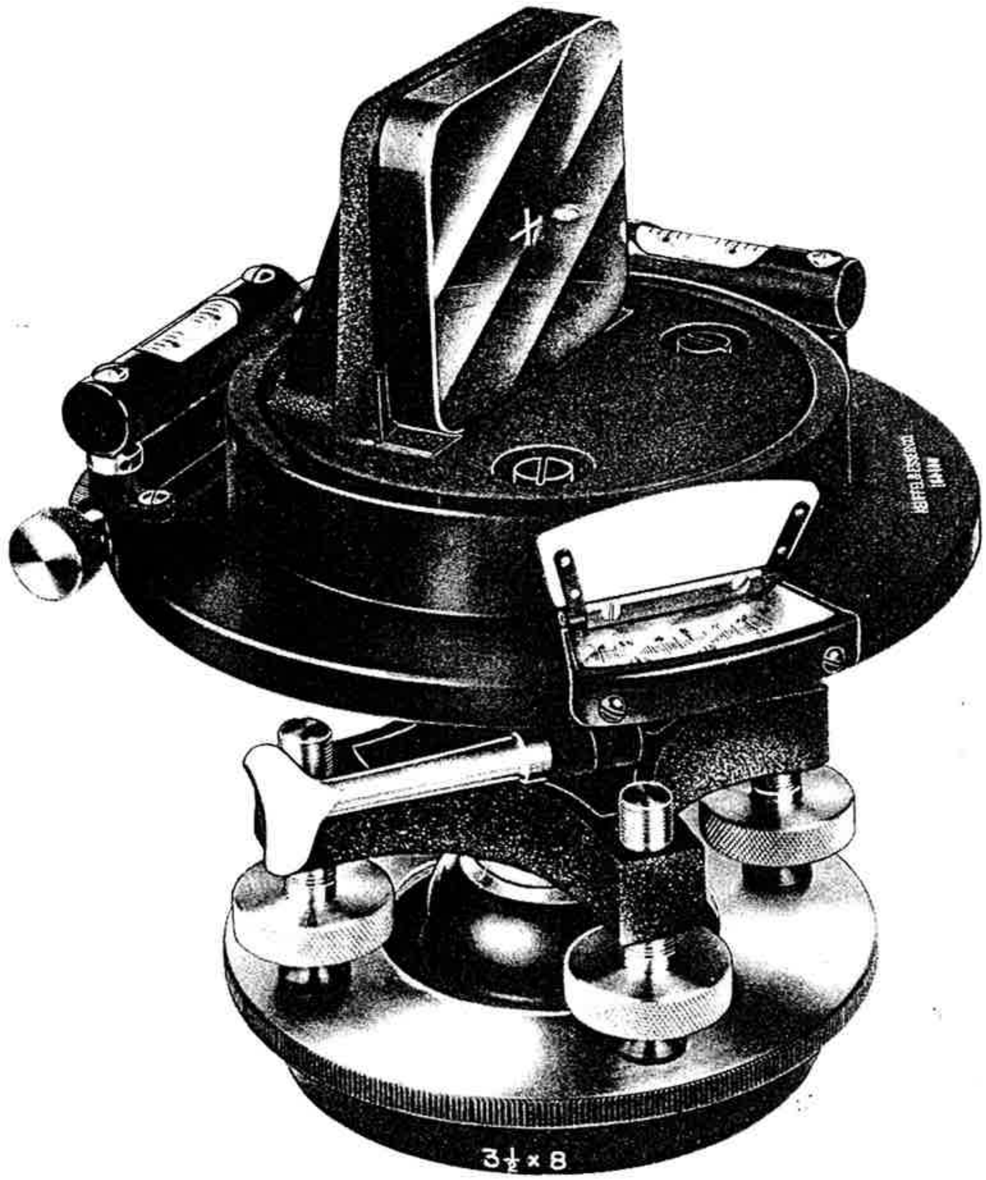


Fig. 103 The Auto-Reflection Angle Mirror

K+E

AUTO-REFLECTION ANGLE MIRROR 9092-13

The Auto-Reflection Angle Mirror. This instrument will reflect a line of sight at any desired horizontal angle (up to about 160°) from the line of sight of any telescope equipped with an auto-reflection target. (See pages 6-2 and 6-3). adapter plate, which can be attached permanently to any bracket, jig or fixture.

To Use the Auto-Reflection Angle Mirror. Fig. 104 shows the arrangement of the angle mirror in

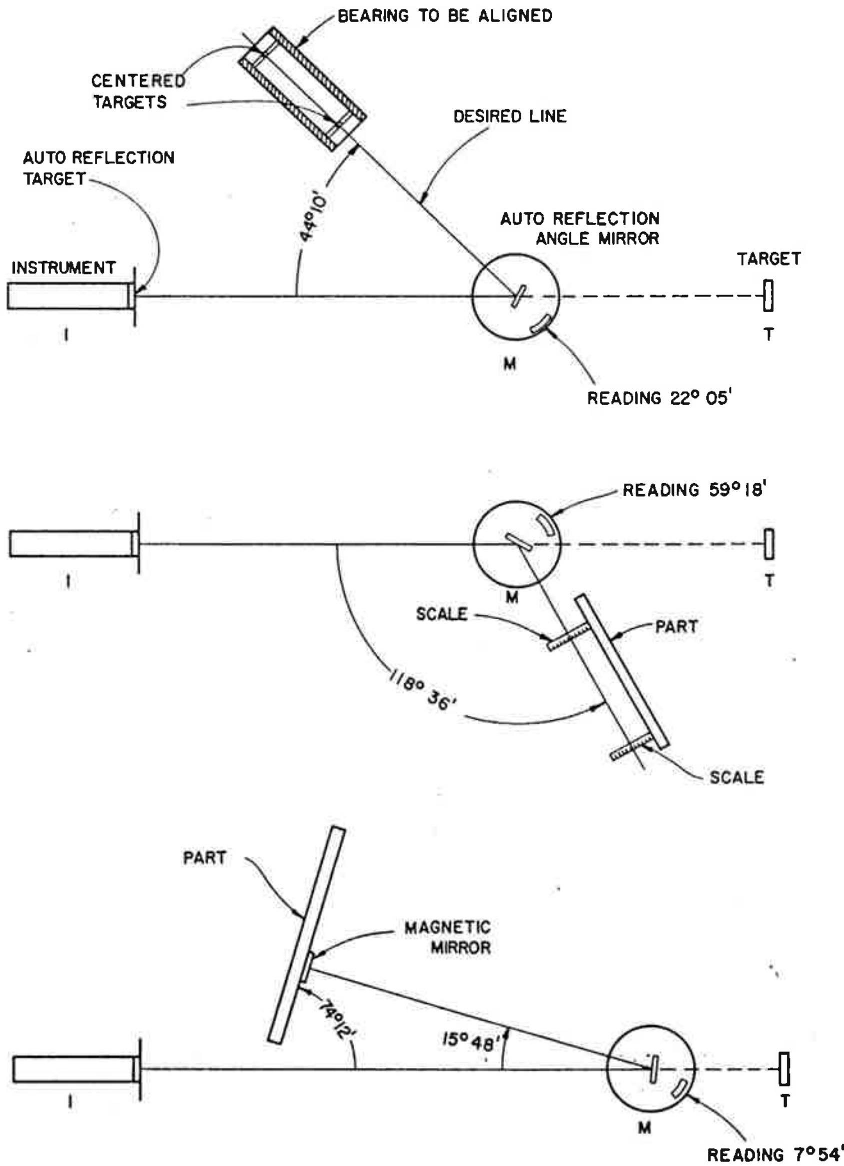


Fig. 104

The instrument consists of the base of an engineer's transit with an optically flat, front surface mirror mounted vertically on it. The mirror is adjusted so that its surface coincides exactly with the line of the vertical axis. A cross on the mirror surface shows where this line crosses the mirror.

The instrument has the standard 3½ x 8 thread base and can also be equipped with a mounting

use. *I* represents any telescope aimed at target *T*. Place the angle mirror *M* approximately in position and turn the mirror so that the cross can be seen in telescope *I*. Approximately level the mirror and then loosen all four leveling screws an equal amount, but only slightly so that the mirror does not rock. It can now be shifted horizontally a short distance in any direction. By alternately shifting and releveling, bring the cross on the mirror into the line of sight at the desired distance along the line of sight from *I*. Tighten all four leveling screws firmly, making sure that the mirror remains exactly level. Check to see that the vertical line of the cross has not moved out of the line of sight.

Free both the upper and the lower clamps. Turn the horizontal circle until one of the verniers reads approximately zero. Tighten the upper clamp and set the vernier precisely at zero with the upper tangent screw. A magnifier should be used to set the vernier.

Turn the mirror until the reflection of the auto-reflection target appears approximately on the vertical cross line of the telescope *I*. (See Fig. 28 on page 2-10.) Clamp the lower clamp and set the auto-reflection target precisely on the vertical cross line with the lower tangent screw.

Free the upper clamp and turn the mirror in the desired direction until the vernier reads approximately one-half the value of the angle it is desired to establish. In Fig. 104 at the top, the desired angle is 44° $10'$ so that the vernier is set at 22° $05'$. Clamp the upper clamp and make the setting precisely with the upper tangent screw. In laying off the angle, both verniers may be read and their values averaged to provide greater accuracy.

The vernier can be set either left or right as required. It reads directly 60 seconds of arc. With skill it can be set to the nearest 30 seconds so that the angle established should be within 60 seconds of the desired value.*

It should be noted that the operation of the instrument is almost exactly like that of an ordinary engineer's transit. If the reader desires further information on the operation of such instruments, it is suggested that he refer to one of the many available text books on surveying.

Fig. 104 shows three of the many applications of the Auto-Reflection Angle Mirror. Other applications will occur to the user.

*If desired, instruments which permit the angle to be established within 20 seconds can be furnished on special order.

K+E

COLLIMATORS

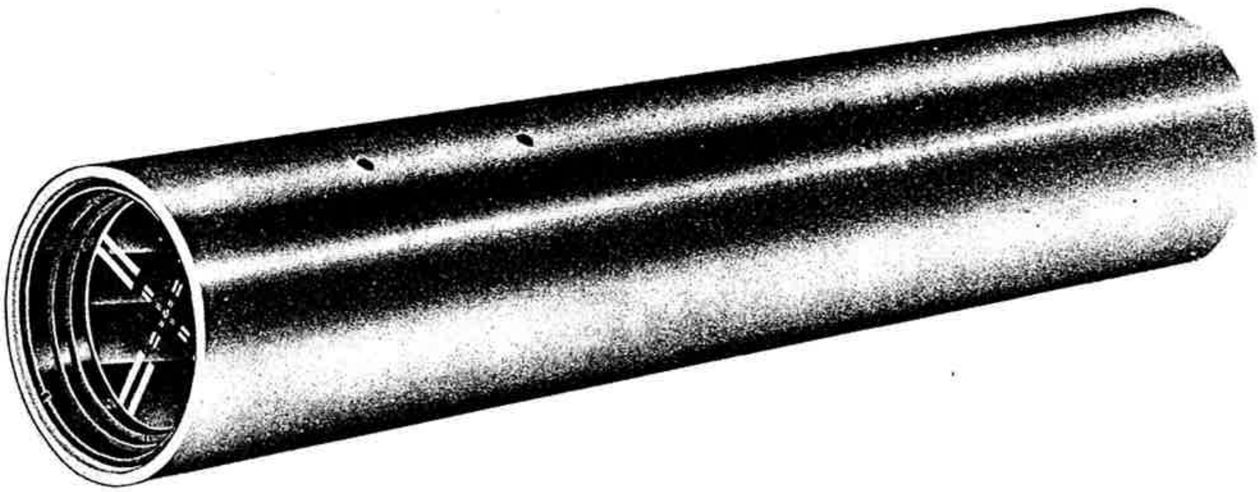


Fig. 111. **The Alignment Collimator.**

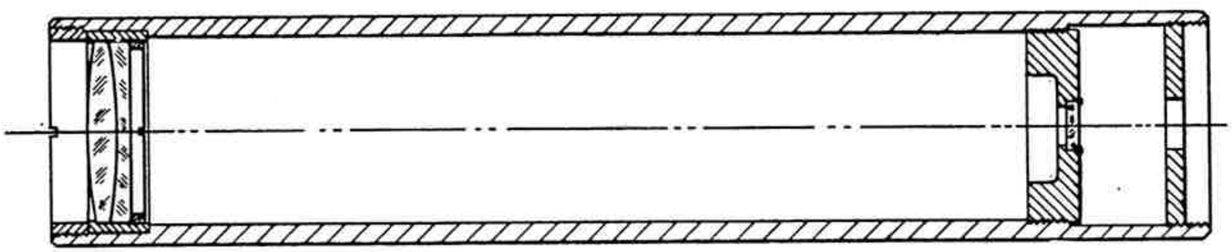
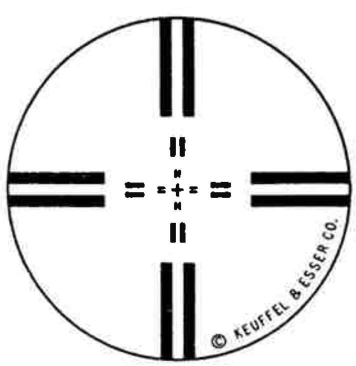
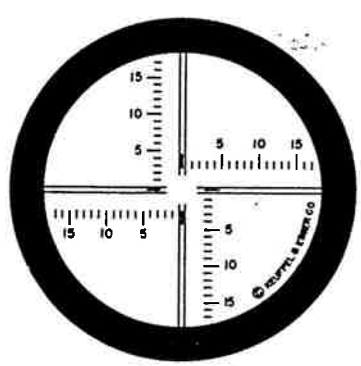


Fig. 112. **Cross Section of the Alignment Collimator.**



The Alignment Target.



The Tilt Target. The Scales Read in Minutes of Tilt.

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ALIGNMENT COLLIMATOR 9092-4

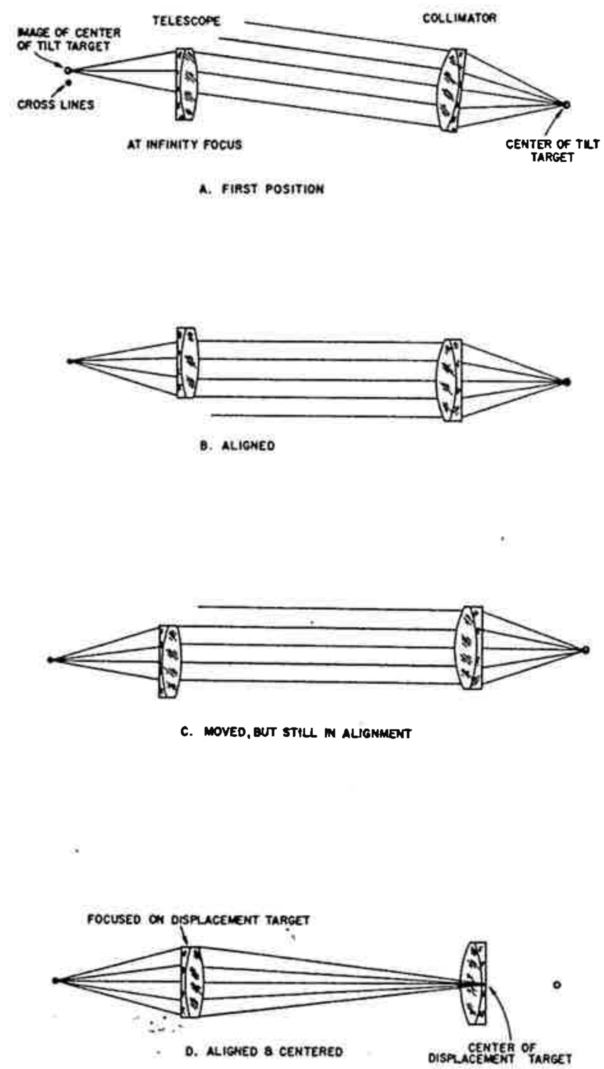
Purpose. The K&E Alignment Collimator Fig. 111, is a device that can be made to coincide with an optical line of sight in *direction* and *position* to a very high degree of accuracy. It is usually mounted on a facility gauge or on some other small jig part so that the tilt and the position of the part can be controlled by the line of sight of the alignment telescope.

Construction. Essentially the alignment collimator consists of a hardened stabilized steel tube with a hard chrome surface. Its outside diameter is the same as that of an alignment telescope, 2.2498 inches. An achromatic lens is mounted near the front of the tube and a special tilt reticule (target) is mounted near the rear of the tube at the principal focus of the lens, Fig. 112. The rear end of the tube has an inside thread 2 inches in diameter by 24 threads per inch to take a standard lighting unit (see page 11-4) which illuminates the target. An alignment target pattern is laid out on the rear surface of the lens. A small hole is provided in the wall of the tube to take a cross level. See page 8-2.

Operation. Since the tilt target is at the principal focus of the lens, the rays of light from the tilt target emerge from the lens parallel to each other. When some of these rays strike the lens of the alignment telescope, the tilt target can be made to appear in the alignment telescope. See Fig. 113a. To make the tilt target appear, the focus of the alignment telescope must be set at infinity, because the rays to be focused are parallel, like rays coming from an infinitely distant object.

When the collimator is tilted with respect to the alignment telescope, the center of the tilt target will not appear on the cross lines of the alignment telescope. See Fig. 113a. To bring the center of the tilt target on the cross lines, the collimator must be directed so that the rays that emerge from it are parallel with the line of sight of the alignment telescope as shown in Fig. 113b. When the collimator is moved by a small amount parallel to itself (without introducing tilt) and so that some rays still strike the lens of the alignment telescope, the center of the tilt target will remain exactly on the cross lines of the alignment telescope. See Fig. 113c. This must be the case, as such a movement of the collimator keeps the rays from the collimator parallel to the line of sight of the alignment telescope, as they were before.

Fig. 113. **Collimator used with a simple type of telescopic sight.**



To observe the alignment target (in the collimator), the alignment telescope is focused on it. See Fig. 113d. Since the tilt target is now out of focus, it disappears. The collimator is then brought on the line of sight as with any alignment target.

The Alignment Collimator is built and adjusted so that, when the tilt target and the alignment target are on the line of sight, the axis of the cylindrical surface of the collimator coincides with the line of sight.

Fig. 114. **K&E Collimator 9092-30 for checking straightness of line of sight.**

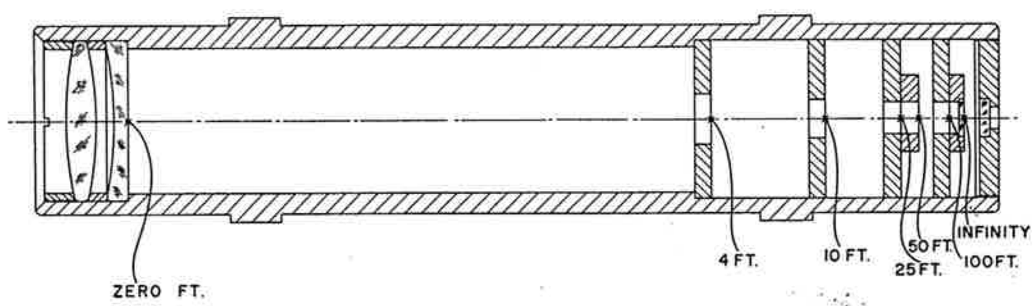
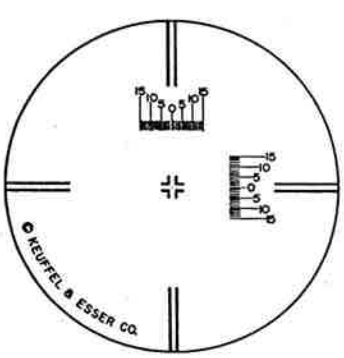
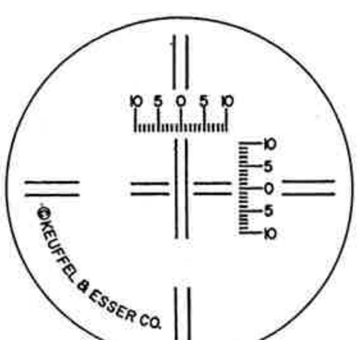


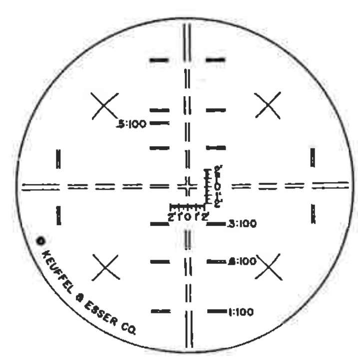
Fig. 115. **Cross section of the Collimator.**



Zero ft. target



10 ft. target



Infinity target

K+E

COLLIMATOR FOR CHECKING THE STRAIGHTNESS OF THE LINE OF SIGHT

9092-30

Purpose. Every type of optical tooling telescope contains optical parts that must be moved to focus the instrument on points at different distances. Unless the telescope is carefully constructed, this movement may affect the direction of the line of sight. If the line of sight is affected, points aligned with such a telescope will not be on a straight line, and the line of sight is said to be curved.

The straightness of the line of sight can be tested by taking careful measurements to the line of sight at different distances from the telescope and then repeating the procedure with the telescope rotated 180° on its axis. Any difference in the measurements would indicate curvature or out-of-roundness of the telescope barrel or collars. The errors sought, however, are so small that the average of a series of readings should be taken at each point and a computation made to eliminate the effect of any shift of the line of sight caused by the rotation of the telescope. The reference points from which the measurements are made to the line of sight must be so rigidly supported that there is no possible chance that any movement can occur during the test.

The K&E Collimator for Testing the Straightness of the Line of Sight is designed to offer a practical means of making this test. See Fig. 115. It contains seven reticule patterns (shown by X's in the figure) placed so that they simulate targets placed at different distances. Actually they form virtual images at the following approximate distances behind the objective: 0, 4, 10, 25, 50, 100 ft. and at infinity. When any sighting telescope is aimed into the objective, its focus must be regulated as though the reticules were actually at these distances. The targets have been centered as closely as possible on a single straight line at the factory. Since this adjustment can never be perfect, the operator must follow the procedures outlined below for the use of the collimator.

To Use the Collimator. The collimator can be used to check an alignment telescope, a jig transit, or any transit, level, or other optical sighting device, provided these can be equipped with an optical micrometer.

A light is placed behind the collimator. The telescope to be tested is bucked-in between the 0 ft. target and the 100 ft. target. Each of the other targets is sighted in turn. Any error can be measured with the optical micrometer on the telescope to be tested. If there is any doubt that the collimator is in adjustment, the collimator is rotated 180° on its own axis and the process is repeated.

Even though the collimator is out of adjustment, if a series of readings is taken, first with the collimator in the normal position, and then with the collimator rotated 180° about its own axis, any lack of straightness of the line of sight of the instrument being tested, can be calculated.

This collimator can also be used to check the conventional adjustments of optical instruments. It is used on the K&E Instrument Test Stand for this purpose.

Precise Test. A more precise test is recommended. When the position of the line of sight is measured with the optical micrometer, each drum reading is estimated to the nearest 0.0001 inch. Ten readings are taken at each target and the average used. The collimator is then rotated 180° on its own axis and the process is repeated. The mean of the averages of the direct and reversed readings for each target is computed and plotted and a smooth curve is drawn through the points, as shown in the accompanying diagram. See Fig. 116 (The data from which Fig. 116 was plotted are shown in Fig. 117). The curve is free from any possible errors of the collimator but it will show the average of the errors of position and direction caused by slight discrepancies in bucking-in on the zero and 100 ft. targets.

To find the actual deviations of the line of sight from a straight line connecting any two working points, for example the 3 ft. point and the 80 ft. point, join these points on the diagram with a straight line as shown. The deviations are the scaled offsets from this line to the curve.

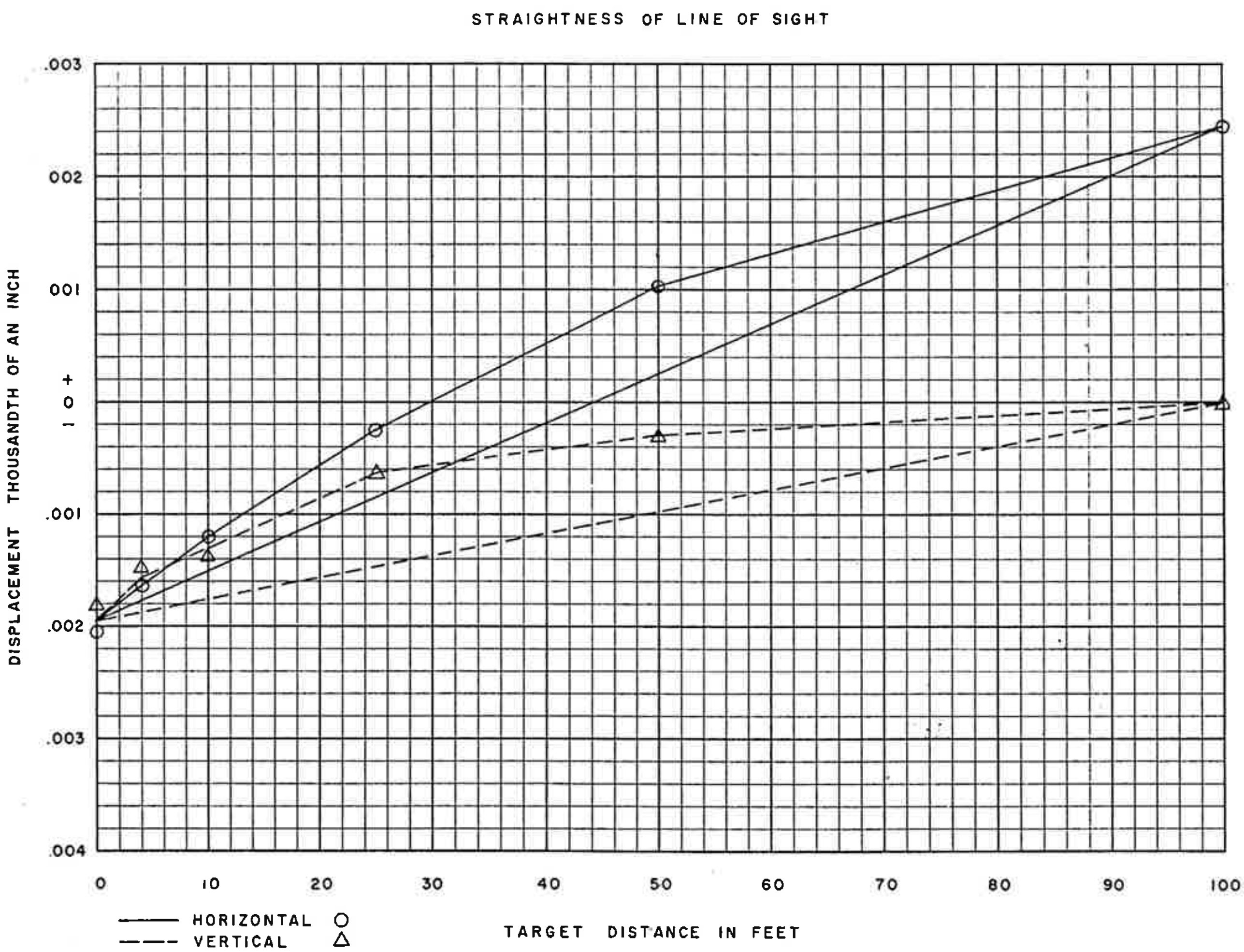


Fig. 116.

READINGS TAKEN ON TARGETS OF LINE OF SIGHT COLLIMATOR

Horizontal Readings

100 Ft. Target

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

MEAN OF AVERAGES +2.47

50 Ft. Target

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

MEAN OF AVERAGES +1.03

25 Ft. Target

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

MEAN OF AVERAGES −0.25

10 Ft. Target

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

MEAN OF AVERAGES −1.2

4 Ft. Target

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

MEAN OF AVERAGES −1.64

0 Ft. Target

Direct	Reversed
−1.9	−2.0
−1.8	−2.1
−1.8	−2.2
−1.9	−2.2
−1.8	−2.1
Avg. −1.84	Avg. −2.12

MEAN OF AVERAGES −1.98

Thus values to plot are:

100 Ft. +2.47
50 Ft. +1.03
25 Ft. −0.25
10 Ft. −1.2
4 Ft. −1.64
0 Ft. −1.98

K+E

COLLIMATOR WITH ZERO AND INFINITY TARGETS
9092-31

Purpose. This collimator is designed for use in a collimator room for adjusting instruments. See page A-4.

Construction. It is similar to the Collimator for Testing the Straightness of the Line of Sight, except that only two targets are provided, one at infinity and one at zero. The zero target is on the inside surface of the objective lens. Both targets have scales reading in both directions from zero.

Use. The instrument is used as described on page A-4. Since there are scales on the zero target, the need for external scales is eliminated.

K+E

LAMP HOUSING
No. 9092-11

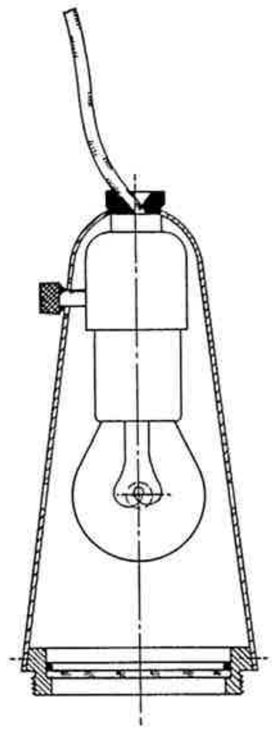


Fig. 121

The K&E Lamp Housing, (Fig. 121) is designed to illuminate the cross lines of an Alignment Collimator or any transparent target mounted in a Spherical Adapter 9099-50. It provides a socket for a minature base, pear-shaped 10 watt 120 volt frosted bulb, a thumb switch and a standard three-wire six foot cord and plug with ground lead. In front of the light is a green filter which ensures uniform illumination over the entire area and good contrast with the cross lines. The front end of the socket has a standard thread two inches in diameter with a 24 pitch.

K+E

OPTICAL TOOLING INSTRUMENT STANDS

9092-20 & 9092-20½

Purpose. It has been found that an instrument stand provides a means of supporting an instrument that is so much better suited to optical tooling than a tripod, that tripods have become almost obsolete in most plants. An instrument stand provides a very firm support that can be safely used on hard floors.

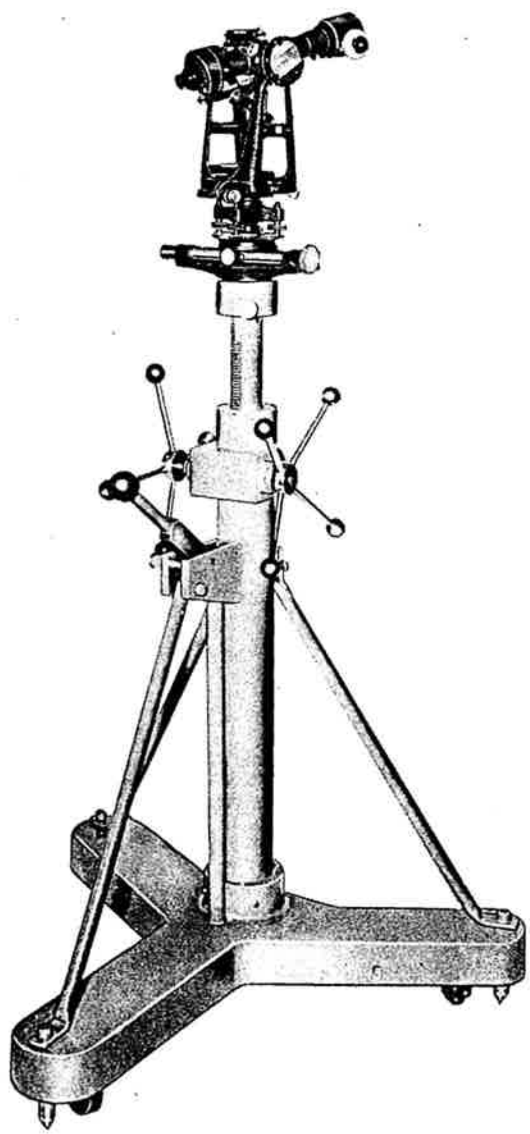


Fig. 131. **The K&E Instrument Stand with the K&E Mechanical Lateral Adjuster.**

The K&E Optical Tooling Instrument Stand. The K&E instrument stand (shown in Fig. 131) not only provides a firm and safe support but it is especially resistant to possible disturbance. It is designed to bring the instrument into exact position with a minimum of delay or difficulty.

The stand has a heavy, rigid cast iron base, with a low center of gravity. It is mounted on three rubber wheels, one of which is a caster. It can easily be rolled to the desired position, without any need for tilting it or removing the instrument from it. By means of a lever the wheels are raised off the floor and the stand is simultaneously lowered onto its three fixed steel trivet points with practically no lateral displacement. This provides a three legged support, which prevents any possibility of rocking, however uneven the floor may be, and makes it impossible to move the position of the stand accidentally.

The instrument is supported on a steel central column, raised or lowered by a rack and pinion operated by two star wheels on the horizontal pinion shaft. The column may be raised or lowered with either hand or both hands at once. Height can be smoothly and easily adjusted to thousandths of an inch. The column can be clamped at any height. When clamped, the pinion shaft can be disengaged, eliminating any possibility of the set-up being accidentally raised or lowered. When the clamp is released, the column will not drop of its own weight. The top is provided with a standard 3½ x 8-thread head. The top of the column can be turned and clamped in any direction through 360°

For the greatest convenience in bucking-in an instrument on two points or at a given station, the use of the Mechanical Lateral Adjuster No. 9099-71 (see page 14-1) is recommended.

The height of the stand is adjustable from 44 in. minimum to 72 in. maximum. When the Mechanical Lateral Adjuster is attached, the height is 46 in. minimum and 74 in. maximum.

The stand is painted a bright red so that it can be easily seen and avoided by industrial trucks, etc.

K+E

OPTICAL TOOLING LOW INSTRUMENT STAND
9092-20½

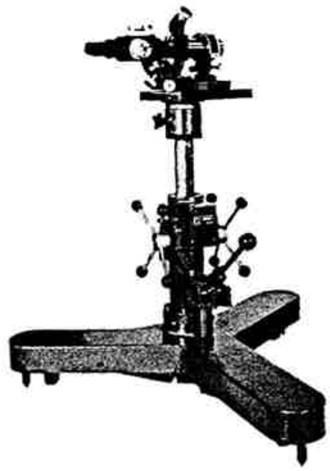


Fig. 132. The K&E Optical Tooling Low Instrument Stand.

This instrument stand is identical in all respects to the standard instrument stand 9092-20 except that it has a minimum height of 24 inches and a maximum height of 34 inches. 10 inch extension pieces can be furnished to increase the maximum height of this stand. Special extension pieces of other lengths can be furnished to order. The range of adjustment of the stand, however, is always limited to 10 inches.

EXTENSION PIECE
9092-20E

A 10 inch extension piece, 9092-20E, can be furnished to increase the maximum height of both stands 9092-20 and 9092-20½. This extension piece is fitted with a 3½ x 8 male thread at one end and a 3½ x 8 female thread at the other end.

Special extension pieces of other lengths can be furnished to order. The range of adjustment of the 9092-20½ stand however is always limited to 10 inches.

K+E

MECHANICAL LATERAL ADJUSTER

9099-71

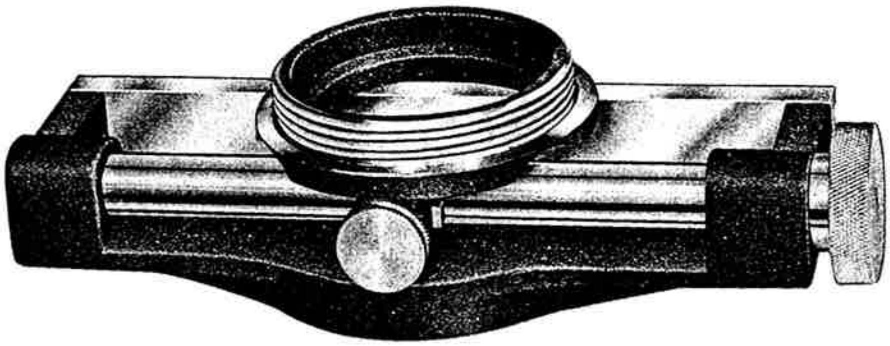


Fig. 141. The K&E Mechanical Lateral Adjuster.

Purpose. A mechanical lateral adjuster is a device to simplify the process of bucking in a transit. See page 2-7. It moves the transit left and right, thus moving the line of sight parallel to itself.

The K&E Mechanical Lateral Adjuster. Fig. 141 shows the K&E Mechanical Lateral Adjuster. It has been carefully designed for very nearly straight line movement and especially smooth action. This eliminates most of the releveling after the instrument has been moved and makes placing the instrument on line a smooth, precise operation.

The adjuster is operated with a clamp and slow motion screw. When the clamp is free, the transit can be slid freely left and right over a range of 5½ inches for approximate positioning. When the clamp is tightened. the slow motion screw is used to bring the instrument into precise position. Since large movements are not dependent on the slow motion screw, a fine thread can be used to increase the accuracy of setting.

The adjuster can be screwed onto a standard 3½ x 8 inch thread so that it can be mounted on a K&E Instrument Stand, trivet or any tripod. The mount for the transit is also a standard thread so that any instrument can be mounted on it.*

* Some very old instruments and tripods do not have standard thread and may require special adapters.

K+E

OPTICAL TOOLING SQUARE

9092-14

K+E

OPTICAL TOOLING SQUARE
9092-14

Purpose. An optical tooling square is a device which, when used in conjunction with an alignment telescope, will establish a plane in a given position perpendicular to an established line of sight. Due to the necessity for great accuracy, most optical squares are based on pentaprisms, which, for several reasons, can be used to establish very accurate right angles.

Pentaprisms. A pentaprism has the ability to turn a line of sight through a right angle even though it is not accurately aligned itself. Fig. 151 shows how it operates. Although it is rotated to different positions in the two parts of this figure, the line of sight is turned exactly 90° in both.

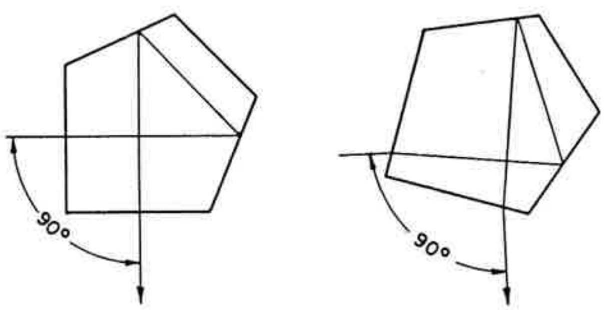


Fig. 151. **A pentaprism. It turns the line of sight exactly 90° no matter how it is rotated.**

Adjusting Wedge. The accuracy of the right angle depends on the accuracy to which the angles between the surfaces of the pentaprism are ground. Since it is next to impossible to grind the glass to precisely the required angles, a flat wedge should be used to correct any residual error.

A flat wedge bends the line of sight slightly towards its thickest part. By turning the wedge, the exact value of the right angle may be regulated. (See Fig. 152).

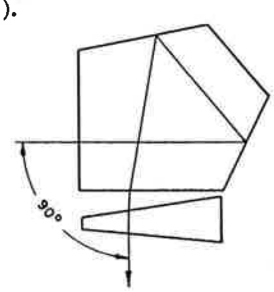


Fig. 152. **An adjusting wedge is used to perfect the right angle.**

Tilting the Pentaprism. It must be remembered that the line of sight is turned 90° only when it is in a plane parallel to the paper in Figs. 151 and 152, that is to say, in a plane perpendicular to the line which would be formed by the intersection of the two reflecting surfaces of the pentaprism. If it enters at an angle, it will be turned slightly more than 90°. This error does not build up very fast at first when the pentaprism is only slightly tilted out of the proper plane. Nevertheless, the pentaprism must be properly aligned with the basic line of sight to prevent errors of this type creeping in.

Operation of the K&E Optical Tooling Square. Fig. 153 shows a cross section of the K&E Optical Tooling Square. It can be mounted on: (a) Alignment Telescopes; (b) Aligning Tubes; (c) Alignment Collimators, which have barrel diameters conforming to Aircraft Industry Association standards.

The pentaprism is mounted in a spherical housing of standard diameter. The housing is so designed that when it is positioned on the barrel, the line of sight will pass through the center of the spherical surface of the housing. The pentaprism is so placed that the vertex of the right angle formed will also be at the center of this spherical surface. Accordingly, once the cup mount has been located on the work so that the line of sight is in its desired position, when the whole assembly is removed and replaced, the line of sight will be returned to its original position.

A standard bracket may be used, but a K&E Alignment Telescope Bracket, 9099-57, with the 9099-57½ Bracket Extension, is preferable because this combination has tangent screws that make it possible to control the rotation of the pentaprism exactly as desired, and will give more stable support for an alignment telescope. If the combination is to be mounted on a tooling bar, or any other flat surface, where a cup mount has not been provided, the K&E Y Bracket, 9099-58, should be used. This device is especially easy to regulate. Fig. 154 shows the Optical Tooling Square with the alignment telescope mounted in a bracket.

The Optical Tooling Square is slid over the end of the device on which it is mounted. When the end of the telescope tube is almost in contact with the surface E, (Fig. 153), and the pentaprism

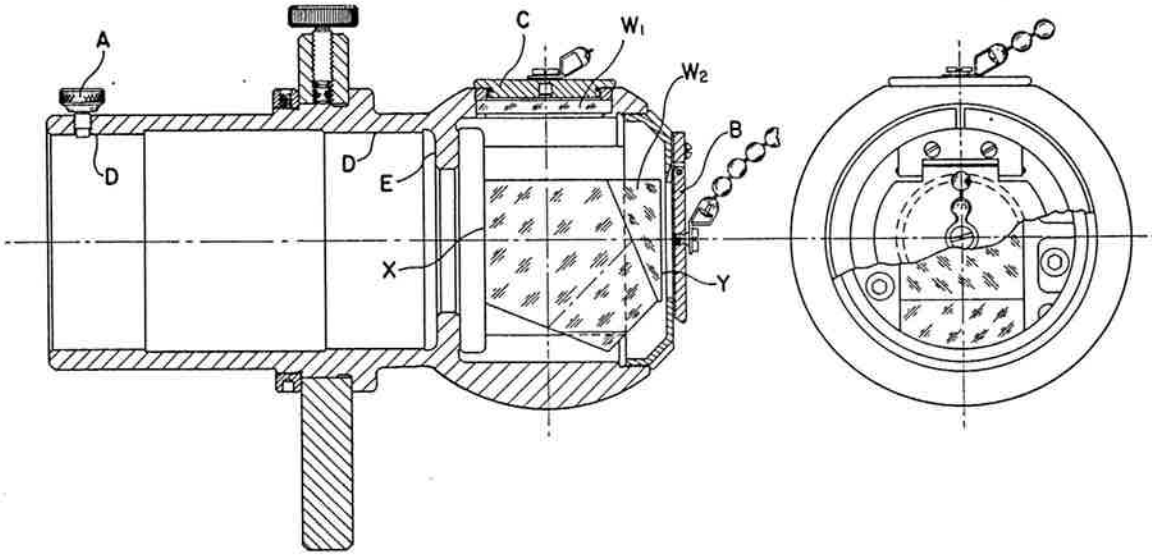


Fig. 153. **Cross Section of Optical Tooling Square.**

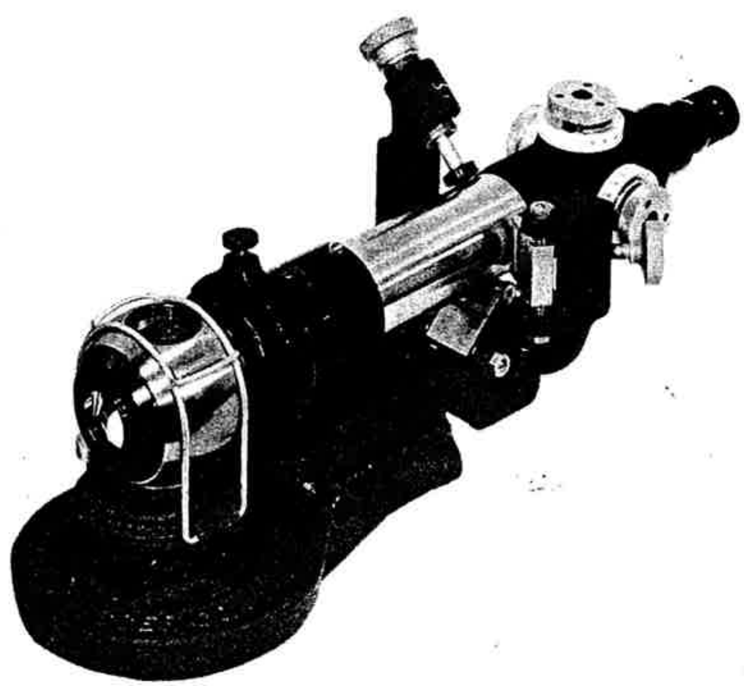


Fig. 154. **Optical Tooling Square attached to alignment telescope supported in alignment bracket with bracket extension.**

is square with the telescope cross lines, screw A may be seated in the hole of the telescopic tube. (This is on K&E telescopes only.) The two surfaces D ensure perfect alignment between the line of sight and the pentaprism. The very small amount of play between the barrel and the surface D is so slight that it will not affect the centering of the line of sight in the sphere or the 90^o angle.

When cap C is removed, the line of sight is turned through the right angle. It then passes through the correction wedge W_1. This has been set at the factory so that the right angle is correct to within one second. When cap B is turned out of the way, and cap C replaced, the line of sight goes straight through the device. Wedge W_2 is made so that surface X is parallel to surface Y, and both are perpendicular to the line of sight. Therefore, there is no deflection or displacement of the line of sight as it passes through the optical square.

Application of the Optical Tooling Squares. Optical Tooling Squares are used when it is desired to establish a line of sight in a plane perpendicular to an established line of sight. In the aircraft industry, such a plane is usually established at several station positions along the jig or the tooling bar, so that interior parts of the jig can be accurately positioned. In the machine tool industry, they may be used to establish or check the perpendicularity between horizontal and vertical ways or two horizontal ways of large machine tools, or the perpendicularity of a rotating spindle to a machine table.

In any set-up, to accomplish these objectives, it is necessary first, to establish a basic line of sight parallel to whatever fundamental plane or line is to be used as a reference. It is then necessary to place the optical square in the line of sight, correctly positioned for station, displacement and tilt.

K+E

ADJUSTABLE CUP MOUNT

9099-54

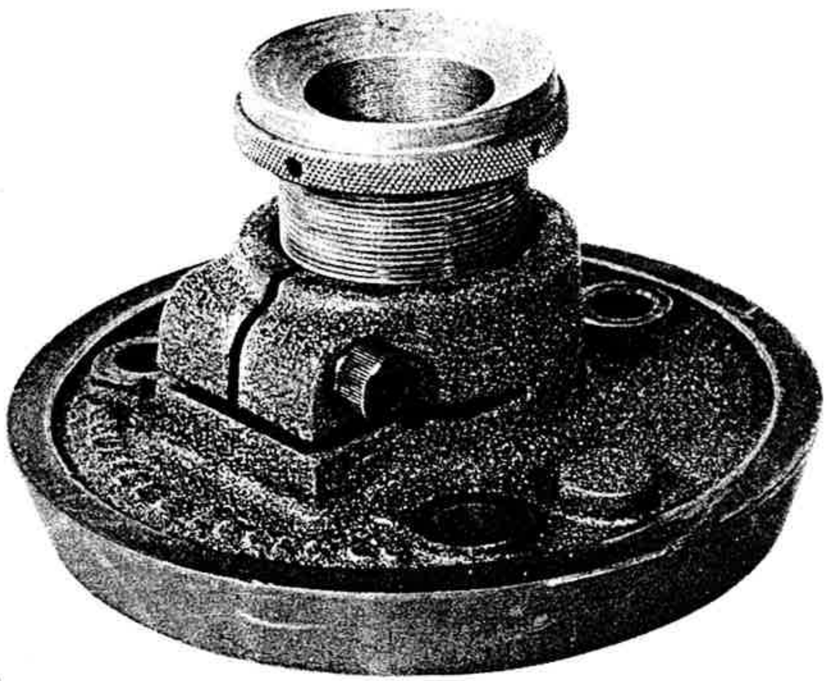


Fig. 161. Adjustable Cup Mount

The K&E Adjustable Cup Mount, 9099-54, furnishes a convenient support, adjustable in height, for the Spherical Adapter, 9099-50, or the Spherical Adapter without Collet, 9099-53. The combination of the adjustable cup mount and the spherical adapter is used for the permanent positioning of the target, alignment telescope, alignment collimator, or alignment tube, on the jig or fixture. It may also be used as a support for the Optical Square 9092-14.

The base is of cast iron and is provided with three holes which may be utilized when the mount is being bolted to a jig or other fixture.

The cup mount is adjustable in height through a range of 1¼ inches, and a clamp is provided to secure the height to which it has been adjusted. The base is machined to the correct diameter for insertion into the opening provided in the alignment telescope bracket, 9092-57. The vertical column of the cup mount is hollow so that a line of sight may be projected downward into it as might be desired when using it to support the optical square.

K+E

CLAMP FOR CUP MOUNT

9099-54½

Fig. 171. K&E Clamp for Cup Mount attached to Cup.

The K&E Clamp for Cup Mount 9099-54½ furnishes a convenient means of clamping the sphere attached to an alignment telescope or a spherical adapter, carrying a target, etc., to a cup mount.

The clamping action is around the head of the cup mount so that if the latter is of the adjustable type, the whole assembly may be raised or lowered without the necessity of constantly adjusting the clamp as this is done. It is designed to accomodate spheres of standard diameter when these are placed in cup mounts having either wide or narrow lips.

A unique feature of this clamp is that it grips the sphere near the edge of the opening passing through it so that measurements may be made to the sphere's surface directly opposite its center and at right angles to the line of sight.

The clamp holds the sphere securely in the cup mount regardless of whether or not the column of the mount is vertical, horizontal or inclined at some other angle. The open basket-like construction will not obstruct the line of sight of the K&E Optical Square.

 July 1955

K+E

ALIGNMENT TELESCOPE BRACKET

9099-57

K+E

ALIGNMENT TELESCOPE BRACKET
9099-57

The K&E Alignment Telescope Bracket, 9099-57, is an exceptionally well designed standard type bracket. It will accomodate all makes of alignment telescopes which can be supported near the objective end in a sphere or spherical adapter of standard diameter. It may also be used for collimators and similar instruments with this type of support. The bracket is of a very rugged construction. The aiming mechanism provides a smooth, precise movement for aiming the telescope or collimator both in azimuth and elevation. The aiming screws can be clamped in position so that they cannot be turned accidentally. The bracket can be attached to the base of a standard cup mount and clamped at approximately the desired azimuth by means of a lock screw located near the other adjusting screws.

The clamp screw, in the yoke cradling the telescope near the eye end, which is spring loaded, as is conventional in most alignment telescope brackets, has in addition a fast action multiple thread screw for backing off. This permits the telescope to be inserted or removed from the bracket quickly.

The two arms in the yoke terminate in rollers on which the telescope barrel rests. These dissipate any friction or strain resulting from clamping or adjusting the position of the telescope in elevation and azimuth. The pivot points about which these two supporting arms rotate, are cone shaped and adjustable to compensate for wear.

The yoke may be removed from the base of the bracket and repositioned so that it will cradle a telescope when the base is secured to an inclined or vertical surface or to the under side of a horizontal surface as well as on top of a horizontal surface.

An Extension Bracket, 9099-57½, is provided when the alignment bracket is used to support an alignment telescope with the K&E Optical Square attached.

Fig. 181a. K&E Alignment Telescope Bracket.

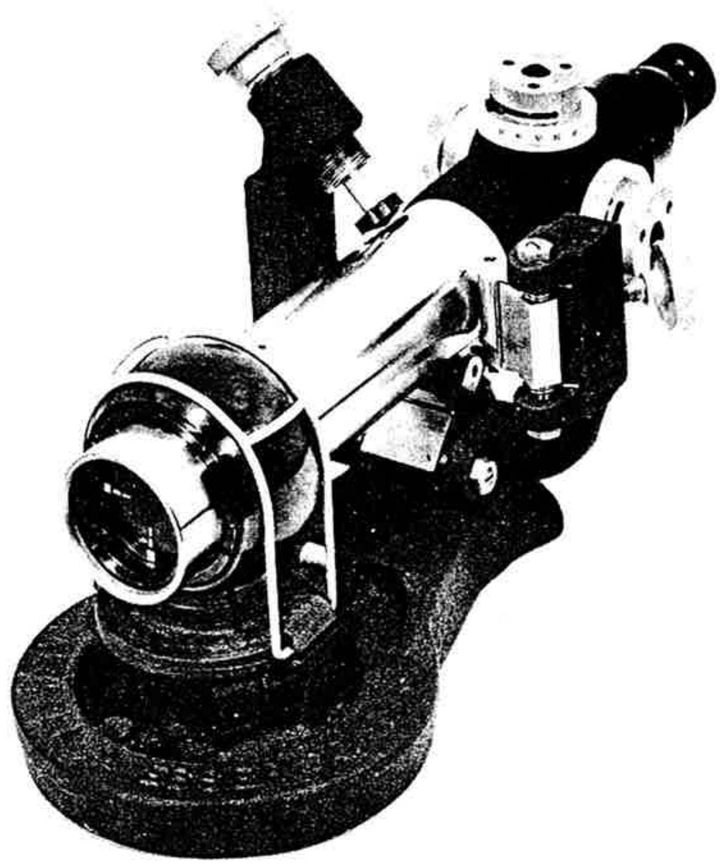


Fig. 181b. K&E Alignment Telescope Bracket supporting an alignment telescope on top of a flat horizontal surface.

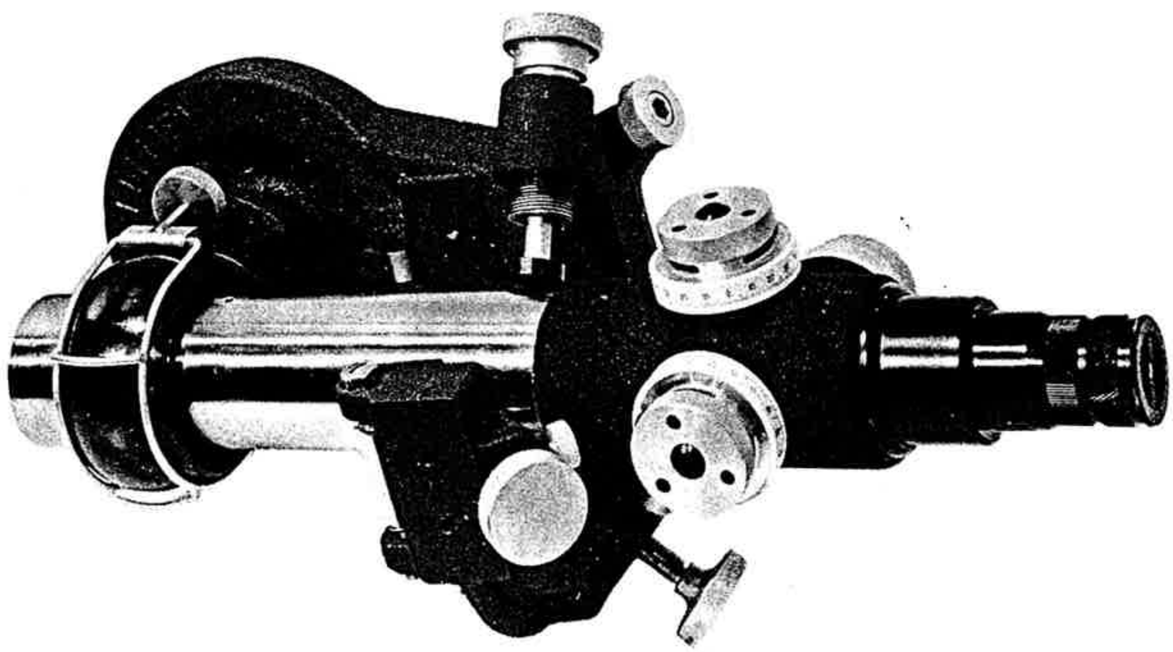


Fig. 181c. K&E Alignment Telescope Bracket supporting an alignment telescope from a vertical surface.

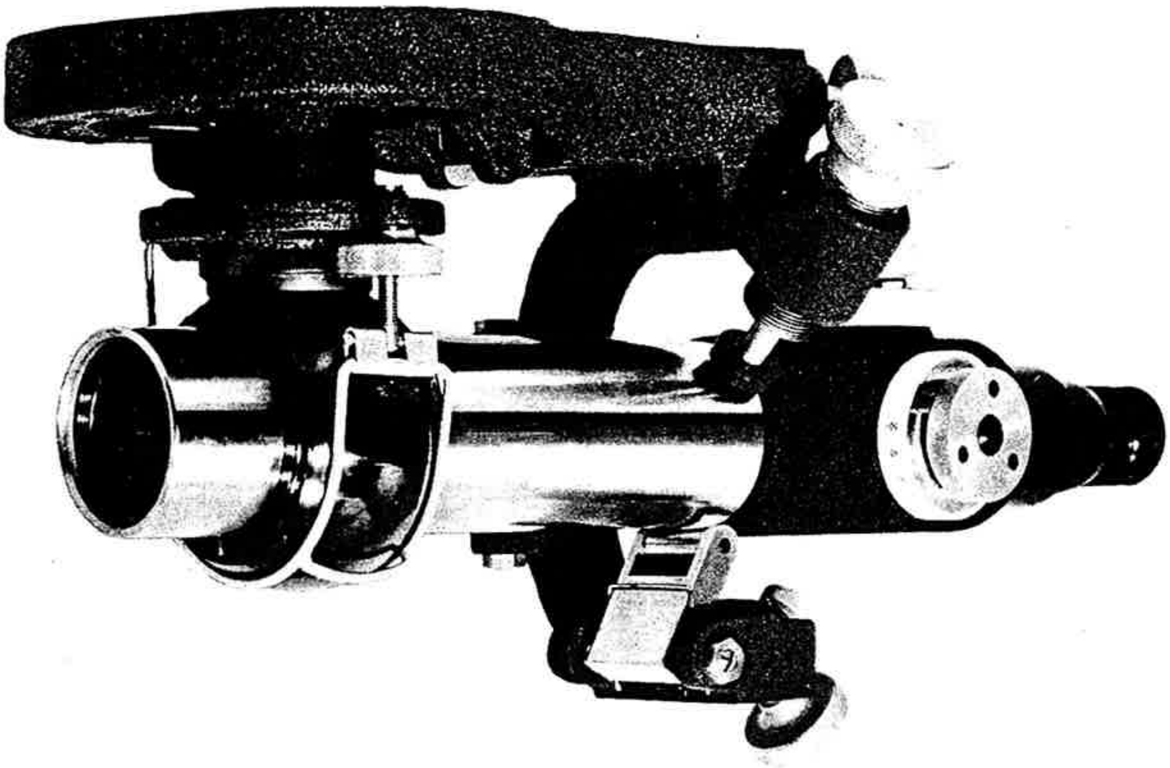


Fig. 181d. K&E Alignment Telescope Bracket supporting an alignment telescope from the under side of a horizontal surface.

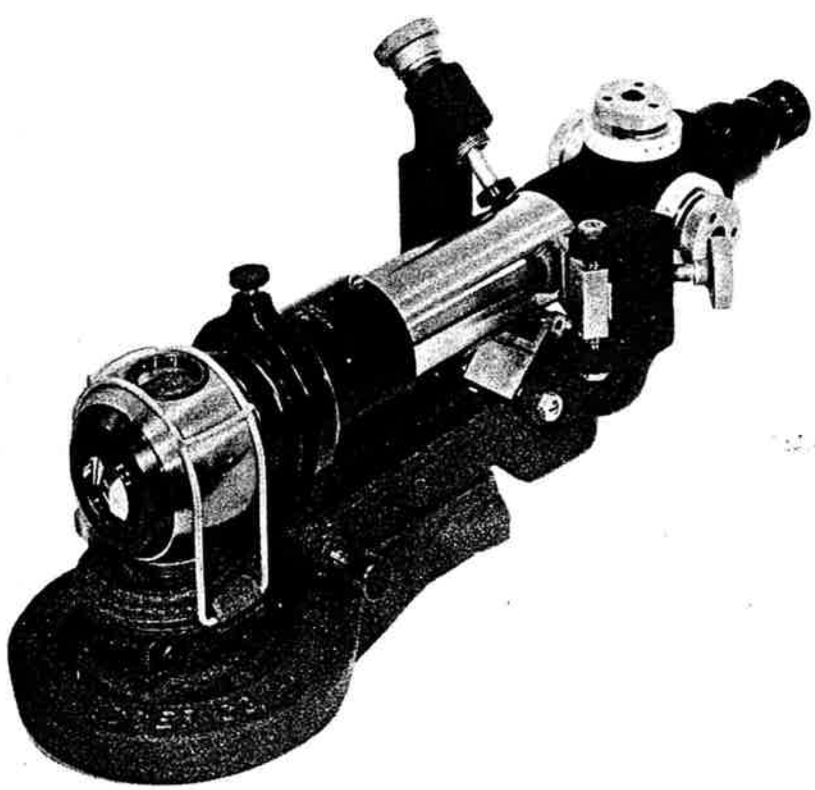


Fig. 181e. K&E Alignment Telescope Bracket with extension supporting an alignment telescope with K&E Optical Square attached.

K+E

ADJUSTMENTS OF OPTICAL TOOLING INSTRUMENTS

APPENDIX
TO THE
K&E OPTICAL TOOLING MANUAL

Page

Adjustments of Optical Tooling Instruments A3-A5

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THE ADJUSTMENTS OF OPTICAL TOOLING INSTRUMENTS

The adjustments of optical tooling instruments should be tested frequently, but no adjustment should be changed unless it has been tested several times and each test has shown the same degree of error in the adjustment. If the indications differ, either an error has been made in the test or the test procedure is not sufficiently precise to be used as a basis of adjustment.

The adjustments are not entirely independent of each other. They interfere with each other least when they are made in the order given in the following pages for each instrument. However, all of the tests should be rechecked when any adjustment is changed. In the case of some adjustments, one adjustment may seriously change another. Interference of this kind is specifically noted in the instructions.

PERMANENT TESTING EQUIPMENT

Where instruments are frequently tested, permanent testing equipment should be installed. Collimators facilitate these tests and they can be set up in a small room, but, if space is available, ranges can be substituted. Both arrangements are described. The test equipment should be located where there is a minimum of vibration and where air currents, particularly from fans, air conditioners, or heaters do not interfere with sight lines.

A Test Range

Fig. 1 illustrates a test range. The instrument can be placed on any type of firm support not subject to movement caused by deflections in the building or the movements of the operator. If necessary, it can be placed on a tripod outside a building. Preferably it should be placed on an elevating stand located where the distance *ID* can be as long as possible.

Targets must be placed at *A, B, C, D, E*, and *F*.

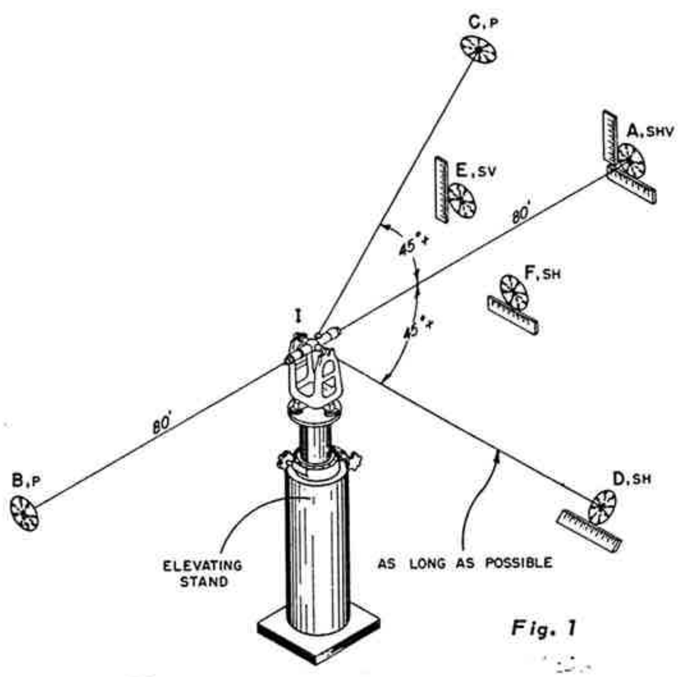

Fig. 1

Each should present a well defined point. Some must have scales in addition. Those marked *P* (at *C* and *B*) require no scales, those marked *SH* (at *D* and *F*) require horizontal scales, the scale marked *SV* (at *E*) must be a vertical scale and the scales marked *SHV* (at *A*) must be both vertical and horizontal. Optical tooling targets are recommended. Any target can be used as long as it is well illuminated. The scales can be arbitrary but the vertical scales at *A* and *E* must be laid out in the same units. The line *BIA* should be approximately straight and level, *BI* and *AI* should be nearly equal in length and each about 80 feet long. The lines *IC* and *ID* should be in approximately a vertical plane but the plane need not contain *IA*. The vertical scales at *E* and *A* should be carefully set with a precise level so that the zeros or corresponding divisions are exactly at the same elevation. The distance of *E* and *F* from *I* should be not less than the longest minimum focus of any instrument to be tested, and *E* and *F* should be placed as close to the line *AI* as possible, without obstructing the sight from *I*.

a horizontal scale on the reticule. If it does not have a horizontal scale on the reticule, it *must* be provided with an eyepiece that can be mounted in the place of the illuminating lamp.

Collimator *A* *must* be mounted so that it can be quickly and easily adjusted to point up or down a few degrees. If it has no horizontal scale on the reticule, it *must* also be mounted so that it can be quickly and easily adjusted to point left and right a

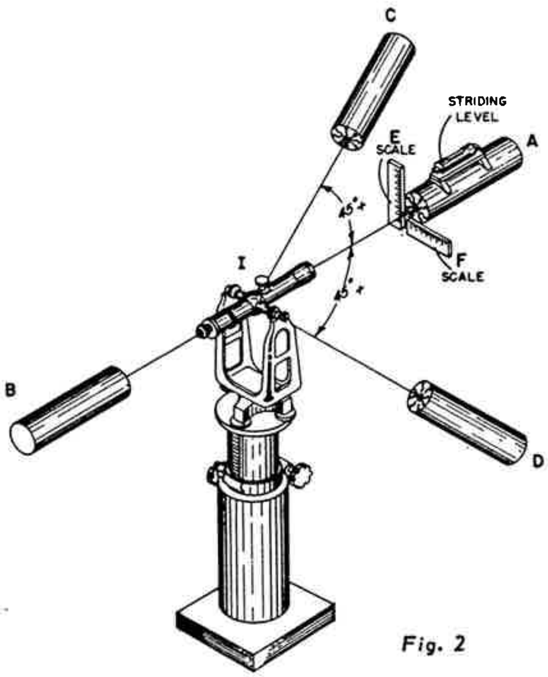

Fig. 2

A plumb bob (not shown) hanging in a bath of oil should be placed where it can easily be seen through the Jig Alignment Telescope when it is being adjusted.

A Collimator Room

Fig. 2 illustrates the arrangement of a collimator room. The instrument should be supported on an elevating stand. Neither the instrument nor the collimators should be subject to movement caused by deflections of the building nor the movements of the operator.

A plumb bob (not shown) hanging in a bath of oil should be placed where it can easily be seen through the Jig Alignment Telescope when it is being adjusted.

Four collimators are required as shown. Each must have a *point reticule*, that is to say, a reticule that presents a point by the intersection of lines or otherwise. In addition, collimator *D* must have a horizontal scale on the reticule as well.

Collimator *A* may be equipped in several ways. The test procedure depends somewhat on how *A* is equipped. It *must* have a striding level. It *may* have few degrees.

A finely divided vertical scale and a similar horizontal scale must be mounted beside and below the objective of collimator *A* as shown. The distance to the instrument stand should be not less than the longest minimum focus of any instrument to be tested.

The other collimators may be permanently mounted at any convenient distances from the instrument. It is convenient to design the mountings so that they may be moved laterally as well as pointed a few degrees in any direction before they are permanently set in position.

Collimator *B* must be mounted so that the line *AIB* is straight. This is not a simple process, as explained below.

Even when the collimators are set in the *incorrect* positions as shown at the top of Fig. 3, when observed with an eyepiece on collimator *A*, the cross lines in *B* will appear on the cross lines in *A* and the cross lines of both collimators will appear on the cross lines of the instrument *I* when observed with this instrument. But it will be seen that the

The Striding Level
No. 9099-10

Object. ***To make the striding level center when the horizontal axis is horizontal.***

Test. Place the striding level on the telescope axle collars. Turn the telescope in azimuth in line with a pair of opposite leveling screws. Center the striding level bubble using the leveling screws. Reverse the striding level. The bubble should center.

Adjustment. Move the bubble halfway toward the center with the leveling screws. Center it with the opposed capstan nuts at one end of the level tube.

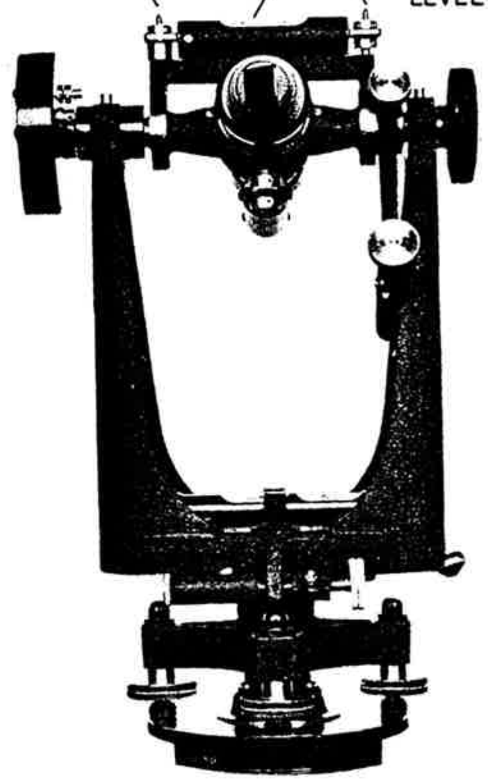

Fig. 7

ADJUSTMENT OF THE K&E JIG ALIGNMENT TELESCOPES
Nos. 9092-2 and 9092-2½, etc.

There are only three field adjustments which may be necessary to K&E Jig Alignment Telescopes.

a. To adjust the vertical cross line relative to the cross level locating hole.
b. To adjust the cross lines so that the line of sight is parallel to the outside diameter of the telescope barrel.
c. To adjust the optical micrometer so that the line of sight is centered with the telescope barrel.

To make the above adjustments it is necessary to first remove the eyepiece from the telescope by unscrewing it. (See illustration below). The reticule cover should then be unscrewed and the eyepiece replaced in the telescope. The alignment telescope should then be set up in V blocks.

Before testing the instrument, note the paragraphs at the beginning of the section on The Adjustments of Optical Tooling Instruments.

1. Object. ***To adjust the vertical cross line relative to the cross level locating hole.***

Test. Aim the telescope so that the vertical cross line is lined up with a plumb line. Mount the cross level on the alignment telescope and rotate the telescope in the V blocks until the bubble in the cross level is centered. Reverse the cross level and if the bubble does not center, rotate the telescope in the V blocks until the bubble has moved back one-half of the error observed. Repeat the whole operation until the bubble stands at the same graduation in either position. The vertical cross line of the telescope should then be checked against the plumb line by sighting through the telescope. If the cross line is not parallel to the plumb line the reticule must be rotated until it is.

Adjustment. Loosen two adjacent reticule adjusting screws. Gently tap the sides of the screws so that they move around the telescope until the

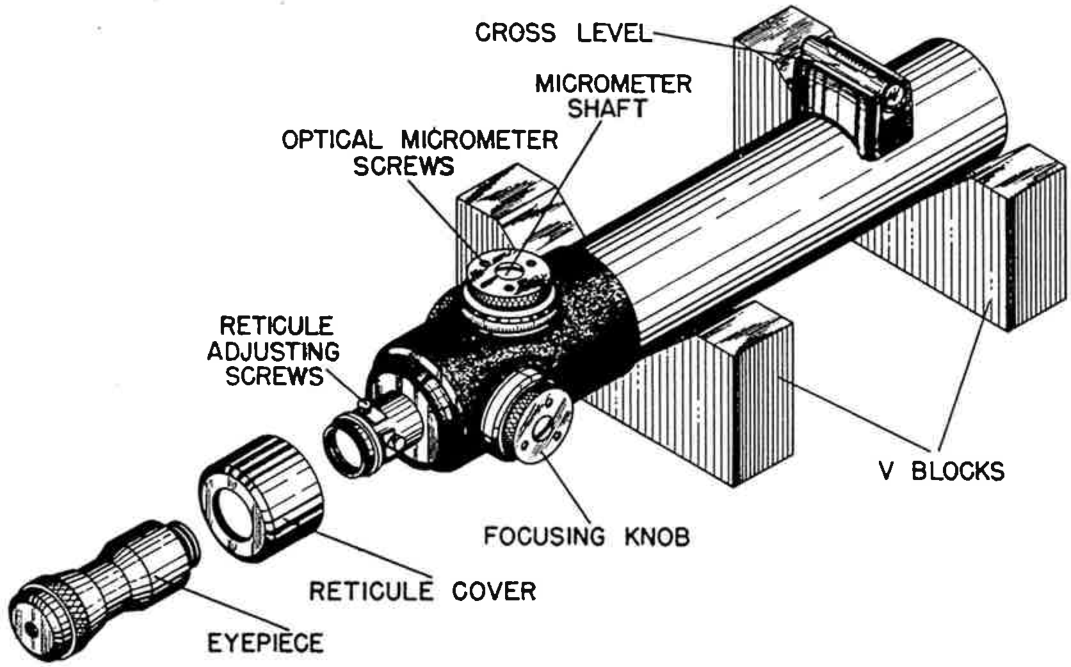

Fig. 8

vertical cross line is rotated to its correct position. Tighten the same screws. As the cross lines are placed on the reticule at right angles at the factory, when the vertical line is correct, the horizontal line is also in its correct position.

This adjustment destroys Adjustment 2 and may affect Adjustment 3.

2. Object. ***To adjust the cross lines so that the line of sight is parallel to the outside diameter of the telescope barrel.***

Test. Aim at a collimator or at a target 200 ft. or more distant. Rotate the telescope 180 degrees in the V blocks. The cross lines should remain centered on the target.

Adjustment. Loosen the bottom reticule adjusting screw. Then by loosening one side screw and tightening the other alternately by small equal increments, correct for one-half the horizontal error observed. Tighten the top screw to its original tension. Repeat the test. Adjust the reticule vertically in a similar manner. Repeat both the test and the adjustments until the cross lines remain on the target when the telescope is rotated 180° in the V blocks.

In making this adjustment, the position of the vertical cross line relative to the cross level locating hole may have been disturbed. It is therefore necessary to recheck Adjustment 1.

3. Object. ***To adjust the optical micrometers so that the line of sight is centered with the telescope barrel.***

Test. Set both optical micrometers at zero. Aim the telescope at a target placed as near the objective end as possible. Rotate the telescope 180° in the V blocks. If any apparent movement of the cross lines with respect to the target is observed, turn the horizontal and vertical micrometers so that the cross lines appear to have moved one-half of the error noted. Recenter the cross lines on the target by aiming the telescope. Rotate the telescope 180°. If apparent movement of the cross lines relative to the target is still observed, the micrometer must again be reset. This operation should be repeated until no movement of the cross lines relative to the target is observed.

Adjustment. With the micrometer in the final position, loosen the three screws on the top of the micrometer knob, taking care not to turn the micrometer shaft. Turn the micrometer knob so that the zero division is lined up with the index on the barrel. Tighten the three screws. With the micrometers set at zero, repeat the test.

The telescope should now be reassembled. First remove the eyepiece. Replace the reticule cover and reinsert the eyepiece. Recheck all three adjustments.

ADJUSTMENT OF THE K&E AUTO-REFLECTION ANGLE MIRROR NO. 9092-13

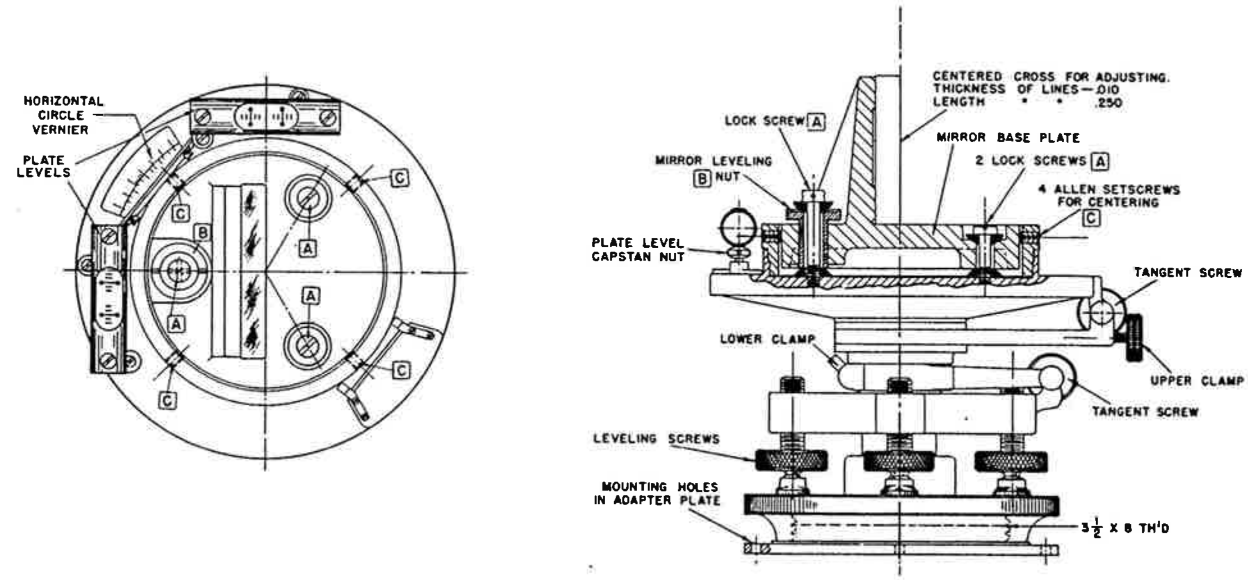

Fig. 9

There are only three adjustments needed for the Auto-Reflection Angle Mirror. They are:

a. To adjust the plate levels.
b. To adjust the mirror so that its front surface is parallel to the vertical or azimuth axis.
c. To adjust the mirror so that the vertical cross line on its front surface coincides with the vertical axis.

Before testing the instrument note the paragraphs at the beginning of the section on the Adjustments of Optical Tooling Instruments.

1. Object. ***To adjust the plate levels so that the bubbles will center when the vertical axis of the instrument is placed in the direction of gravity, i.e., made truly vertical.***

Test. Set the horizontal circle vernier at zero. Clamp the upper clamp. With the lower clamp free, turn the instrument in azimuth until each plate level is aligned with a pair of opposite leveling screws. Set the lower clamp. Center the bubbles precisely, free the upper clamp and turn the instrument 180 degrees in azimuth. The bubbles should center.

Adjustment. If either bubble fails to center, bring it half way back with the leveling screws. Then by turning the capstan nut at the adjustable end of the level tube, raise or lower that end of the level tube until the bubble centers.

This adjustment is independent of any other adjustment.

2. Object. ***To adjust the mirror so that its front surface is parallel to the vertical axis of the instrument.***

Test. An engineer's level is required such as the K&E PARAGON Tilting Level P5022, and also a K&E Auto-Reflection Target, such as the 9099-17.

Set up the auto-reflection angle mirror on its regular mount and level it accurately with the leveling screws. Set up the engineer's level with its auto-reflection target in place, at such a height that the line of sight strikes about the center of the mirror. Level the engineer's level carefully, aim it at the mirror and turn the mirror so that the auto-reflection target can be seen through the level telescope when it is properly focused.

Turn the angle-mirror clockwise and counterclockwise in azimuth. The horizontal cross line of the level telescope should not appear to move with respect to the horizontal paired lines of the auto-reflection target.

Adjustment. Loosen the three lock screws *A*. (See figure). Be sure that the four screws *C* are not in contact with the mirror base plate. Adjust nut *B* until the image of the horizontal paired lines of the auto-reflection target appears to coincide with the horizontal cross line of the level telescope.

3. Object. ***To make the cross on the mirror coincide with the vertical axis.***

Test. Focus the level telescope on the cross and turn the level in azimuth until its vertical cross line coincides with the vertical line of the cross.

Turn the auto-reflection mirror left and right in azimuth. The vertical cross line of the level telescope should appear to remain fixed with respect to the vertical line of the cross.

Adjustment. Shift the mirror base plate in such direction as may be indicated by tightening and loosening the opposed screws *C*, until no motion of the cross is observed as the mirror is turned in azimuth.

Tighten the three lock screws *A*. Loosen the four screws *C*. Recheck all adjustments.

ADJUSTMENT OF THE K&E PARAGON TILTING LEVEL P5022

Before testing the instrument note the paragraphs at the beginning of the section on the Adjustments of Optical Tooling Instruments.

There is only one field adjustment which may be necessary to the PARAGON Tilting Level.

The Tilting Level should be placed on the stand and leveled approximately by means of the circular level. The instrument should be elevated until the line of sight strikes the center of the objective of collimator *A*, if tested in a collimator room, or strikes the graduated portions of vertical scales at *E* and *A*, if tested on a range.

Object: ***To make the coincidence of the ends of the bubble occur when the line of sight is horizontal.***

Test: ***When collimators are used.*** Make sure that collimator *A* is accurately leveled. Aim at *A*, using the micrometer tilting screw. The ends of the bubble should be in coincidence.

When a range is used. Aim at *E*, bring the ends of the bubble into coincidence using the micrometer tilting screw, read scale *E*. Focus on vertical scale at *A*, again bring the ends of the bubble into coincidence, and read the scale. The reading should be the same as on *E*.

Adjustment: Aim at collimator *A* or, when a range is used, raise or lower the line of sight by means of the micrometer tilting screw until the readings on *E* and *A* are the same.

There are three capstan head screws at the back of the bubble housing. Loosen the two outside screws. Turn the middle screw until the ends of the bubble are in coincidence. Retighten the two outside screws.