COLLIMATING SYSTEMS

PROJECT NO. 9047

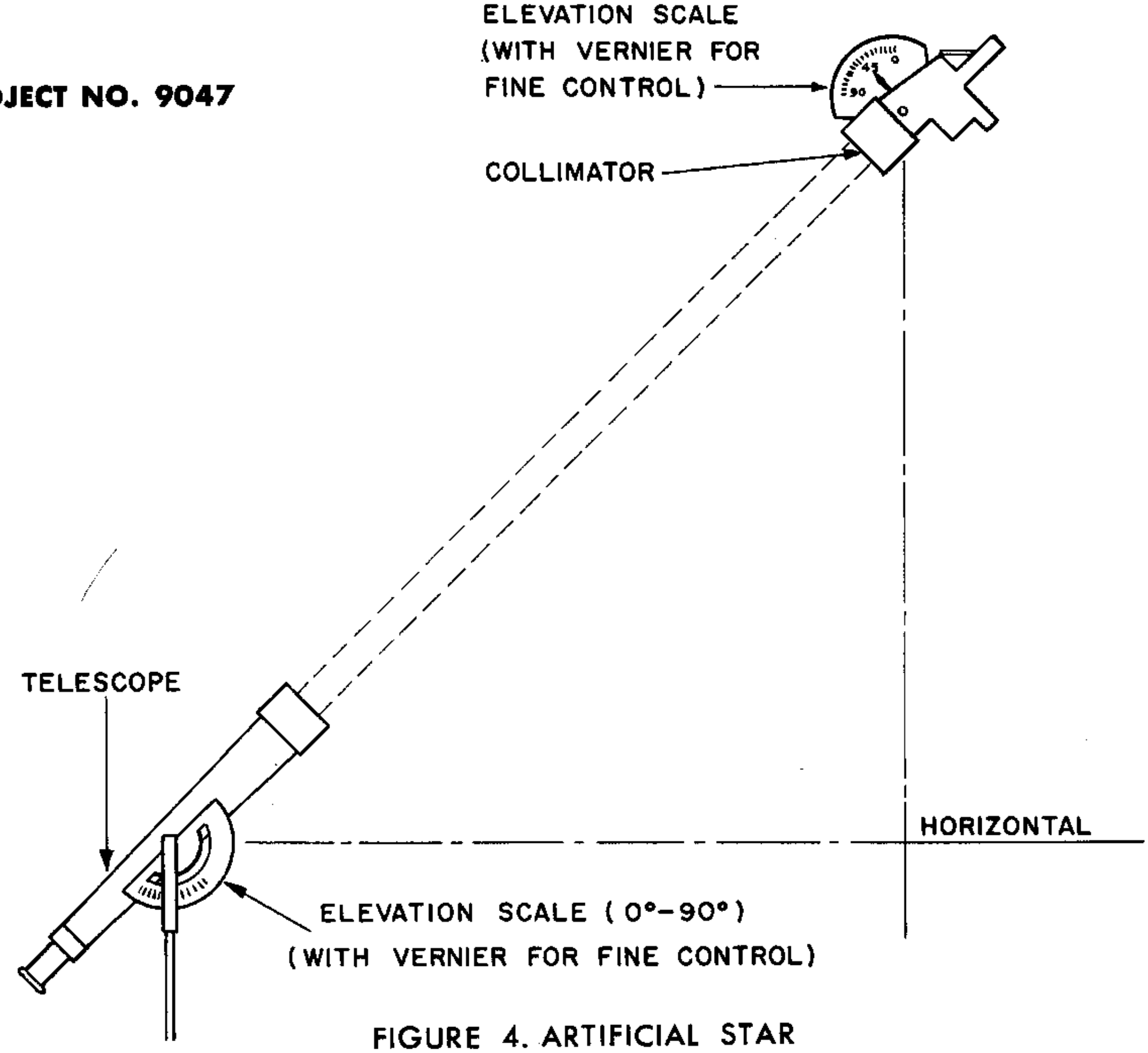

FIGURE 4. ARTIFICIAL STAR

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BARRINGTON, N. J.

COLLIMATING SYSTEMS

PROJECT NO. 9047

EDMUND SCIENTIFIC CORPORATION
BARRINGTON, NEW JERSEY

The collimator is an arrangement of an illuminated target and a lens, designed to produce collimated light; that is, light which consists of bundles of parallel beams converging at infinity. Thus, a collimator is a means of providing a target at an infinite distance, or for all intents and purposes, light beams with angles of convergence so small that they are negligible.

Within the collimator is a light source, a frosted bulb situated so that the light rays pass through a reticle and a lens. Without a reticle, the image of the lamp filament is projected through the lens. The filament or the reticle image, either one, will be sighting point or target at an infinite range.

Collimators are available in various models and styles. It is even possible that parts could be purchased and a collimator constructed by the amateur or student. It could be designed for the particular application or need.

Because expense is so often a factor in the purchase or construction of such equipment, the least expensive yet most adequate collimator is desirable. Many of the precision gunsights prepared for the Armed Forces in World War II were nothing more or less than carefully designed, accurately machined and precision-ground collimators. They provided an illuminated target at an infinite range.

These gunsights or collimators are predominately of two styles. One collimator consists of a source of illumination, a reticle, a mirror, and a lens. The first collimator (Figure 1) might be called the gun type because of its shape.

A second type of collimator, with an added element, might be described as a box-type. This collimator uses a source of illumination, a reticle, a small lens, a focusing mirror (or lens), and a glass which serves as a screen to show the reticle and as a right-angle reflector. (Figure 2).

There are many types of reticles for many uses (see our pamphlet "RETICLES AND THEIR USES") and almost any one of them is adaptable to the collimator for a specific use. None in particular is recommended since individual taste will more often than not determine ease of use and accuracy of results.

Within the base of the gunsight collimators are 28-volt light sources. For best results, a frosted, or frosted and partially silvered, bulb is used. This 28-volt bulb light source fits into a bayonet-type holder and has both filament leads on the bottom of the base. Since it is not too easy to cut standard voltage down to 28, the light source must be adapted for standard 110-115 volt or for dry cell (flashlight) operation. Because the 110-115 volt system can provide brighter light, its installation in the collimator will be discussed first.

The entire light source mounting can be removed from the collimator by removing one or two screws, depending upon the type of collimator used. The inner part of the socket mounting can be detached from the bracket. This is done in one collimator by depressing a spring-loaded detent on the side of the bracket and forcing the bulb socket out of the bracket. In the other type collimator, the socket is removed by loosening the screw in a spring-loaded clamp.

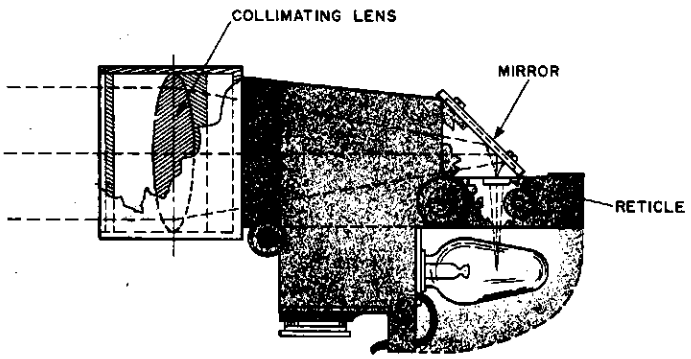


FIGURE 1. GUN-TYPE COLLIMATOR

A small base, screw-type socket, with either a plastic or a paper insulator around it, may be placed in the bracket and the whole returned to the collimator frame or box. The connections to the switch may have to be remade, and the AMPHENOL plug connection on the lead of the stock collimator will have to be replaced with a standard male plug for use with standard building and home outlets.

If the standard flashlight is to be used, a preferable arrangement is one in which the light from the flashlight shines directly into and through the reticle. Either type collimator has openings which can be adapted for flashlight attachment. However, it should be understood that the flashlight application is satisfactory for direct viewing of the reticle, but the light source would be inadequate in, for instance, adaptation of the collimator for use as an autocollimator.

Mountings for the collimators themselves will differ greatly. The gun-type collimator can be tripod-mounted, or a gun-type handle might be added. In another version, the collimator might be mounted so that it can pivot in a vertical plane about an axis at right angles to the direction of projection of the collimator. In addition, this mounting may be placed on a unit which rotates about a verticle axis; and almost all directional problems can be solved and various directional measurements and adjustments made.

The box-type collimator can be mounted in much the same manner as in the gun-type collimator, but perhaps not always so easily. This collimator has side mounting brackets on its case for rigid positioning.

The purpose for which the collimator will be used determines whether it will be tripod or bench-mounted, or if a hand-grip will be used. The hand-grip would be of more use in the autocollimator than in the collimator. The autocollimator is simply a combination of a collimator, an attached telescope, and a mirror. Ideally, the box-type collimator would be used here, but either collimator might be adpated without too much difficulty.

Because application determines the type of mounting used with the collimator, it would be well to discuss and illustrate some uses for the collimator or autocollimator.

Hunters often are faced with the problem of the adjustment of the telescopic sights which they may use. Since these are primarily range adjustments, and there is also the problem of bore sighting, two targets must be available; i.e., one for the bore sighting and one for optical adjustment of the telescopic sight. The gun can be mounted by resting the barrel on a fork, the stock of the gun serving as the third leg of a tripod. (See Figure 3). The collimator could then be mounted on a tripod with a variable height adjustment. With a properly measured distance between the rifle and the collimator, and a scaled reticle, all range adjustments for the rifle, up to and including infinity, could be accomplished.

The hunter's telescope alone can be mounted for adjustment with the collimator. Various types of holders can be developed for the scope and for the collimator. One mounting for both could be a lathe bench. A V-slotted holder might be mounted on a lathe bench and the telescope set in it. Telescopic sights might also be mounted in rings with three clamp-screw fittings which would permit centering of the telescopes in the ring at a predetermined height. The ring holder might also be bench mounted. In these cases, the collimator would also be bench-mounted so that the axis of the collimated light bundle and the ring coincided. With this mounting arrangement, the scope would be situated so that the reticle image would be visible through it, and, therefore, a target at an infinite range would be available.

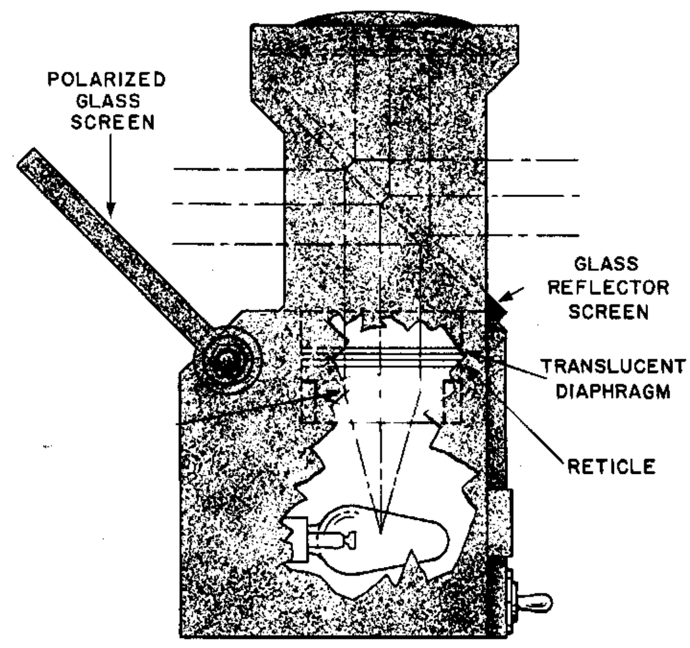


FIGURE 2. BOX TYPE COLLIMATOR

For adjustment of an astronomical telescope, another type of mount might be desirable. In this case, the type of mount might depend more upon the size of the telescope than upon any other factor. A base for the collimator is, of course, necessary. And, because the collimated image is at infinity, any telescope position is satsifactory if the image in the collimator is visible. The reticle image is thus the star at a tremendous range, a range which, for all practical angular measuring purposes is infinite; and it is the adjusting target for the telescope.

The determination of zero degrees of elevation can also be accomplished with a 90 degree setting on the collimator and a 45-45-90 prism. (See Figure 5). The light from the collimator at a 90 degree elevation (pointing directly downward) would have a 45 degree angle of incidence and a 45 degree angle of reflection with the prism. The artificial horizon is not necessary in this latter setup, but is needed for use with the sextant.

Were one to obtain a 90 degree prism, a means of determining parallelism in work faces of some precision equipment is available, using the collimator. An example of this would be the determination of parallelism of the faces of a micrometer. Setting up as shown in figure 6, it can be seen that coincidence of the virtual and the reflected images would indicate proper face machining and alignment. In this operation, the collimator is best mounted with the collimated light bundle being directed vertically downward, and the prism mounted on a horizontal table. Bench marks should be made on the base or platform used once proper position of the collimator mount and the prism have been determined. Because of the sizes and types of instruments to be checked, it is often difficult to determine the exact positions for the various precision tools and instruments to be checked. This, though, is a minor problem since careful observation will insure reasonably accurate positioning of one face or surface of the instrument. Lack of coincidence of reticle and reflected images indicates improper alignment.

FIGURE 3. ADJUSTING TELESCOPIC SIGHTS

Other mounting equipment, such as compasses, compass roses, and elevation arcs might be added to the telescope for angular elevation and distance measurements, and for directional determinations. With a properly scaled reticle in the collimator, that is one with angular distance and elevation scales upon it, properly adjusted, micrometer adjustments can be set and vernier errors determined and corrected with extreme accuracy.

A collimated star may be constructed using the collimator. Because of the distance of the star from the earth, its light may be considered as a bundle of collimated light. The collimator can duplicate this condition, unaffected by time of day or night, season of the year, or by weather conditions. With an accurately aligned angular scale in a vertical plane, passing through the axis of the collimated light bundle, a collimator can be placed so that it points directly downward at 90 degrees of elevation, and horizontally at 0 degrees of elevation. Placed on a wall and about 7 ft. above the floor, the collimator can represent a selected star of the Cosmos. A horizontal line at eye level can serve as an artificial horizon. With the star elevation known, the elevation scale of a telescope can be adjusted. The horizontal line and a bubble level can be used for adjusting the telescope horizontally or at zero degrees elevation. (See Figure 4).

The collimated "star" and horizontal line can also be used as a practice tool or teaching aid in the use of navigational instruments. The U. S. Navy uses this collimated "star" method, with an artificial horizon, gimbal-mounted, to teach the use of the sextant in both the elementary and advanced stages, that is, with a round sea running. The gimbal mounts of the artificial horozon permit the introduction of pitch and roll of a ship into the problem of navigational star sights.

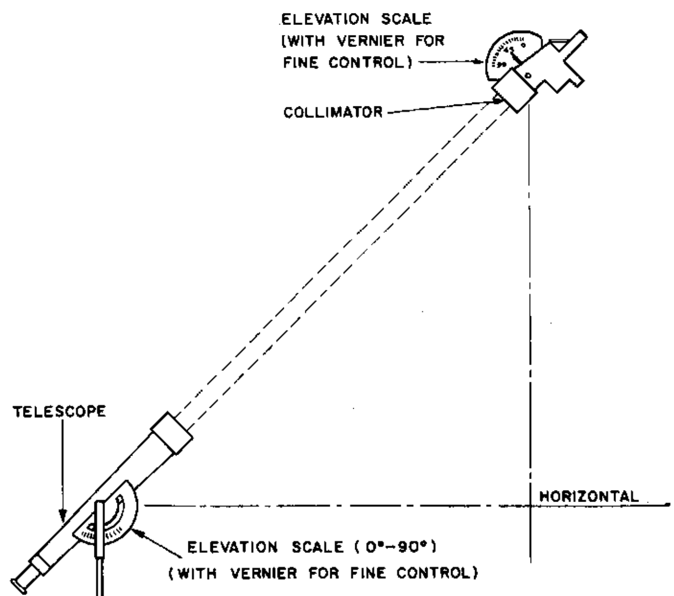


FIGURE 4. ARTIFICIAL STAR

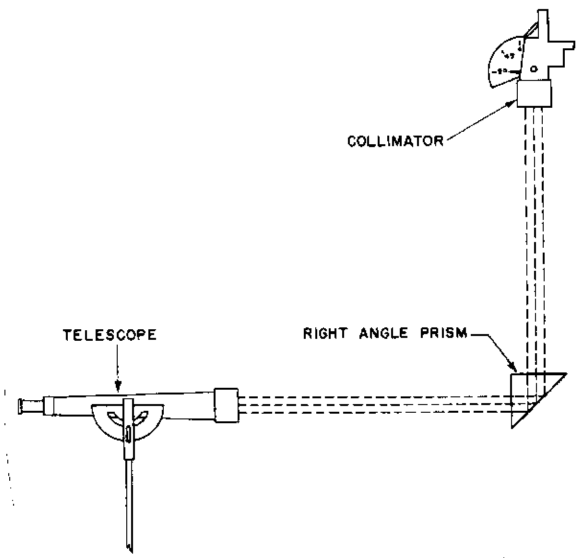


FIGURE 5. DETERMINING ZERO DEGREES OF ELEVATION

If the reticle and image in one half of the screen coincide, that side is properly aligned. Disagreement or non-coincidence on the other side indicates misalignment. If this information is true for a micrometer, it can be seen that the micrometer is of little use since measurements wherein a micrometer might be used are usually extremely critical. This would show that the micrometer was valueless for precision work and it would have to be replaced or remachined and checked.

Non-parallelism in micrometer faces is very serious when scales are small, but with larger scales and no need for extreme precision, there is little need for the critical readings obtained with the collimator. But, it is possible, with the proper reticle in the collimator, to determine or measure the degree of divergence of two surfaces from the parallel.

The autocollimator has been mentioned previously. Except to describe the elements, there was no further information. The box-type collimator is best-suited for this use. The telescope is mounted behind the collimator so that the reticle image is centered, and the mirror is mounted on a flat surface some distance away. In this application, it is desired to ascertain a perpendicular to a plane surface, at or in about the position of the mirror. If the collimator and telescope combination is moved so that the reflection of the reticle and virtual image appear concentric through the telescope, the autocollimator is in line which is at a 90 degree angle to the plane of the mirrored surface. If a plumb line were dropped from the collimator, that plumb line and the line of sight would determine a vertical plane at a 90 degree angle to the original plane surface.

Figure 7 illustrates a condition in which the center-line of the collimated light beam is not in a plane perpendicular to the mirrored surface. If the reflected image is to the right of the virtual image then the autocollimator must be moved to the right. With the reflected image to the left, the angle of reflection is again somewhat less than 90 degrees and the autocollimator must be moved to the left.

Because there is no noticeable sag or deviation from a straight line in the line-of-sight, the autocollimator, or a straight collimator, may be used in the setting up of a form or a template. Air foils may also be determined more accurately with the use of this equipment. The collimator is also useful in the machine shop for determining table level and accurate angular relationship between non-intersecting plane surfaces, as well as angles between regular intersecting plane surfaces.

Determination of a curved surface is a relatively easy proposition with a collimator. An accurately machined base, as shown in figure 8, with a mirror attached, will follow an outside curve. A collimator mounted on knife edges so that the projected beam is always verticle, can project the reticle image into the mirror and back to the glass screen. An angular scale scribed on the glass screen, or a reticle with the proper angular scale, will permit the actual reading of the angle from the horizontal, thereby permitting the actual construction or measurement of an outside curve.

Almost any optical equipment with range adjustments can be checked or set by use of a collimator. Binoculars can be adjusted or realigned, and camera rangefinders can be set with the collimator providing a target at maximum or infinite range.

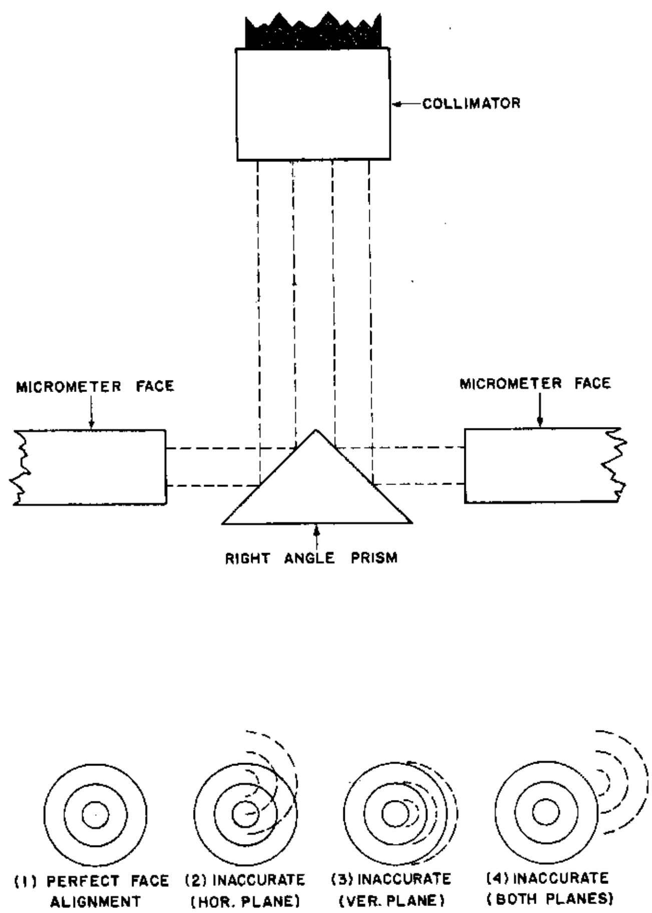
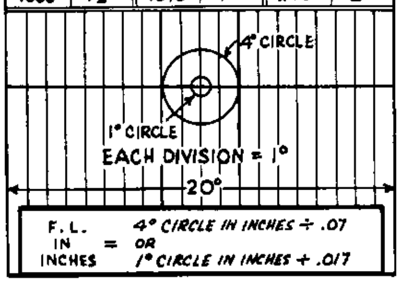
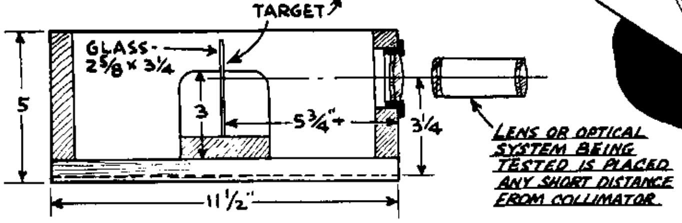


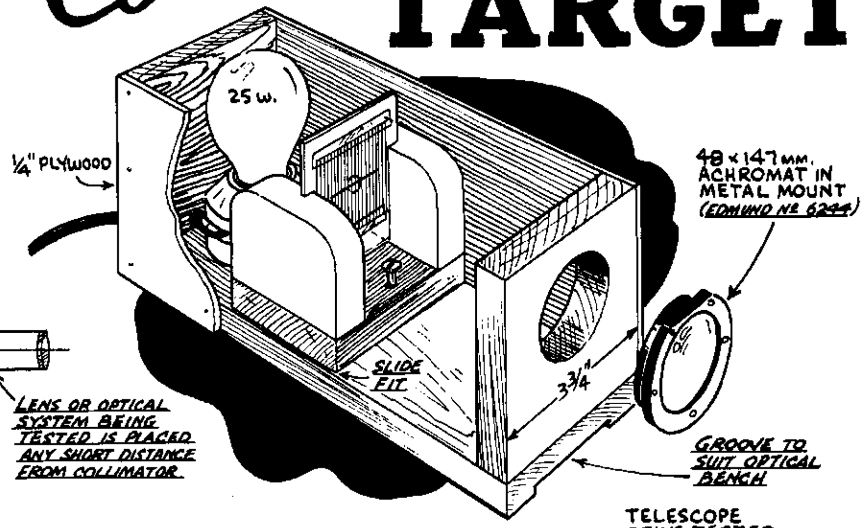
FIGURE 6. TESTING MICROMETER FACES

DIRECT-READING ANGULAR SCALE Collimator TARGET

4° CIRCLE	F.L.	4° CIRCLE	F.L.	4° CIRCLE	F.L.
.009"	1/8"	.044"	5/8"	.078"	1 1/8"
.017	1/4	.052	3/4	.087	1 1/4
.026	3/8	.061	7/8	.105	1 1/2
.035	1/2	.070	1	.140	2

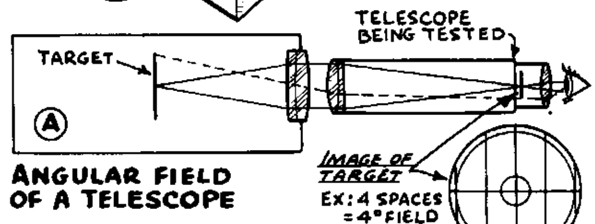


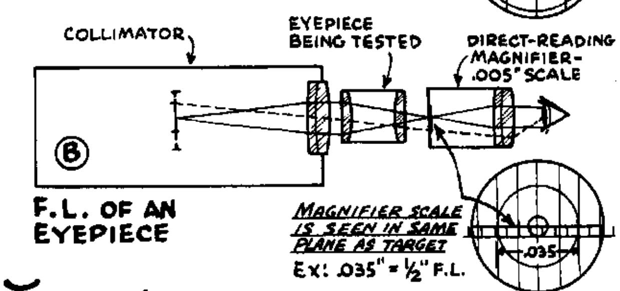




THE COLLIMATOR TARGET is a handy gadget for the telescope builder, providing as it does the equivalent of a distant target--right at the work bench. This one is also scaled so that you can read the angular field of any telescope by simply counting the degree marks.

The construction is simply a wooden box with the target taped to a piece of glass. The target must be located in the exact focal plane of the lens. This will be about 5-3/4 inch plus 1/32 inch from the front of the box. You can check exactly by using the collimator as a camera, pointing the lens toward a distant object. Then, adjust target until image of distant object is sharp on the target.





How to Use the Collimator Target

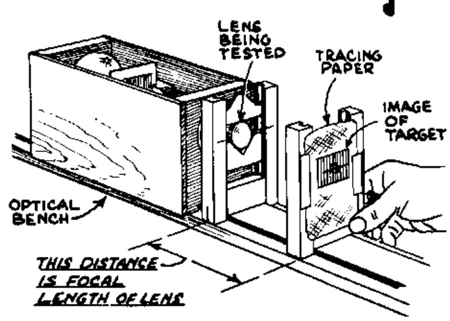
INFINITY TARGET

SET UP YOUR TELESCOPE, CAMERA OR OTHER OPTICAL SYSTEM FACING COLLIMATOR LENS, AS SHOWN IN DIAGRAMS. FOCUS ON COLLIMATOR TARGET - IT SERVES THE SAME PURPOSE AS A DISTANT TARGET

ANGULAR FIELD (DIAGRAM A)

READ THE TRUE ANGULAR FIELD DIRECTLY BY COUNTING NUMBER OF LINES WHICH ARE VISIBLE. EACH DEGREE OF FIELD IS EQUAL TO ABOUT 17 YDS. OF LINEAR FIELD AT 1000 YDS.

THE APPARENT FIELD (ANGLE COVERED BY TELESCOPE EYEPIECE) IS THE TRUE FIELD TIMES THE MAGNIFICATION OF THE TELESCOPE



FOCAL LENGTH OF A LENS

SET UP LENS AS ABOVE. MOVE TRACING PAPER SCREEN ALONG OPTICAL BENCH TO PICK UP A SHARP IMAGE OF COLLIMATOR TARGET. DISTANCE FROM SCREEN TO CENTER OF LENS IS THE FOCAL LENGTH OF LENS

F.L. OF LENS SYSTEM (DIAGRAM B)

IN THIS SETUP, THE IMAGE OF THE TARGET PRODUCED BY THE LENS SYSTEM BEING TESTED MAY BE VERY SMALL. IF SO, IMAGE MUST BE VIEWED AND MEASURED WITH A DIRECT-READING SCALE MAGNIFIER. MEASURE DIAMETER OF 4° CIRCLE. REFER TO TABLE ON TARGET TO OBTAIN CORRESPONDING F.L. OF LENS SYSTEM

FOR FOCAL LENGTHS NOT GIVEN IN TABLE, CALCULATE BY USING FACTORS AT BOTTOM OF TARGET

EX: TESTING A 6" F.L. SYSTEM: 4° CIRCLE MEASURES .42"

$$.07 \overline{)\,.42} = 6"$$

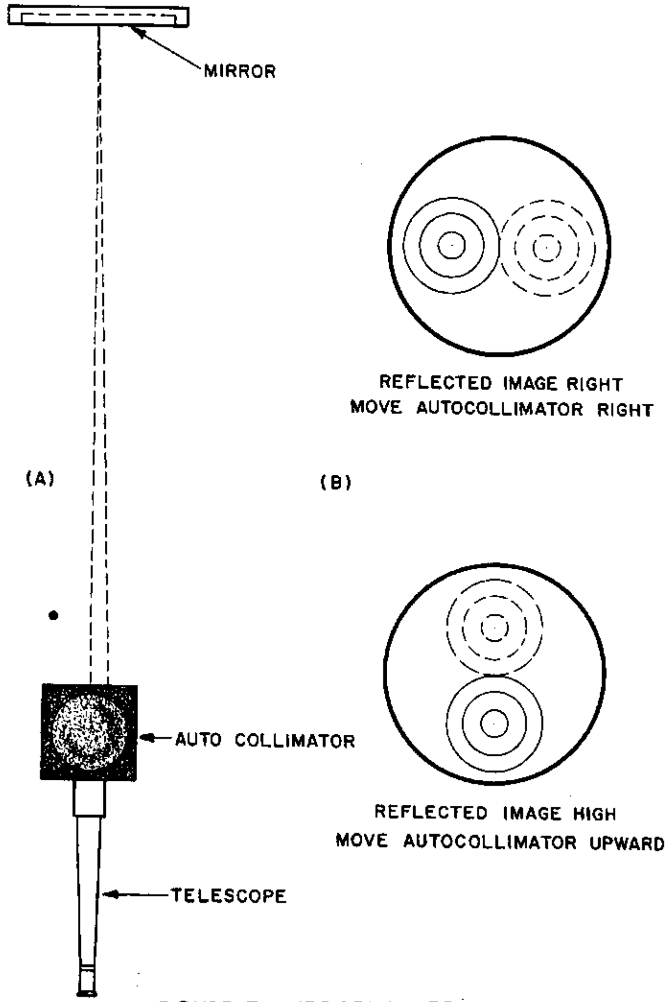
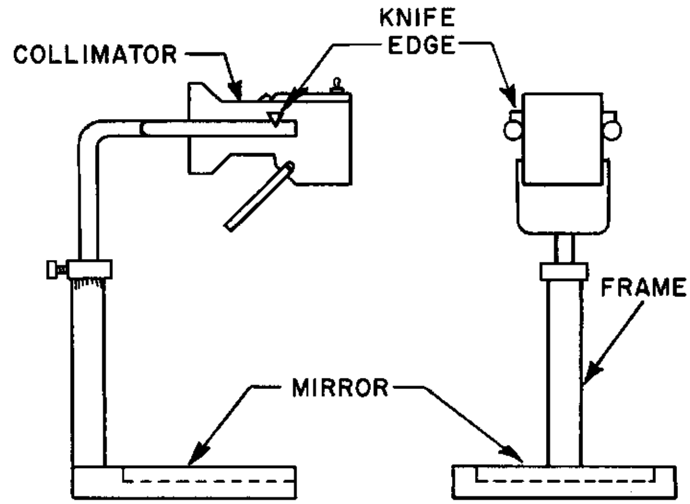


FIGURE 7. AUTOCOLLIMATOR



(A) COLLIMATOR AND MOUNT

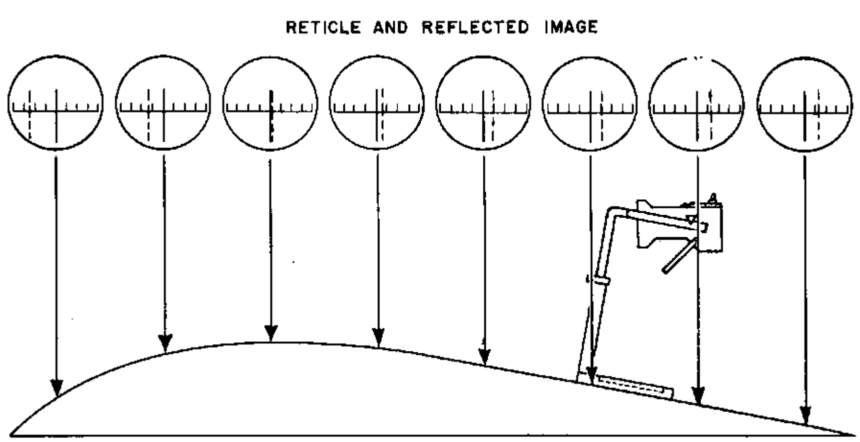
FIGURE 8. DETERMINING CURVATURE

A gun-type collimator can be rebuilt to provide a lightpointer for use in showing slides or home movies, pointing out pertinent facts and salient points for better understanding, or to assure that they are noticed. Again, the 28-volt bulb should be replaced with something of a higher candle-power rating, and the reticle must be one suitable as a pointer, such as an arrow circle of light. A gun-type handle, with a spring-loaded trigger switch for quick closing and opening, provides an inexpensive and simple pointer.

A directed beam of light from a collimator might serve to activate a photo-electric cell or switch if the light should be interrupted.

The collimator is, then, a source of directed light, concentrated within given limits, such that it can be used in precision measurements, or under conditions wherein an infinite range must be accomplished within a confined space. It can provide a distant target without the interferences of weather, built-up areas, trees and hills, fog, smokes, or other outside influences. With proper attachments, it can perform some of the jobs of a surveyor's transit, a gunsmith's bench marks, a navigator's star, an astronomer's tool, an instrumentman's checking equipment, and a templatemakers' side.

There are undoubtedly other uses for the collimator, but its primary application is one in which precision measurements are desired at the lowest possible cost.



PICTURE OF INSTRUMENT IN OPERATION

FIGURE 8a DETERMINING CURVATURE

APPENDIX

For testing and measuring lenses and telescopic instruments, it is highly desirable to make use of a test target upon which the instrument or lens in question may be focused at infinity. The appearance of such a target is not difficult to imagine. It might consist of a large vertical wooden structure similar to a billboard with a test pattern painted on its surface. While a large outdoor target might be very useful, there are many serious objections to it which are fairly obvious. In view of the great size and expense of an outdoor target, a suitable substitute must be used.

A Collimator Target is just such a substitute upon which a telescope may be focused at infinity and yet not be more than a few inches away.

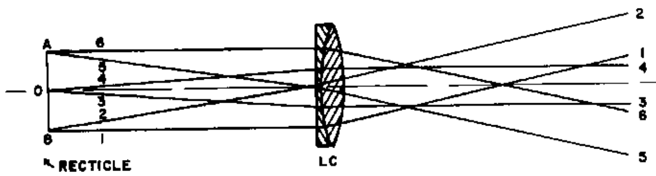


FIGURE I

In Figure 1, line AB represents a small illuminated target, or reticle, placed in the left-hand focal plane of a lens LC, designated the Collimator Lens. All rays originating from any point on the target will emerge from the Collimator Lens parallel to each other. To an observer at the right of lens LC, the emergent rays, 5 and 6 from point A appear to have their origin in a point that is at an infinite distance to the left of the lens and above the principal axis O. Similarly, emergent rays 3 and 4 appear to have their origin in a point that is on the principal axis at an infinite distance to the left of the Collimator Lens. Emergent rays 1 and 2 appear to have their origin at an infinite point beyond the lens LC. Therefore, the visual effect of placing a small illuminated reticle in the focal plane of the Collimator Lens, is exactly the same as that produced by viewing a large target from an extreme distance.

Needless to say, the Collimator Lens must be a good achromat with excellent correction over a small field. Thus, one can contribute defects observed in the final image to the test lens and not to the collimator. An excellent telescope objective is usually suitable.

If one chooses an achromat for a collimator, the problem of color correction is not completely solved because of secondary spectrum and cannot be considered negligable unless one chooses an achromat having a focal length in inches at least 5 times the square of the diameter of the lens in inches. The table below should be helpful.

Desired Dia. of Collimating Lens	Minimum required focal length of Collimating Lens
1 inch	5 inches
2 inches	20 inches
3 inches	45 inches
4 inches	80 inches
5 inches	125 inches
6 inches	180 inches

Figure 2, below illustrates a home-made collimator system which may be made in an evenings time. It consists of an appropriate reticle, an achromatic lens with a focal length chosen as above, and a light source located behind a piece of ground glass which acts as a diffusing screen. A mounting tube is cut approximately to the focal length of the lens being used, and is painted black on the inside. The collimator lens is then mounted squarely into one end of the tube. The desired reticle and light source are mounted as illustrated within a smaller tube which slide-fits into the larger tube.

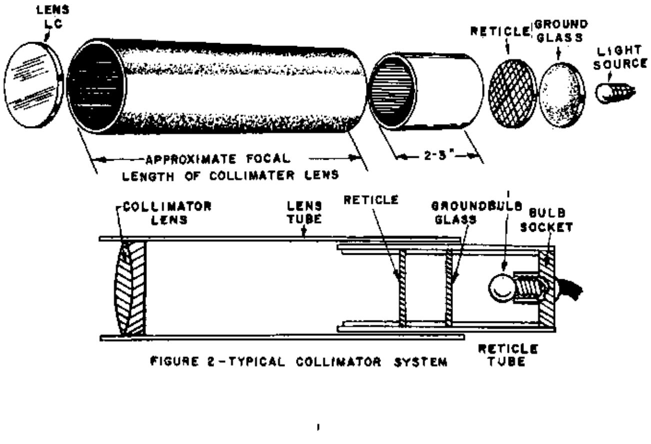


FIGURE 2-TYPICAL COLLIMATOR SYSTEM

By the use of a small telescope, the reticle may be adjusted to the correct distance from the collimator lens, and then secured permanently in place. The adjustment procedure is outlined below.

1. Focus the telescope at an infinite object such as a star, and secure the draw tube with a piece of scotch tape.
2. Mount the collimator system and the pre-focused telescope on an optical bench, with the principal axis of each coinciding.
3. While looking through the telescope, adjust the collimator reticle by means of the small sliding tube until it comes into accurate focus.
4. Gradually move the telescope away from the collimator target. The image of the reticle should remain the same size and be in focus at all times.
5. If step 4 is accomplished, fasten the small reticle tube permanently to the collimator lens tube.

An alternate method is available to those who have not the use of an auxiliary telescope. The method is auto-collimation. When the reticle is in the proper position with respect to the collimating lens, all rays leaving the collimating lens are essentially parallel. Thus, a flat mirror placed in front of the collimating lens and perpendicular to the beam will cause the rays to reflect upon themselves and form an image of the reticle superimposed on the reticle itself. When this occurs the reticle is in the proper position with respect to the collimating lens. The mirror is then removed.

The collimator lens should be as large, or larger, in diameter as the largest objective likely to be tested with it, and a provision to change reticles may also be useful. Once the reticle position is established, it need not be adjusted again for the same collimator lens.

RETICLES: For testing Telescope Objectives, pinholes are recommended about as follows:

Dia. of Telescope Obj. to be tested.	Maximum diameter of pinhole. Focal Length of Collimator.					
	5"	20"	45"	80"	125"	180"
1 inch	.0004	.002	.004	.006	.010	.020
2 inches		.001	.002	.003	.005	.007
3 inches			.001	.002	.003	.005
4 inches				.001	.002	.004
5 inches					.001	.003
6 inches						.002

Pinholes may be made in tin foil, or other thin metal. To puncture holes in tin foil, draw a fine fibre of a chemical stirring rod over a gas flame and use it to puncture the hole. Another method is to sharpen a needle on a fine stone, twirling and drawing it out at the same time under the finger tip until it appears perfectly sharp under a magnifier.

For Photographic Lenses: When one is testing photographic lenses one is interested in resolution. Therefore, a reticle for the collimator should contain a known number of lines in each unit distance. These lines should be both horizontal and vertical. The Edscorp E-17 (Stock No. 30,075) Reticle is an example (10mms. divided into 100 parts).

It must be remembered that a magnification or demagnification will result in the image obtained from the photographic lens. This magnification is equal to the focal length of the photographic lens divided by the focal length of the collimator lens.

As an example, let us test a photographic lens having a 2 inch focal length with an E-17 reticle and a collimating lens having a 20 inch focal length. Therefore, the size of the final image will be 1/10 the size of the original reticle. If each line of the reticle is resolved in the final image the resolution of the photographic lens is 100 lines/mm as the original reticle had 10 lines/mm.

Illumination of the reticle is a matter that must be determined experimentally as the proper illumination will depend upon the use to which the collimator is subjected. When using some of the smaller pinhole reticles, it may be necessary to replace the ground glass with a condensing lens. In general, a high illumination should be provided. If a test requires a lower illumination this can then be easily obtained by using a neutral filter.

Provisions should be made for mounting the collimator system securely to an optical bench. By so doing, a source of infinite focus will always be available and will be a great aid towards designing, testing, and measuring optical equipment. For maximum results when using a collimator system, the principal axis of the system and the lens or instrument being tested must be in alignment.