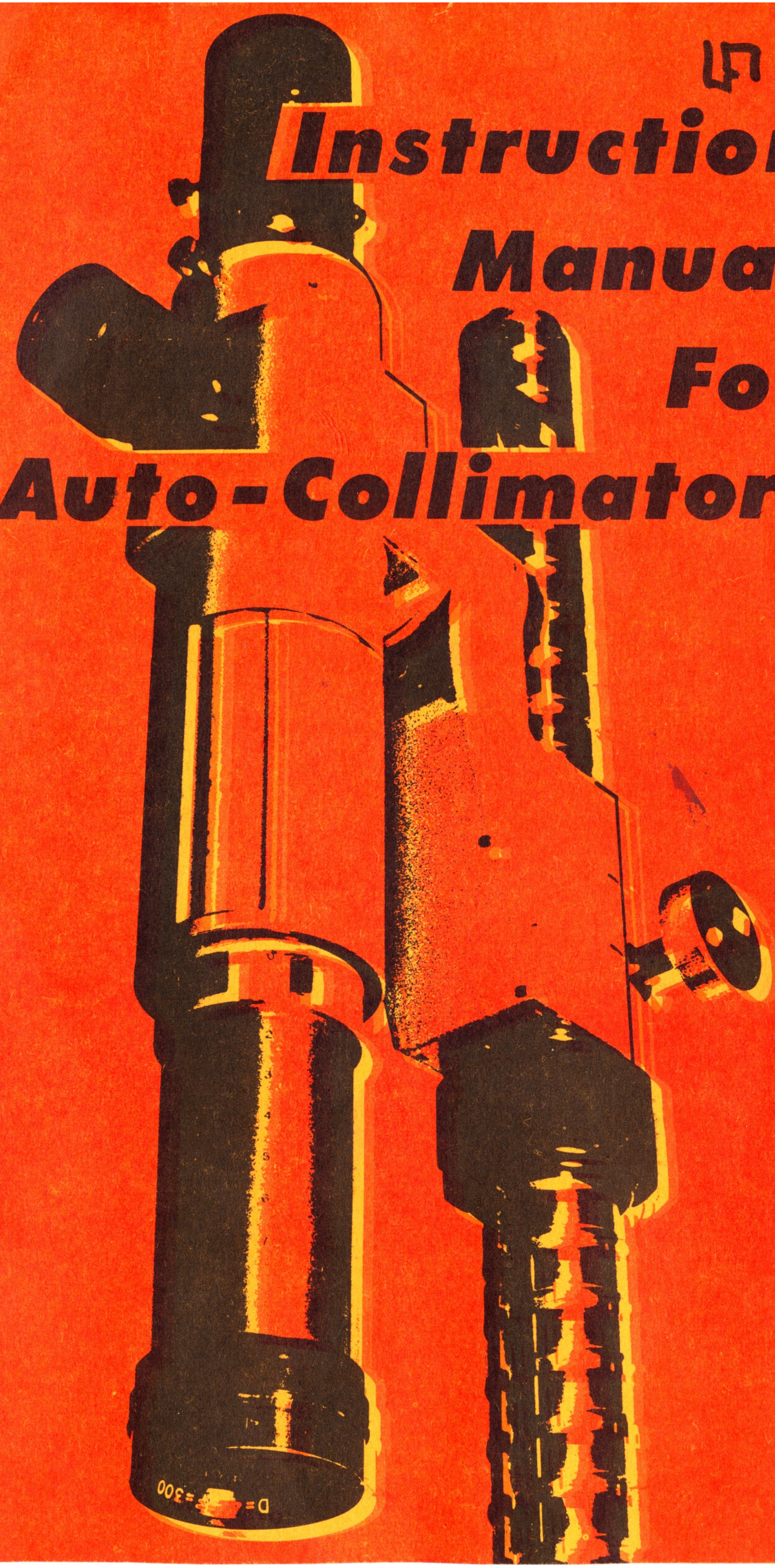
National Camera
2000 West Union Ave.
Englewood, Colo, U.S.A. 80110
Phone (303) 789-1893

Instruction Manual For Auto-Collimators



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Instruction Manual for Auto-Collimators

National Camera auto-collimators are instruments used to determine the calibration of camera and similar objective-lens focus. They will provide indication of the focus of a lens of any focal length and may be used to check focus setting in the repair shop, studio or in the field. In addition, the auto-collimators may be used for certain angle measurement for precise alignment testing. The C-6810 model may be used for angle measurement to about 15 seconds of angle.

Basically, the collimator consists of an illuminated target and an objective lens which produces an image of the target that is equivalent to having the target at an infinite distance. National Camera collimator lenses are adjustable so that the image may be changed from an infinite distance to closer distances.

For ordinary use, the collimator lens is set at the infinity mark. When a camera (with its shutter open) is placed in line with the collimator objective lens, the camera lens either will or will not produce a sharp image of the target at the focal plane, depending on the focus setting of the camera. If the camera is properly focused on infinity, a sharp image of the target will be formed. Either a mirror or an ordinary piece of film may be placed in the focal plane of the camera to provide an imaging surface. The image thus produced on the camera focal plane may then be examined through the reflecting system of the auto-collimator by looking into the eyepiece on the auto-collimator. If both the auto-collimator and the camera lens are focused on infinity, a sharp image of the target may be seen in the eyepiece of the auto-collimator.

As either the camera lens or the collimator lens is adjusted until it is no longer focused on infinity, the image observed through the eyepiece of the collimator will blur. If the sharpest visible image is obtained when the camera lens is not set at infinity, the lens may be shimmed or otherwise adjusted to bring it into focus and proper calibration simultaneously.

The calibration markings on the camera lens at distances other than infinity may be checked in a similar manner, simply by changing the setting of the auto-collimator. Important: when using the auto-collimator at distances other than infinity, the film plane should be accurately positioned in relation to the collimator objective lens. When making a test at infinity, the distance between the camera and collimator is not critical.

TESTING AND READJUSTING THE AUTO-COLLIMATOR

The auto-collimator may be checked and readjusted by a series of precise steps in order to assure that the instrument is capable of precision service. The graticule visible in the eyepiece must be focused for each individual operator. The ocular (eyepiece) is focused until the image of the graticule is sharp. The collimator may then be used in the manner of a telescope in order to verify the focus of the objective lens at infinity. When the collimator is pointed at a distant subject (like a star or the moon) the best focus should be obtained when the objective lens is focused at infinity. If this is not the case, the position of the graticule must be adjusted (in some models the beam-splitter position provides the adjustment) in order to provide the sharpest image of an infinite subject under those conditions.

The calibration of the collimator target may then be checked by placing a good-quality plane mirror in line with the collimator lens axis and at right angles to that axis. Observation through the eyepiece of the auto-collimator will then reveal the adjustment of the target position. If the adjustment is correct, the target will appear sharpest when the collimator lens is set at infinity (∞).

USE OF THE AUTO-COLLIMATOR

Prior to using the auto-collimator, the preceding test technique is essential. Generally, only the first and last steps need be taken to quickly verify that the collimator has not suffered any damage since it was precisely calibrated. First, each operator should adjust the position of the eyepiece to obtain a sharp image of the graticule. Verify the adjustments of the target and lens by observing the image produced in the eyepiece reflected from a mirror placed in line with the collimator axis.

For production flange-focal-distance measurement of lenses, a test fixture is desirable. Such a fixture fundamentally consists of a flange on which the lens can be mounted aligned with the collimator axis and a simulated focal plane on which the lens can focus the

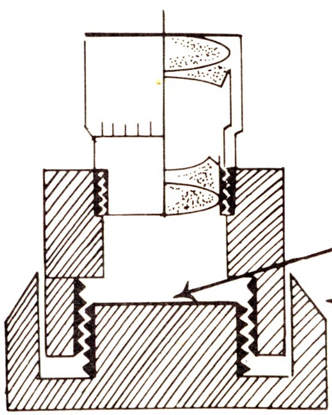


ILLUSTRATION I.

Lens seats on fixture which just clears or fits threads on lens

Flat imaging surface (may have mirror mounted in position)

Micrometer scale for reading or calculation distance from flange to image surface

image of the collimator target. It is common practice to provide a precision measuring device, like a micrometer, to read the distance between the lens flange and the movable focal plane. A typical setup is illustrated. Depending upon the degree of precision desired, the fixture need not have a built-in micrometer but may rather include a simpler screw adjustment with a flat ground image surface so arranged that after the lens is removed the distance may be measured with a depth micrometer. When making such a fixture, the parallelism between flange and imaging surface may be verified using the system described in a later section of this manual.

Checking Camera Parallelism.

In use, the lens to be tested is placed on the fixture and the image of the target is observed through the eyepiece of the collimator. If the image plane of the fixture is at the position of best focus for the lens, a sharp image of the target will be observed. If the image observed is not sharp adjust the position of the imaging plane until a sharp image is obtained. The flange-focus distance of the lens may then be measured from the fixture.

If a measurement is desired using a non-adjustable fixture (that is, with the flange focal distance set or established) the Vernier scale on collimator Models No. C-6400 and C-6810 may be used to determine flange focus error existing in the particular lens, simply by moving the collimator lens backward or forward until a sharp image is obtained. If the collimator must be set beyond infinity in order to obtain a sharp focus, this indicates that the lens has a longer focal length than normal; and if the collimator must be set closer than infinity the indication is that the lens focal length is shorter than normal.

The following formula can be used to determine the error from standard focal length. If the objective lens of the collimator travels $\Delta l'$ mm from the infinity position, the error (X) from the standard focal length of the lens is:

Formula 1.

$$X = \left(\frac{f}{Fc}\right)^2 \Delta l'$$

Fc = Focal length of the auto-collimator
f = Focal length of test lens

Any lens may be individually tested on the camera to which it is normally fitted. Either a mechanical flat surface, like a mirror, may be placed in the focal plane or film may be fitted into the camera in the normal manner. In either event, the camera lens will focus an image of the auto-collimator target on the focal plane imaging surface. Place the lens and camera in line with the axis of the auto-collimator and observe the image seen in the auto-collimator eyepiece. With the camera lens set at infinity, the sharpest image should be obtained in the eyepiece when the auto-collimator lens is also set at infinity. If the auto-collimator lens produces the best image at some position other than infinity, the above formula may be used to calculate the error in the lens or camera mount.

JUDGING THE IMAGE

Models C-6400 and C-6810 have auxiliary green filters which may be swung in or out of the lamp house to control the target illumination. The use of such a filter minimizes color errors, especially in angle measurements. Since the wavelength of various colors varies, the use of white light (a mixture of colors) for focus tests on film often simplifies such tests by showing color fringes because of varying focal length for the red and green ends of the spectrum plus a brighter image.

The image observed in the eyepiece of the auto-collimator can best be interpreted after some practice. When the image is slightly out of focus, red or green color fringes may be seen along sharp edges in the target. When observing the image produced on a film, the precise point of adjustment may not be obvious. Lenses of various focal lengths will produce different sized and different appearing images. The adjustment for best focus is that at which the image is sharpest and provides a minimum of fringe color. When a camera is not precisely aligned (when it is tilted), an image will still be seen. This is an image produced by the lens off of the central axis. The quality of the image produced off axis can thus be interpreted. Circumstances which cause the film to buckle inside the camera will also provide varying focus conditions along and away from the axis of the lens.

Motion picture cameras may be tested with the film running. Such a test may be critical since film at rest may not lie in precisely the same plane as film in motion through such a camera.

Bulky cameras that cannot be fitted between the collimator head and the collimator base board may be tested in one of two ways. The entire collimator stand may be reversed on the edge of a table and the collimator head rotated 180 degrees on its column. The camera may then be held below the collimator head. Where a number of large cameras are regularly tested, it might be desirable to remount the collimator in a manner similar to that used when an enlarger is to be employed for sizes beyond the capacity of the base board. The collimator may be removed from its original base board and built into a bench having an opening under the collimator head. A series of adjustable positions for a shelf may be provided so that cameras of various sizes can be accommodated. The eyepiece of the collimator should, of course, be at a convenient height above the floor in order to permit comfortable viewing.

EVALUATING THE CALIBRATION OF A FOCUSING SCALE

If the collimator produces a sharp image in the eyepiece when a camera and lens under test is set at infinity and the collimator lens is also set at infinity, the calibration of the infinity mark on the camera is correct. If the objective of the collimator must be moved some distance ($\Delta\ell'$ in millimeters), the discrepancy can be calculated from Formula 1.

∞ =

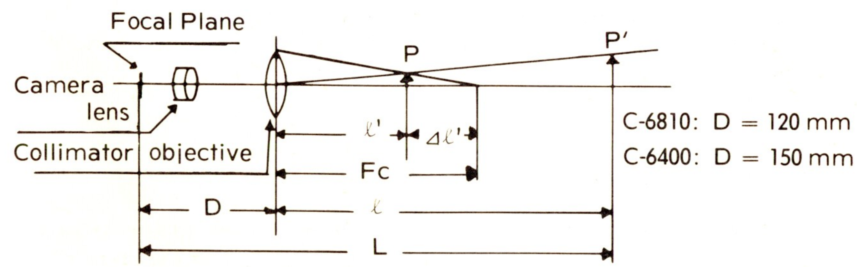
For checking other calibration points on the lens scale using Models No. C-6400 and C-6810, first position the collimator objective for the focusing distance to be tested.

Then place the camera so there is a separation of 120 mm (with the C-6810) or 150 mm (with the C-6400) between the front edge of the collimator objective lens mount and the film plane of the camera under test. Observe the image in the collimator eyepiece, while adjusting the focus of the camera under test. When a sharp image is obtained, observe the position of the lens focusing scale. If the camera lens scale coincides, the camera is correctly adjusted for that distance. For long focal length lenses add an arbitrary distance to $\Delta\ell'$. The scale reading should reflect this added distance. (Example: add 6" at the 4 foot setting - the camera's lens scale should read 4 feet 6 inches.) If the collimator has no distance scale calibrated, the amount of travel necessary to set the collimator objective for checking a specific distance can be obtained using the following formula:

autre distance que ∞

Formula 2.

$$\Delta\ell' = \frac{Fc^2}{Fc+L-D}$$



D = Distance between collimator objective and film plane
Fc = Focal length of the collimator objective
P = Position of the target
ℓ = Distance between collimator objective and target image
P' = Position of the image of the target
$\Delta\ell'$ = Amount of the travel of the collimator objective
L = Distance between film plane and target image

A table of $\Delta\ell'$ distances for Model No. C-6400 is shown on page 12 of this Instruction Manual.

TESTING REFLEX CAMERA RANGEFINDERS

If a reflex-type camera includes a wedge-type or similar rangefinder system in the focusing screen, the adjustment and verification of the rangefinder may be checked by observing the image of the target through the camera system. If the focusing scale of the camera coincides with the distance set on the collimator when the images perfectly coincide, the range-viewfinder system is correctly adjusted.

Remember that two-window rangefinders cannot be checked on collimators of this size, except with the possible use of additional fixtures.

OBSERVATION OF FOCAL PLANE

When a camera lens is set on infinity and observed via the collimator, the collimator permits actual inspection of the film plane and the image focused thereon. If film is in position, the auto-collimator permits observation of the image produced on the film surface. Either a mirror or an imaging block placed in the focal plane will provide higher reflection qualities and a smoother surface, thus producing a brighter image not necessarily indicating whether film would buckle in the film plane. Even if a pressure plate is not perfectly flat, it is possible to observe the image and the change of focus in the various parts of the focal plane on the surface of the pressure plate. Note that even a polished black pressure plate provides an adequate imaging plane, while a pressure plate that is patterned, either having holes or other markings on it, may interfere with observation of the image form.

INSPECTION OF PLANE SURFACE

With the collimator set at infinity, any mirror surface may be tested by placing it on the table of the collimator. If the surface of the mirror is not perfectly flat, with either a curvature or a prism effect being present, differences of image sharpness or placement may be observed. If an image can be observed and improves in focus by moving the collimator objective toward the mirror, it has a concave surface. If a sharper image appears when the objective of the collimator is moved away from the mirror, the mirror has a convex surface.

If the objective lens of the collimator must be moved $\Delta \ell'$ millimeters to obtain a sharp image, the mirror has a convex or concave surface having a focal length (f) calculated according to the following formula:

Formula 3

$$f = \frac{Fc^2 - \Delta \ell' Fc + \Delta \ell' D}{\Delta \ell'}$$

Since the terms $\Delta \ell'$ Fc and $\Delta \ell'$ D are insignificant at such small curvatures, the formula can be shortened to

Formula 3(a)

$$f = \frac{Fc^2}{\Delta \ell'}$$

The curvature permitted in filters is generally 400 times the diameter of the filter. Accordingly, the allowance on a filter of $\Delta \ell''$ millimeters diameter can be converted into the travel ($\Delta \ell'$) of the collimator objective using the following formula.

Formula 4.

$$\Delta \ell' = \frac{Fc^2}{Fc + 400d - D}$$

Note that it is possible to observe the focal length precisely of a curved lens, or the surface of the lens, by picking up the reflection from a single surface. Thus, if you wish to read the curvature of the front surface of a meniscus lens, simply adjust the image in the collimator until a sharp image is achieved. The focal length of the curve can then be determined with the use of Formula 3.

CHECKING FOR PARALLELISM

It is possible to determine parallelism of front and rear surfaces of filters, parallelism of plane glasses, and other similar tests. For filters or optical flats, place the unit under test on the collimator table square with the axis of the collimator. If the two surfaces are not perfectly parallel, you'll discover two images visible in the eyepiece, one reflected from the front and one from the rear surface. The distance between the images shows the error in parallelism between the two surfaces. The Model No. C-6810 graticule has an angular graduation scale with 30'' (1/2) markings. You can directly read an error in parallelism using that scale. If the two surfaces of a plane glass or optical flat are perfectly parallel, the two reflected images will be superimposed on each other and appear as one image.

It is similarly possible to check the parallelism between the focal plane and the lens mount of a camera body. First provide a mount on which the camera can be positioned so that the camera will be held squarely in line with the axis of the auto-collimator. The mount may consist of a steel block fitting the focal plane of the camera. A good quality plane mirror, when rested on such a block (without the camera being in position), may be used to determine the squareness of the block with the collimator axis using the test described for parallelism. Now note the position of the target related to the scale in the eyepiece. Remove the mirror and position the camera on the block in its place.

The mirror is then placed on the front lens flange, observing any displacement of the image between the two tests. You can take a reading of the error directly on the scale. If the parallelism is perfect, the reflected images will appear in the same location.

An alternate technique is to use a first-surface mirror as the positioning point for the camera focal plane. This requires the use of such a first-surface mirror sized to properly support the camera at the focal plane. The mirror must lie accurately in the focal plane. A piece of precise plane parallel glass may then be fitted on the camera lens flange. The distance between the images reflected from the focal plane mirror and the glass on the lens flange may be read on the scale of the Model No. C-6810.

OTHER TESTS INVOLVING ANGULAR MEASUREMENTS

Other parallelism and angular measurements may be taken using the collimator. A mirror placed on a lens barrel, for example, should show no movement as the lens is focused from one extreme to the other if the camera lens moves squarely during the focusing operation. If an error is present, the image will move within the eyepiece and a scale measurement of angle of error can be taken.

SUMMARY OF OPERATING INSTRUCTIONS

Look into the eyepiece with the light switch turned on. You can see an image of the reticle when you look into the eyepiece. Focus the eyepiece lens until the reticle is sharpest for your eyes. Then put a plane mirror on the base of the collimator in line with the lens. It may be necessary for you to adjust the position of the collimator by loosening the clamping handle A (see drawing on page 13) slightly. Then you can swing the collimator head in order to see an image in the eyepiece reflected from the mirror.

The objective lens operating ring should be adjusted so that the range scale on the barrel reads infinity. This focuses the objective lens of the collimator for infinity. Unless the collimator has been damaged (and it's unlikely) you should see a sharp image of the target in the eyepiece. This is the check of collimator focus referred to on page 2. The sketch on page 13 shows a lens mount fixture in position on the table of the collimator. This is the position in which the camera is placed with the lens up and film in the camera. If the camera is too tall, you may have to loosen clamping handle B and raise the collimator head by rotating the elevation ring.

With test film in the camera (it will be exposed), and the shutter open, the camera lens set on infinity should produce an image of the

target in the collimator on the film. When you look into the collimator eyepiece you'll see that image. If the image is sharp, the camera is focused properly. If the image is not sharp, the camera lens is not properly focused. You can judge this by changing the focus of the camera lens while looking through the collimator eyepiece and observing the change in sharpness. It's also possible to observe this change in sharpness by leaving the camera lens set at infinity and carefully rotating the collimator objective lens operating ring a small amount back and forth to find the sharpest image point. The sharpest image point should be when the scale on the collimator reads infinity.

The lens focusing scale may be checked for other distances simply by setting the lens at the particular distance, rotating the collimator objective lens operating ring until a sharp image is seen in the eyepiece and then reading the scale on the collimator. This is also described on page 5. Even though this collimator manual covers several models, the operation of the different instruments is not different at all. The technique is the same in every case. Note that when you are making this kind of a test using the C-6810, and accuracy is required, you should make certain that the distance between the camera film and the flange of the collimator lens mount is 120 mm. (about 4-3/4"). Note ~~For~~ Model C-6810

There are additional checks and techniques that you can use when working with your collimator, but the simple steps just described are all that are fundamentally involved. Notice that we suggest that you use film in the camera. This is not essential but it does provide you with more precise information. For example, film may not lie flat and what you are observing when you look into the eyepiece of the collimator is the image produced by the camera lens on the film. If the camera lens isn't producing a sharp image, it will appear unsharp. You are, of course, seeing a greatly magnified image of the film, and with a little experimentation, you will observe that you can actually see defects or other markings that might happen to be on the film when you look into the collimator.

If the camera has a film pressure plate of almost any type, you can usually see the image created on that pressure plate when there is no film in the camera. Some cameras employ pressure plates which do not make contact with the camera aperture plate and therefore do not lie near the plane where the film will lie and where the image will be sharpest. In these cases, you will quickly observe that the image is not sharp when you look into the collimator. Even though the brightest image visible in the auto-collimator is usually obtained when no film is in the camera and when the pressure plate is a bright, highly polished surface, you can also see the image created by the camera lens when the pressure plate is a black surface, a matte surface, ground glass (such as is the case in press cameras with a spring back) or any other material or object which lies in the focal plane of the camera. When testing motion picture cameras, it must be remembered that the smallest image and therefore the most difficult to see is created by a wide-angle lens on 8 mm. film. The image must be so greatly magnified that the position of the camera under the collimator and other small variables make such a test complex. On the other hand, your collimator is capable of measuring and observing the image created by a wide-angle lens on 8 mm. film. For use in motion picture cameras, of course, it must be remembered that the shutter is only open when the camera is operating. It is often desirable to prepare a short loop of film which can be loaded into the camera so that you can run the movie camera while checking the quality of the image. This is important, since film does not always move smoothly through a movie camera and you will discover, as you watch the image on film in such a movie camera, that the image will jump, vary in focus, and show other apparent problems depending on the quality of the camera and lens.

ANALYSIS OF THE LINES PER MILLIMETER IN THE SIEMENS STAR TARGET AS USED IN THE C-6810 AUTO-COLLIMATOR

The diameter of the target is 4 millimeters. The distance from center to outside or radius is 2 millimeters. The diameter of the open space in the center of the star is .21 millimeter and the diameter at indicia extending from that point outward in the target then would be .5 millimeter, .79 millimeter, 1.00 millimeter, 1.58 millimeters, 3.05 millimeters, and OD of course, being 4.00 millimeters. The Siemens Star may be converted into lines per millimeter, considering that the arc of each segment is 10°

Using these figures, the following lines per millimeter may be associated with each index on the Siemens Star proceeding from the point of the segment out to the OD: inner point of segments represent 95 lines per millimeter. Index or line one represents 57 lines per millimeter. Line two represents 25 lines per millimeter, line three represents 20 lines per millimeter, line four represents 13 lines per millimeter, line five represents 6 lines per millimeter, and the OD represents 5 lines per millimeter.

The size of the star is reduced on the imaging plane of the lens under test in proportion to the focal length of that lens, using the following formula:

$$\frac{300}{\text{focal length of test lens (millimeters)}} \times \text{resolution of target} = \text{resolution on film}$$

where – –

300 = focal length of the collimator objective in millimeters.

For example, a 50 millimeter lens under test will reduce the target to an image 1/6 the actual size of the original so that the target image on the film will represent a range of resolution from approximately 600 lines per millimeter to 30 lines per millimeter.

The resolution produced on the film can be generally seen when examining the target image by the auto-collimator telescope.

Although not a purely objective test, results are interpretable according to the imaging surface, position of image on film plane, etc.

ANGLE RELATIONSHIPS

National Camera Auto-Collimator Model No C-6810

1 division = 30″ (30 seconds, or one half minute)

1 division = .000145″/inch (inches per inch)

.001454″/10 inches

.001745″/foot

2 divisions (1 minute of angle) = .000291″/inch

.002909″/10 inches

.003491″/foot

Graticule is calibrated in minutes of angle with every 5th minute numbered.

Thus, a 1.75″ (1-3/4) diameter lens flange that is 7 minutes out of parallel should be shimmed using the following formula:

$$S = a \times d \times .000291$$

when S = shim required
a = angle of error in parallelism (minutes)
d = diameter of lens flange

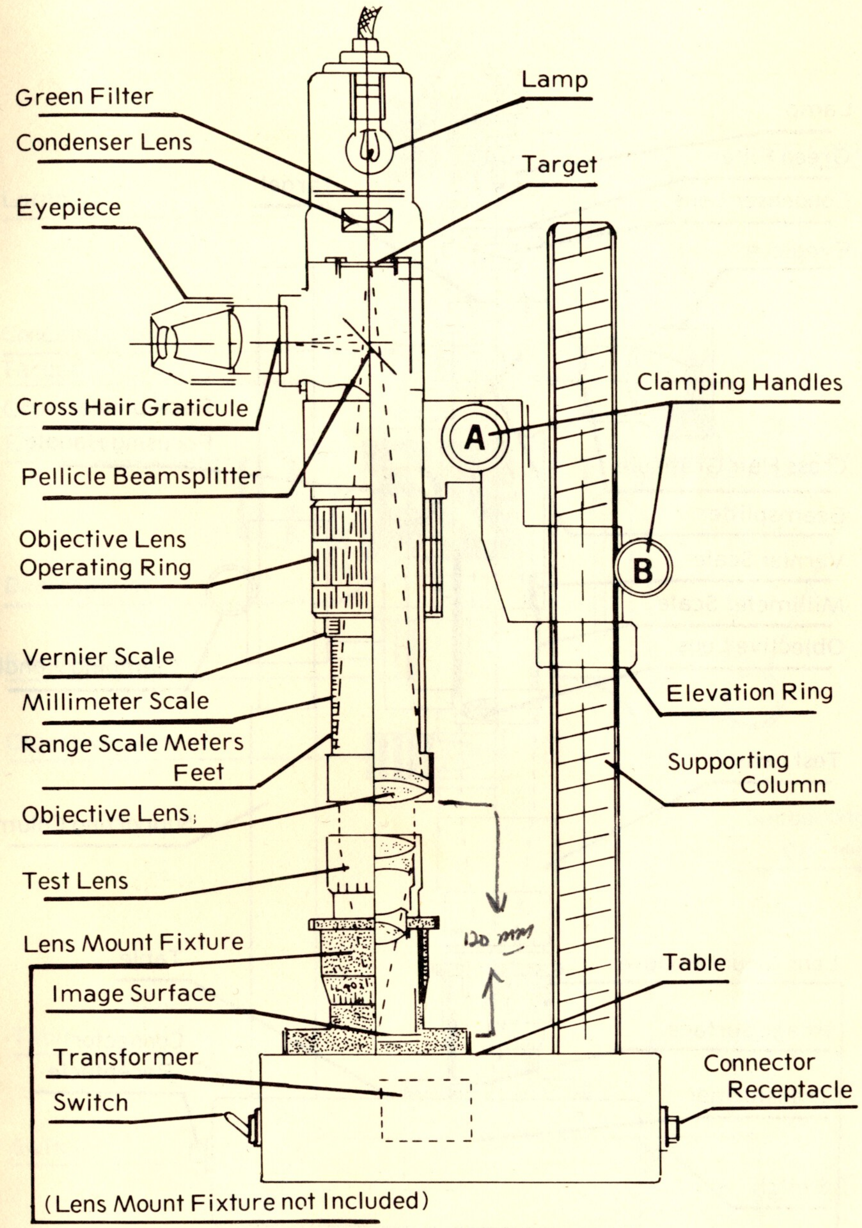
or $S = 7 \times 1.75 \times .000291$

or S = .00357″ or .004″ shim stock

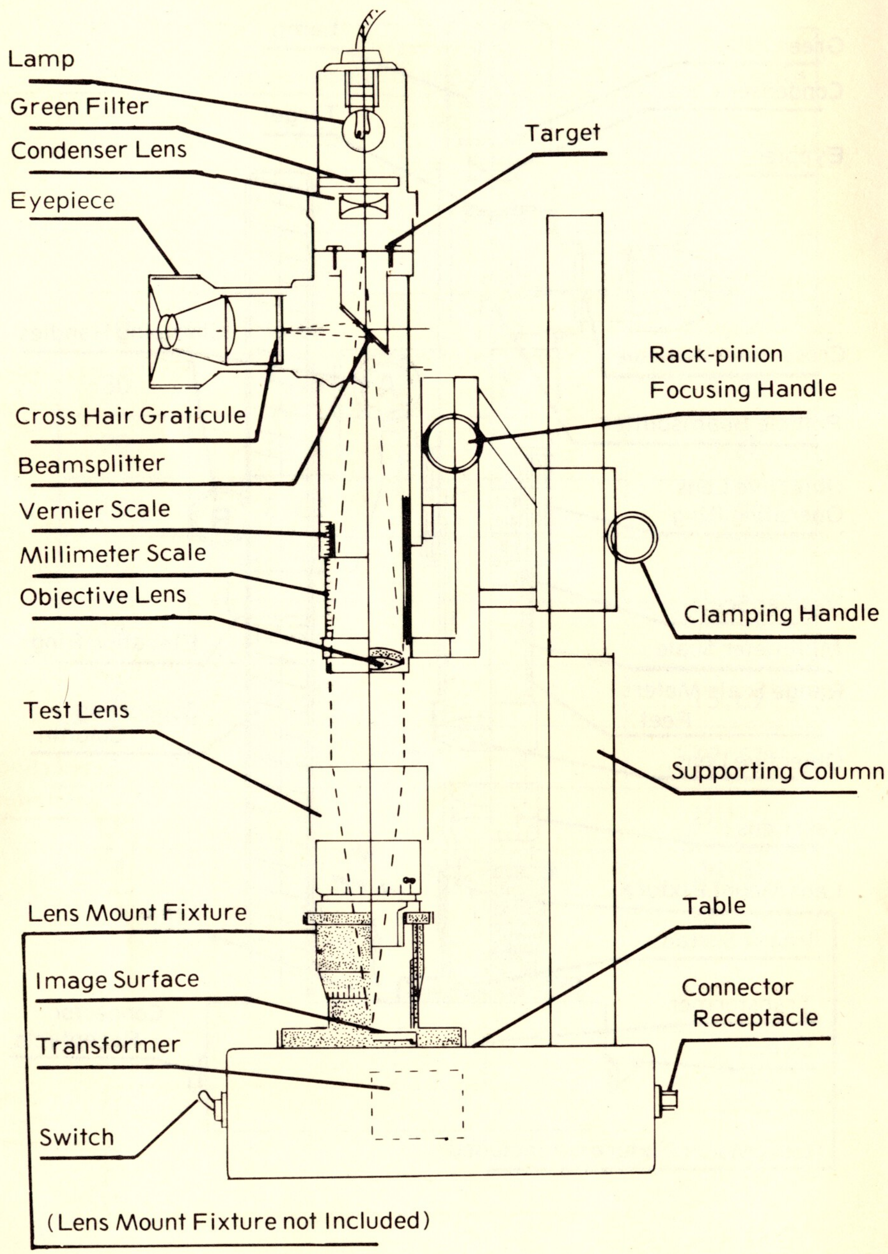
CONVERSION TABLE FOR MODEL NO. C-6400

Feet	Vernier Scale	Meters	Vernier Scale
200	.656	50	.799
100	1.31	30	1.33
60	2.18	20	2.00
50	2.62	15	2.66
30	4.35	10	3.98
20	6.51	7	5.68
15	8.65	5	7.92
12	10.79	4	9.88
10	12.91	3	13.11
8	16.11	2.5	15.69
7	18.32	2	19.51
5	25.41	1.7	22.86
4	31.52	1.5	25.81
3	41.48	1	38.10

MODEL NO. C-6810



MODEL NO. C-6400



MODEL NO. C- 6005