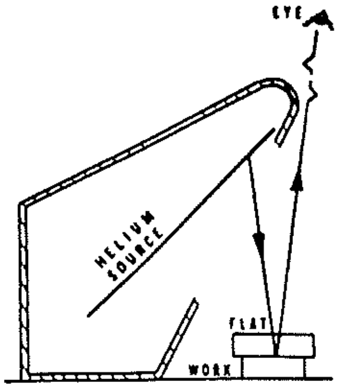
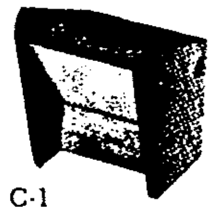
# MONOCHROMATIC LIGHTS




Typè C Light,
for General Purpose Use,
4", 7", and 12" Capacity.

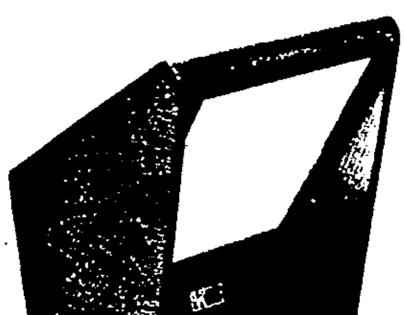


C-1
for work up to 4"

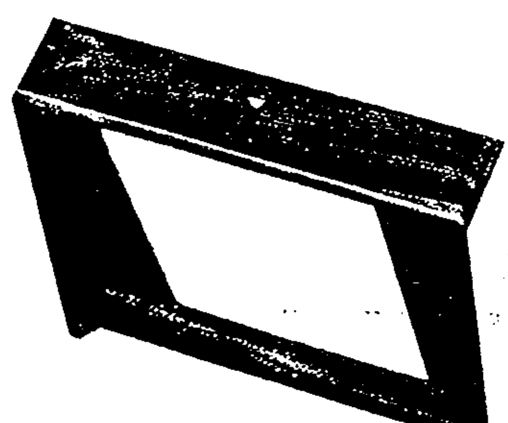
The C-1 Monochromatic Light is similar to the Standard model, and will accommodate work in sizes up to a full 4" square. The cabinet has a sloping top, and measures 6½" wide, 7½" high, and 9" deep; weight is 7 lbs. The C-1 light has all the features of the other Type C lights, including brightness, and has the extra advantage of small size.

The Standard C-2 Monochromatic Light will form bright, sharp fringes on almost any surface which is flat and reflective, and has the capacity for work pieces to over 6" diameter. The cabinet is 12" wide, 11" high, and 11" deep; weight is 15 lbs. This model is the latest improvement of the early prototype, and certain time-tested features are still retained.

The Large C-3 Monochromatic Light is also similar in its features to the other two, but has a work capacity of over 12". The wide and deep area flooded by bright helium light can be effectively used for either very large work or for several small work pieces at a time; or it can be used by two operators simultaneously on small work. Exterior dimensions are 22" wide, 16½" high, and 18½" deep; weight is 42 lbs.



C-2
for work up to 8"



C-3
for work up to 12"

# REFLEX INTERFERENCE VIEWER

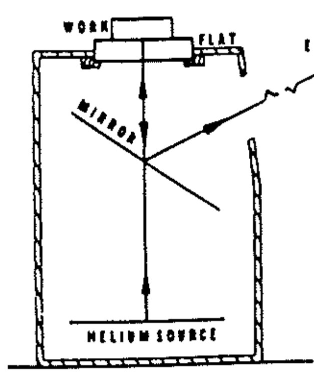
## rapid production inspection to maximum precision on brightly finished work

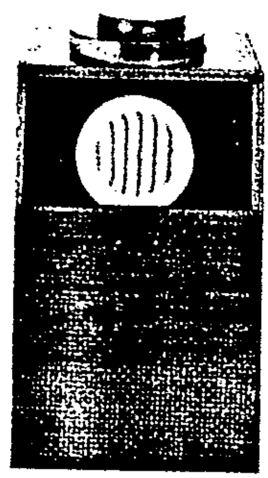
In the VK Reflex Viewer the optical flat is secured above in a fixed cell; the work is placed on top of the flat and bands noted, and the work is ready to exchange. Keeping work on top of the flat avoids serious distortion due to the weight of the flat when the work is small or delicate; work larger than the flat can be inverted and moved across the flat for two or more observations. Handling of the optical flat is entirely eliminated and risk of accidental damage or excessive wear is greatly diminished.

U-6 Monochromatic Reflex Interference Viewer — For use with 6″ flat, (masks available for smaller flats). Light dimensions are 10½″ wide, 17″ high, and 13½″ deep: Net weight is 19 lbs. case natural mahogany finish, 110V — 60Hz, complete with cord and switch.

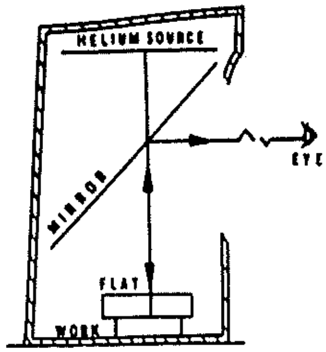
U-12 Monochromatic Reflex Interference Viewer — For use with 12″ flat, (masks available for smaller flats). Light dimensions are 24″ wide, 48″ high, and 24″ deep: Net weight is 46 lbs. case natural mahogany finish, 110V — 60Hz, complete with cord and switch.

A dust cover (masonite disk) is furnished to cover flat opening when light is not in use.

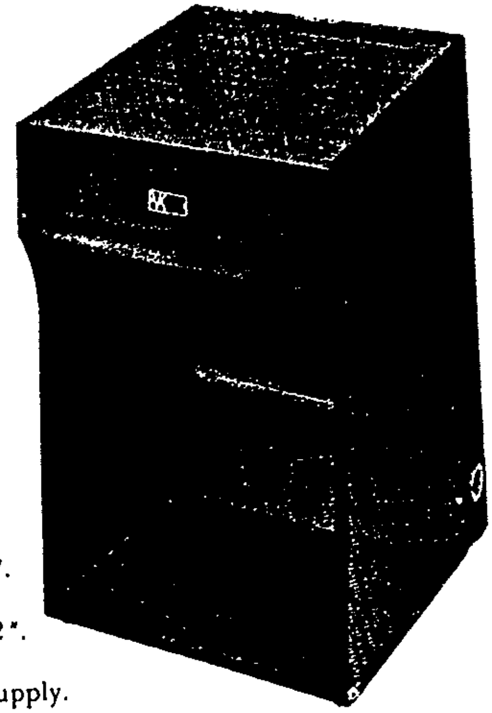


Type U Reflex Viewer, for Production Use, 6″, and 12″ Capacity.




Type L Light, for Lab use,
8" and 12" Capacity.



L-1A Monochromatic Light for work up to 8".

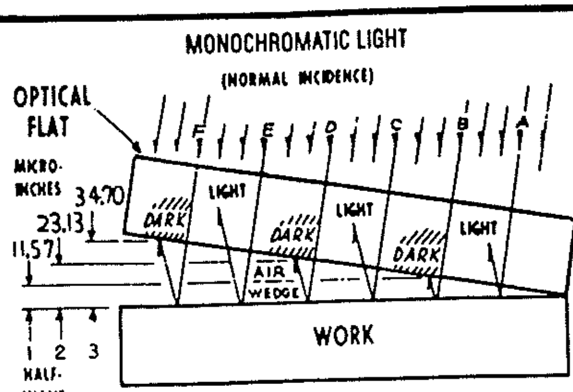
L-2A Monochromatic Light for work up to 12".

All lights: standard 110 volt, 60 cycle, A.C. supply.

The Standard L-1A Monochromatic Light was originally designed for use in standards laboratories for inspection of work pieces as large as 8", or for simultaneous examination of several smaller gages or parts. This unit is 15" wide, 22½" high, and 17" deep; weight is 36 lbs. The optical system of this monochromatic light justifies the interpretation of interference band patterns in helium light at the correct value of .0000116" per band. To exploit full advantage of this feature we recommend that the observation point be at least several feet from the work in a dimly lighted room.

# HOW TO MEASURE FLATNESS
## with Optical Flats

The easiest and best way to test the flatness of a flat lapped or polished surface is with an optical flat. Such surfaces are found on micrometers, measuring machines, gage blocks, snap gages, ring seals, valve seats, and precision flat lapped parts. The surface must be sufficiently finished to reflect light; ordinary ground surfaces are too irregular to show light wave interference bands. However, unless the material is extemely soft or porous, a few rubs on a flat lap will smooth off the top of the grinding ridges and enable bands to be seen in monochromatic light.




INTERFERENCE DIAGRAM

Fig. 10

Certain rays, B, D, F, etc., fall where wedge thicknesses are just one, two, three, etc., half-wavelengths, and are reflected partly from the flat and partly from the work. At reflection each of these particular rays interferes with itself, in accordance with optical laws, thus cancelling its own light and appearing from above as a narrow dark band. Since each dark band is like a contour line, it defines a path across the wedge wherever its thickness is exactly uniform. The dark bands are thus useful for precise measurement of work flatness. Other rays, A, C, E, etc., reflect upward without interference and appear as wide alternate bright bands.

### The Phenomenon Of Interference Bands

When there is an extremely thin wedge between two flat surfaces a series of interference bands or fringes appear. The bands occur at right angles to the slope of the wedge. They represent intervals of approximately 11.57 millionths of an inch (293.8 nanometers) from the surface being tested to the optical flat when a monochromatic light of 23.13 millionths (587.6 nm) wave length is used. The Van Keuren series of helium monochromatic light sources provide a highly diffused light of this wave length.

Dark bands occur because light reflections from the two surfaces which form the wedge interfere with each other where the thickness of the wedge is one half or multiples of one half the wave length of the light. The parallel bands thus form at zones where the wedge thickness changes by ½ wave length. Between each pair of dark bands the reflections reinforce each other and produce bright bands. When viewed perpendicularly in helium light, the dark bands are located where the air wedge thickness changes by equal intervals of .00001157" (293.8 nm).

## Procedure For Making Flatness Tests

1. Remove the dust from the surface of the work and the optical flat with a camel hair brush. Burrs and nicks should be removed by using an appropriate deburring stone.
2. Place the work under the monochromatic light.
3. Place a clean piece of optical tissue (or any other clean paper) over the work piece.
4. Place the optical flat on top of the paper; the optical flat may be on the bottom in cases where a reflex light is used.
5. Hold the optical flat steady with one hand and draw the paper out from between the work piece and the optical flat with the other hand.
6. If bands do not appear, repeat this procedure. This will reduce the possibility of scratching the optical flat and the work piece — as in scrubbing both pieces together.
7. The bands should be viewed from a distance at least 10 times the diameter of the optical flat and with the line of vision as nearly perpendicular to the flat as possible. If the bands are straight, parallel and evenly spaced, the surface is flat. If the bands are curved or are unevenly spaced, the surface is not flat.

## If Bands Fail To Appear

If the bands fail to appear it may be due to one of the following reasons:

1. Dust, burrs or nicks are still holding the optical flat away from the surface. Do not slide the optical flat around on the surface in an effort to make the bands appear as this may scratch the flat. Instead, try again after recleaning the surface or removing the burrs.
2. The wedge between the surface of the work and the optical flat may be:

   a. **Too thick.** Press down on the optical flat with a uniform pressure to squeeze out the air film.

   b. **Too thin.** If moisture or oil is present it may cause the optical flat to wring or adhere to the work so closely that bands cannot appear.

   c. **Too angular.** The flat may be making too great an angle with the work, in which case the bands will be so close together as to be nearly invisible. Try putting pressure at different points around the edge of the optical flat.

   d. **Too nearly parallel.** This rarely occurs. In this case however, the bands would be so far apart that they would not be distinguishable as bands.

## Amount Of Flatness Error

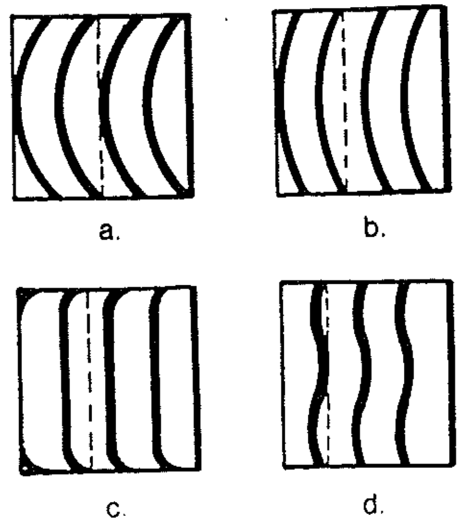



Fig. 11
Different conditions and degrees of flatness error. The right edge of the work is in contact with the flat - explanation of patterns follows.

a. Convex surface: side edges low 11.57 millionths.
b. Convex surface: side edges low 5.78 millionths.
c. Nearly flat: side edges low or rounded 5.78 millionths.
d. Surface both convex and concave: hollow in center, higher each side of center and lower at side edges: error, 3 millionths.

The amount that the bands curve, with reference to the distance between them, indicates the amount of flatness error. In judging the amount of curvature, imagine a line drawn across the surface from one end of any band to the other end of that same band. If this line just touches the previous band the flatness error is 1 band (see figure 11a). If it comes half way between the two bands the error is ½ band (see figure 11b). If the surface is out of flat two bands the line will just touch the second band, if it is out 3 bands it will just touch the third band and so on. In practice the imaginary line may be made real by aligning a piece of fine wire or thread across the face of the monochromatic lights diffusion screen with the ends of the band, or by use of a transparent straight-edge.

## Convex Or Concave?

The rule for determining whether a surface is concave or convex is as follows:

If the bands curve around the thin part of the wedge (contact or pressure point) the surface is convex. If they curve around the thick part of the wedge the surface is concave.

## Irregular Surface

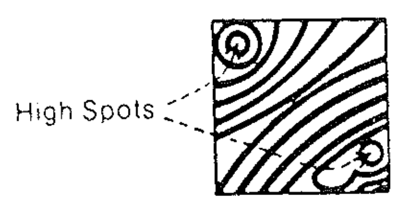



Fig. 12

Where the surface to be measured is irregular, the contact method of flatness testing is recommended. Here the flat is placed in the most intimate possible contact with the work piece; no attempt should be made to maintain a wedge. A band pattern such as shown in figure 3 will appear. The bands are to be interpreted as contour lines on a map, the interval being 11.57 millionths of an inch (293.8 nm).

Thus the total flatness error is equal to half the band count between points of contact. In the figure shown the 12 bands between high spots indicate a valley 6 bands or 69.42 millionths deep.

## Additional Suggestions Regarding Flatness Tests

1. The bands should be viewed as nearly perpendicularly as possible. If viewed from an increasingly oblique angle the value of 11.57 millionths per dark band can increase significantly; there will be fewer bands and they tend to straighten.

EFFECTIVE BAND VALUES

| Viewing Angle | Band Value (micro inches) |
|---|---|
| 10° | 66.61 |
| 20° | 33.82 |
| 30° | 23.13 |
| 40° | 17.99 |
| 45° | 16.36 |
| 50° | 15.10 |
| 60° | 13.30 |
| 70° | 12.31 |
| 80° | 11.74 |
| 90° | 11.57 |

2. Where an observation from a distance of 10 times the diameter is impractical, a monochromatic light employing the bent beam principal such as the Van Keuren type L light is recommended.

3. Van Keuren quartz flats distort very little with temperature changes. However, a warm flat may distort a cold surface. Therefore, all work should be allowed to come to a common temperature before being tested.

4. The number of bands which appear is not an indication of the flatness of the surface but relates only to the steepness of the wedge. The bands may be made fewer and farther apart by pressing on the optical flat until they are most conveniently spaced for evaluation.

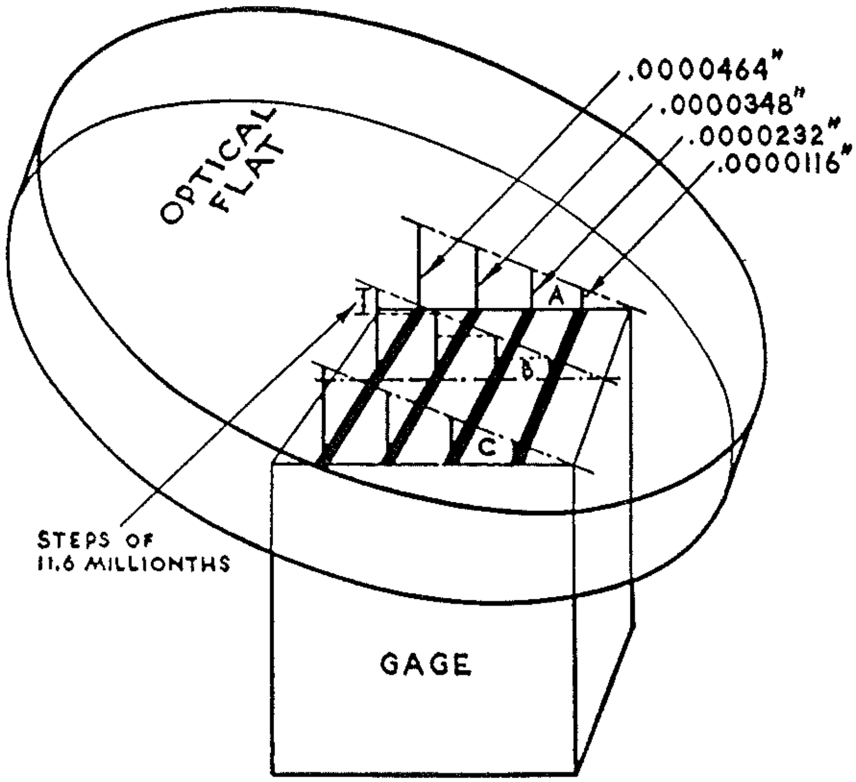
5. A perfectly flat surface will show straight and evenly spaced bands. A cylindrical surface will show straight but unevenly spaced bands. In this case, a test with the bands running at right angles to their original position will show curved bands and make it possible to evaluate the curvature.

# APPENDIX G

## Testing Flatness with an Optical Flat

### MEANING OF THE BANDS

When a series of bands occur between two nearly flat surfaces, there is a wedge of air between them. The slope of the wedge is at right angles to the bands. The bands locate steps of 11.6 millionths vertical distance from the surface being tested to the optical flat, when a VK helium monochromatic light is used. (See Fig. below)




Bands Locate Steps of 11.6 Millionths.

Bands occur because light reflections from the two surfaces which form the air wedge either interfere with, or reinforce, each other, according to the thickness of the air wedge. Interference of two reflections causes darkness, and occurs where the air wedge thickness is exactly one ½ wave length (or multiples) of the light used. Parallel dark bands thus form up and down the slope of the air wedge, at zones where the wedge thickness changes by one ½ wave length. Halfway between each pair of dark bands a reinforcement produces a bright band. When viewed perpendicularly in helium light, the dark bands are located where the air wedge thickness changes by equal intervals of .0000116".

### STRAIGHT, PARALLEL AND EQUALLY SPACED BANDS IDENTIFY A FLAT SURFACE

Referring to Fig. above, it is almost self-evident that straight, parallel and equally spaced bands identify a flat surface. If the surface were convex, with the front and rear edges (A and C) lower than the middle (B), the vertical distance of 11.6 millionths would occur sooner on the wedge at A and C than at B and the bands would curve around the edge of the gage block which is in contact with the optical flat.

# TESTING FLAT RING SURFACES

Optical flats are used extensively for testing flat lapped ring seals made of bronze, carbon, steel and other materials. These rings generally are of narrow face and are likely to be relatively thin. Following production finishing, the surfaces may be warped or distorted from a true plane, while they may or may not be sufficiently flat across the narrow face of the ring. An accurate test of the ring should evaluate both the flatness error across the face and the amount of warp from a true plane.

There are two methods for testing rings, namely the air wedge method and the contact method. Of these, the air wedge method is generally preferred because of the reduced wear on the optical flat and also because of the small chance of bending the ring during the test. However, the contact method is useful and easier to understand and should be used when necessary. Both methods are shown in the following illustrations.

The same principles which have been given in the preceding pages for continuous surfaces apply to rings. However, the one principle which is generally overlooked in evaluating the amount of warp is the variation in the spacing of the interference bands.

On a continuous surface, and across the width of face of a ring, it is convenient and easy to judge the curvature of the bands relative to the distance between them; but to determine the amount of warp of a ring, the variation of spacing of the bands should be noted. In applying the band spacing principle to the air wedge method, it is helpful to imagine the ring to be divided in two halves, such as the front half and the rear half, or the right half and the left half. The bands are then counted on each half.

**Rule: The warp error or distance from the high point to the low point will be ½ of the difference between the number of bands on one half and the number of bands on the other half.**

In general, if the ring is divided into two halves by a line from the point of contact to the thickest part of the air wedge, or at right angles to this line, the maximum error will be determined.

Fig. 100 shows an optical flat making an angular contact with a flat ring at C and sloping upward with an air space at A. The band pattern consists of straight evenly spaced bands, which proves the surface of the ring to be flat. The subsequent Figures 101 to 109 show various band patterns with explanations of the surface errors which exist. The illustrations show only ½ of the optical flat, or no optical flat, in order to present the band patterns more clearly. Figures 106 and 109 show applications of the contact method.

The contact method results in interference bands which are similar to the contour lines of a profile map. To understand the meaning of such bands it is only necessary to locate the high spots, and note how the surface goes down hill from these high spots, 11.6 millionths for every band. If an even number of bands (such as 6) occur between two high spots, the bottom of the valley is ½ band deeper than the 3rd band from each high spot, or 3½ bands deep. Otherwise a light space would not appear between the 3rd and the 4th band. If an odd number of bands (such as 5) occur, the bottom of the valley is at the 3rd band from each high spot or 3 bands deep. Stated mathematically: The error $= \frac{n + 1}{2}$, where n = the number of bands between two high spots.

SURFACE FINISH OF SEAL RINGS. The character of the light wave bands is a good indication of the surface finish. If the bands are jagged or wavy, it means that actual depressions or scratches are present which cause this waviness. If they are well defined and of regular width the surface is smooth. If the bands are faint and hardly visible, the surface may be badly scratched, pitted or otherwise poorly finished. Means should be taken to improve the finish both for speed of inspection and efficiency of the seal, especially in the case of dull or porous material.

TOLERANCE. The determination of a proper specification for the tolerances on flatness and warp of sealing surfaces, as well as the inspection procedure itself, can be a highly critical matter. Numerous instances have occurred where needless expense or difficulty in finishing, inspecting, or functioning originated in the selection of improperly chosen tolerances or inspection methods. For example, although a common tolerance specified for seal rings is "Flat to 3 light wave bands," it is a fact that for many designs this may be too wide a tolerance for flatness across the narrow ring face, and it may be too close a tolerance for warp. (Careful testing will show that very little effort can bend some types of seal rings more than .000035".)

In addition, much confusion and inconsistency has followed attempts to apply and correlate certain mechanical methods, such as straight-edge, and Prussian Blue tests, in fine tolerance requirements. These otherwise excellent methods are usually quite erratic and ineffective for flatness limits finer than .0002", or larger, and in most cases are incapable of any numerical evaluation.

For most fine tolerance applications the optical flat is a valuable tool for both inspection and product control. This method is strongly recommended for seals of all sizes, materials, and tolerances where the surface can be finished reasonably bright or reflective.

The accompanying illustrations (Figs. 101 to 109) are typical only of specialized shapes and exaggerated errors. They are offered solely as an aid to the understanding of principles on which a very precise interpretation of the bands may be made. This detailed analysis of the pattern is rarely necessary in practice except for the most exacting tolerances (such as .00001" or finer) or for analyzing defective finishing procedures.

It should be emphasized that, particularly for intermediate tolerances, a familiarity in judging the band pattern is developed very quickly. Since the bands form across the entire surface, the eye soon learns to easily and rapidly scan the surface as a whole.

In this manner the need may often be entirely eliminated for detailed evaluation of the individual features of the band pattern, and this is especially true when parts are well finished and provide band patterns that are reasonably regular and consistent with good functioning.

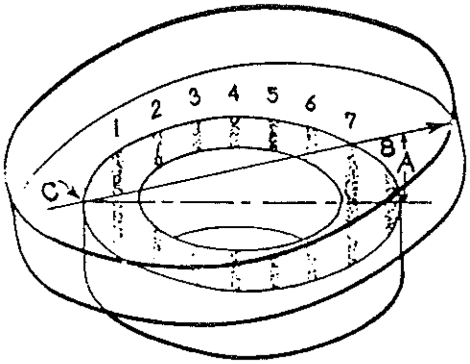


Fig. 100. A flat ring. Straight, parallel and evenly spaced bands.

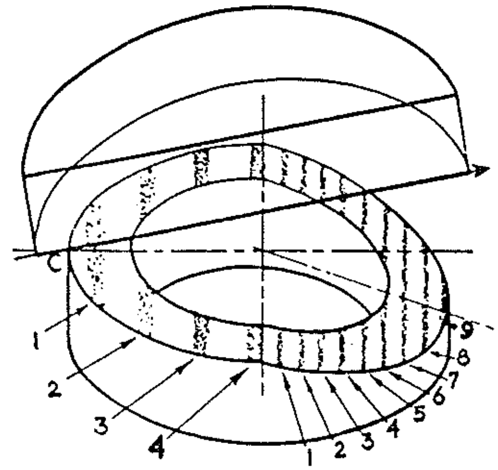


Fig. 101. A roof shaped ring, having 4 bands on the left half and 9 bands on the right half. Error $= \frac{9-4}{2} = \frac{5}{2} = 2\frac{1}{2}$ bands.

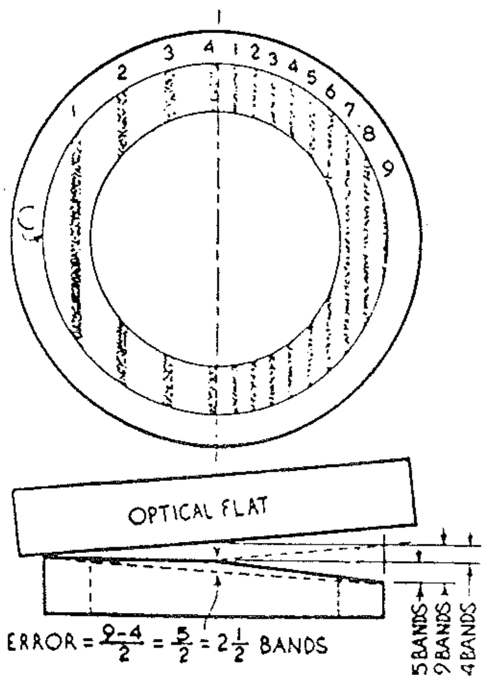



Fig. 102. Diagram of roofed shaped ring same as Fig. 101, showing how the error is ½ the difference between the number of bands on one half and the number of bands on the other half.

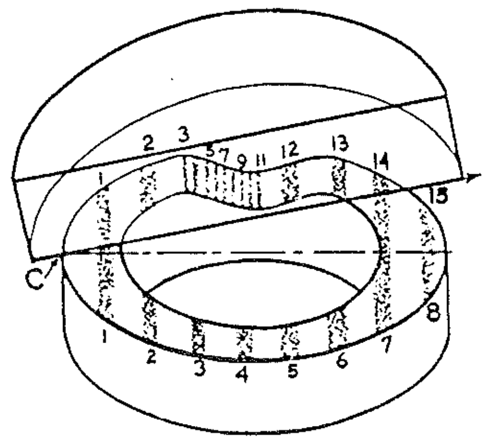


Fig. 103. Local hollow. 15 bands on rear half and 8 bands on the front half.

Error $= \frac{15-8}{2} = \frac{7}{2} = 3\frac{1}{2}$ bands.

Note the closely spaced bands at the start of the hollow. On the up slope of the hollow the surface is more nearly parallel to the optical flat and the bands are farther apart.

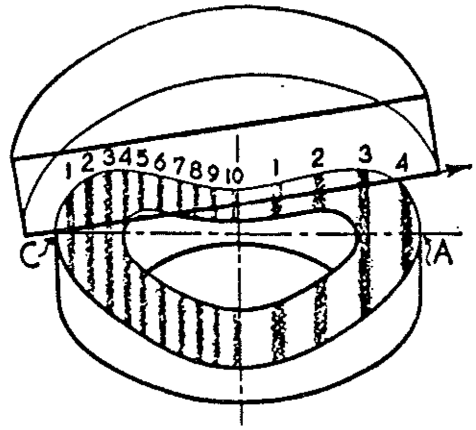



Fig. 104. Saddle shaped ring. 10 bands on the left half and 4 bands on the right half.

$$\text{Error} = \frac{10-4}{2} = \frac{6}{2} = 3 \text{ bands.}$$

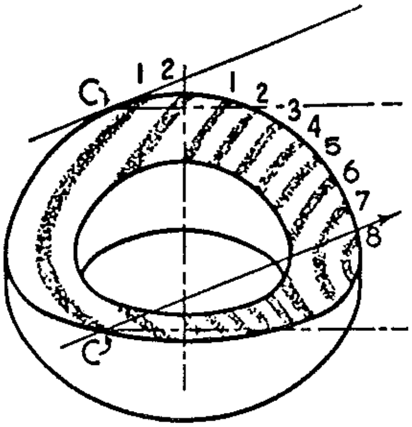



Fig. 105. Saddle shaped ring same as Fig. 104 but ring rotated ¼ turn. The flat now contacts at 2 points (C) and (C).

$$\text{Error} = \frac{8-2}{2} = \frac{6}{2} = 3 \text{ bands.}$$

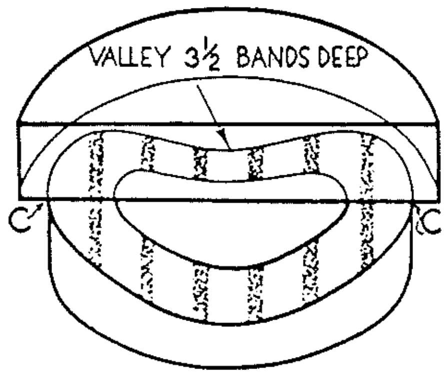



Fig. 106. Saddle shaped ring, same as Fig. 104. Contact method. The optical flat tends to make contact at the 2 high points (C) and (C). The 6 bands between the contact points show a valley $\frac{6}{2} + \frac{1}{2} = 3\frac{1}{2}$ bands deep.

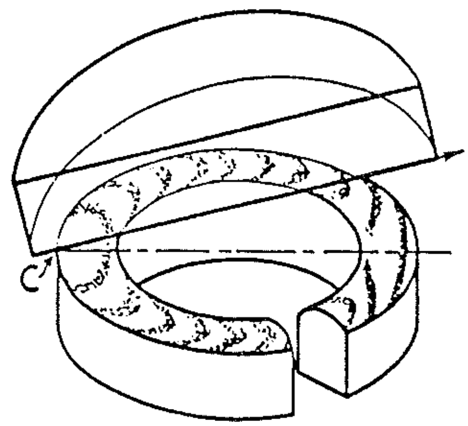



Fig. 107. Toric ring. The surface is like a doughnut or automobile tire. The bands curve the distance between them showing that the outside and inside edge of the ring are 1 band lower than the center.

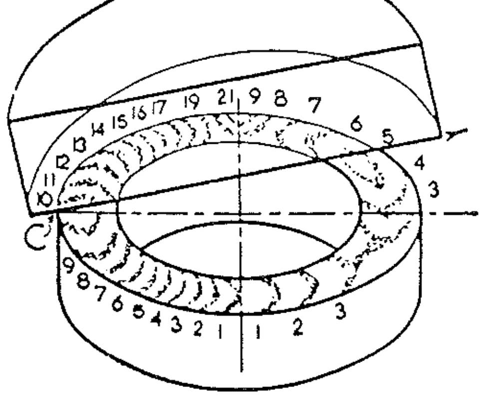



Fig. 108. Irregular ring. 21 bands on the left half and 9 bands on the right half.

$$\text{Error} = \frac{21-9}{2} = \frac{12}{2} = 6 \text{ bands.}$$

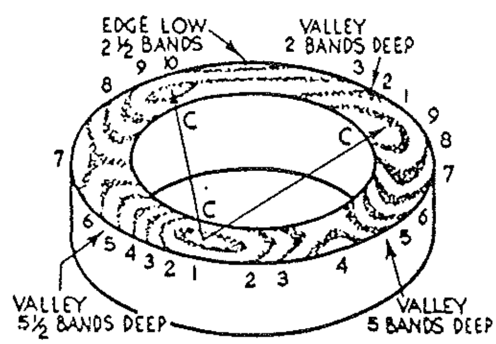



Fig. 109. Irregular ring. Contact method. There are 3 points of contact and 3 valleys between them.