IHF:AC

Letter Circular LC21
(Communication B521)
Gage Section
Bureau of Standards
Washington, D. C.
July 14, 1919
9 Sheets

THE MICROMETER MICROSCOPE AND ITS USES IN GAGE INSPECTION.

The micrometer microscope is a measuring instrument which has many important applications, not only in the scientific laboratory but also in the inspection laboratory, the instrument shop and the tool room. It is particularly valuable in facilitating the accurate measurement of dimensions which can not be readily determined by means of the various forms of contact measuring instruments or precision gage blocks used in conjunction with a test indicator. This instrument has been used by the Gage Section, Bureau of Standards, in various ways for the inspection of munitions gages and from the experience thus gained and other knowledge available the following information as to the construction, the field of application, the conditions essential to the obtaining of correct results, and the precautions to be observed in the use of this instrument are presented.

DESCRIPTION OF THE MICROMETER MICROSCOPE.

The micrometer microscope is a combination of the micrometer screw and the ordinary microscope and, without the use of subsidiary measuring apparatus, is itself a useful instrument for measuring very small lengths. The essential parts of a micrometer microscope, illustrated in Fig. 1, are the objective A mounted in the body tube B, the micrometer box D in which is mounted a system of fixed and movable cross-wires, and a magnifying eyepiece which may be adjusted to focus on the cross-wires. The latter usually consist of pieces of spider web stretched across a brass frame but recently very fine platinum wire has been successfully adapted to this purpose. Fine lines ruled on a glass plate are also sometimes used.

The objective most suitable for the type of work herein referred to is of the simple form having two lenses, which is the smallest number that will give good definition. The objective produces an enlarged image of the object which is adjusted, by focusing, to lie in the plane of the cross-wires. The eyepiece in its simplest form consists of two plano - convex lenses, with the convex sides nearest each other, as shown. It is used to observe the cross-wires and the enlarged image of the object. In the micrometer box the slide F, on which the cross-wires are mounted, is free to move without lost motion. In a tapped hole at one end of the slide the micrometer screw is inserted and from the same end there are two holes drilled along each side of the slide which receive spiral springs. These springs serve the purpose of keeping the slide pressed in the same direction and hold the face of the flange on the micrometer head against the end plate of the micrometer box. The micrometer screw is very accurately made, particularly as to lead, and usually has a pitch of one-fifth or one-half of a millimeter. The micrometer head G is a disc, the periphery of which is graduated into fifty or

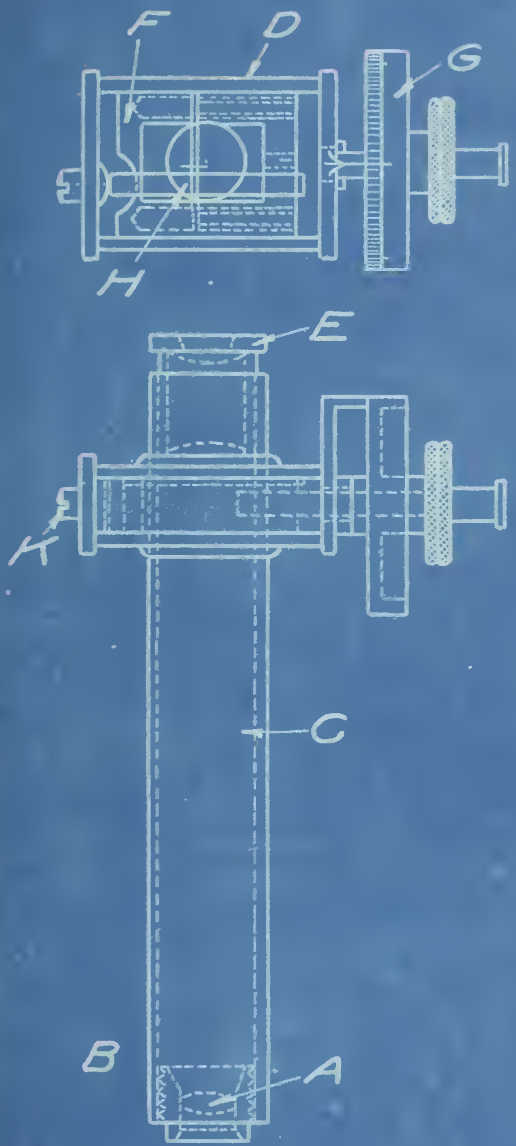


FIG. 1.

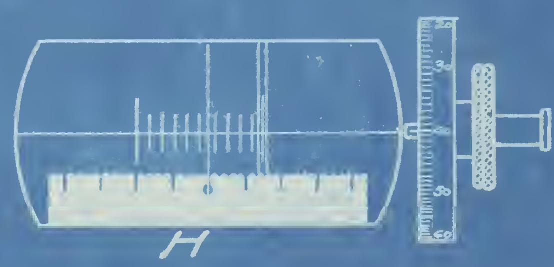


FIG. 1A.

one hundred parts to facilitate reading of fractions of a turn. To enable the counting of whole turns there is located in the field of view at H a saw toothed index or comb, on which the distance from one tooth to another corresponds to the motion of the movable cross-wires in one complete turn of the screw. Every fifth notch is cut deeper than the others to aid in counting. The comb has a small amount of adjustment, the screw K being used for that purpose. The double cross-wires fixed on slide F, are located a little lower than the under side of the comb so that they will not come into contact with the latter and break when the slide is adjusted.

MANIPULATION.

In using the micrometer microscope the deep notch farthest from the screw head (a, Fig. 1A) is taken as the zero position of the cross-wires. When the cross-wires have been set upon a line in the field of view the reading consists of the number of whole notches between the zero notch and the position of the cross-wires plus the reading on the head for the fractional turn. The appearance of the field of view and of the head of the screw is shown in Fig. 1A.

In measuring a short interval the movable wire is first set on one end and then on the other, each position being read as described, and the difference between the two readings is the required length in terms of turns of the screw. Readings should be repeated about four times and the mean should be taken as the measurement since it is practically impossible to set the wires in exactly the same position each time. The interval measured should be central in the field of view and the fixed cross-wires used in adjusting the object to be measured so that it is parallel to the line of motion. The final motions of the screw in making settings should always be in the same direction to eliminate errors due to lost motion; usually that direction is best which gives increasing numbers on the divided head.

Where readings are to be made on scratched lines, such as those on a divided scale, it is desirable to have two parallel wires for the movable index, the distance between them being a little more than the width of the line. In setting upon a line the parallel wires are adjusted so that the line bisects the space between them. Illumination should be vertical to the plane of the scale or, if vertical illumination can not be used, the illumination should be along the line but not across it.

The number of turns of the screw corresponding to a given length depends upon the distance between the objective and the cross-wires and the distance from the object to the objective. To obtain a measurement in any given system of units the microscope is calibrated by determining the number of turns of the screw necessary to move the cross-wires over the enlarged image of a standard unit of that system. This number is a constant for a given microscope only under fixed conditions.

The magnifying power of a microscope depends upon the ratio between the distance from the objective to the cross-wires and the distance from the objective to the object under observation. If, for example, the objective is 32 mm from the object and 128 mm from the cross-wires when focus is adjusted the object is magnified four times at the cross-wires and four revolutions of a screw having five threads per millimeter are required for the cross-wires to traverse the space between the images of two lines which are 0.2 mm apart. The total magnifying power of a microscope is determined by multiplying the magnification at the cross-wires by the number of times which the eyepiece magnifies. Microscopes having a total magnifying power of about eight or ten are best adapted for most gage work while those used on comparators for observing very fine lines usually have a total magnification of about twenty. Various magnifications are obtainable on the same microscope by using objectives of different focal lengths. Objectives are designated by their focal lengths as 8, 16, 32, 48 mm., 1 in., 2 in., etc.

Whenever using a microscope with cross-wires in the field of view, the eyepiece should always be focused on the cross-wires first and then the object should be focused by raising or lowering the microscope itself; a rack and pinion on the main body tube is usually provided for this purpose. In making measurements it is important that the instrument be properly focused. The perfection of focus is indicated by the absence of parallax; that is, when the eye is moved sideways there should be no apparent motion of the image with relation to the cross-wires. Another important precaution to be observed is to have the axis of the microscope perpendicular to the plane of the interval to be measured; otherwise an error is introduced in the measurement.

In making accurate measurements of length with the micrometer microscope, careful consideration should be given to the errors to which the instrument is subject. Errors may be due to deviations from the nominal value of a division, progressive errors of lead in the screw, and periodic errors which may proceed from periodic irregularities of the thread (so-called drunken thread), failure to have the thrust bearing perpendicular to the axis of rotation, or free from dust, an eccentric head, or an irregular division of the head. These errors and those due to lost motion are largely eliminated by good workmanship in the construction of the microscope and careful cutting of the screw. Important features which are sometimes overlooked in the design of the micrometer are the necessity of having the screw mounted centrally and provision for adequate and accurately machined bearing surfaces for the sliding members. Before using the instrument for precision length measurement it should, therefore, be tested for (1) regularity within a turn of the screw, (2) uniformity of successive turns of the screw and flatness of the field, and (3) the mean value of one revolution. Other errors may be due to failure to focus properly and to temperature changes. They are best taken into account by frequently

measuring some known length interval. A complete discussion of the errors affecting micrometer microscopes and the determination and application of corrections is given in Bureau of Standards Bulletin Vol. 10, Page 375 (Reprint 215). Methods for determining the periodic variation in parts of a turn and the change of value in successive turns of the micrometer screw are found in Bessel's Astronomische Untersuchungen, Vol. I, page 77 et seq. Königsberg, 1841.

ADAPTIONS AND APPLICATIONS.

Applications on Measuring Machines. The micrometer microscope is the best and probably the only indicating device for accurately determining the position of a ruled line and which, therefore, is suitable as an index for determining length intervals between the lines of a scale or for comparing scales and end standards with a length standard having ruled lines. For this reason it has universal application on comparators, dividing engines and measuring machines.

One type of comparator consists essentially of a rigid bar to which two micrometer microscopes can be firmly clamped at any desired distance apart and serves to facilitate the comparison of two nearly equal lengths and to determine the difference between them. The bar, to which the microscopes are attached, is fastened to a base on which rolls a carriage provided with two adjustable tables which support the scales to be compared. The movement of the carriage permits either scale to be brought quickly into view and the comparison is made by the transverse displacement of the two scales or bars under the two microscopes.

Another type of comparator, which is intended for the rapid measurement of divided scales, the distance between ruled lines or the points of intersection of surfaces on gages, spectra photographs, diffraction gratings, or such other objects which can be focused under the microscope, - consists of a base upon which a microscope is fixed and a movable stage supported in accurately lapped guides. The position of this stage is set and its movement is accurately measured by means of a micrometer screw. In a simpler form of this machine the stage is stationary and the microscope is moved on ways by a micrometer screw in a direction perpendicular to its axis.

A dividing engine is a machine for ruling lines which shall divide a given length into any required number of subdivisions. It usually consists of a screw of known pitch which moves a table designed to carry the object to be graduated. A steel or diamond graver is supported by an adjustable mechanism which permits the cutting of lines at right angles to the screw. It is often provided with two microscopes, attached to the base on which the table is mounted, so that it may be used as a comparator, or for

measuring lengths when the exact pitch and the lead errors of the screw are known. These are determined by placing a standard length upon the table and observing the number of turns of the screw necessary to move the table this length. A dividing engine for graduating circles is governed in its operation by the same general principle as the linear dividing engine and the microscope is applied in a similar manner although the machine is designed for circular work.

A measuring machine is an instrument of precision for comparing and duplicating existing length standards, originating gage sizes, and testing gages and standards. On such a machine a micrometer microscope serves to locate a sliding head at a positive known distance from a stationary head by bringing the cross-wires into exact coincidence with one of the various ruled lines of a standard scale which is attached to the machine. Measuring machines vary in the details of their construction but all have the common feature of a measuring screw mounted in either the stationary or sliding head by means of which intermediate readings between the divisions of the scale are obtained.

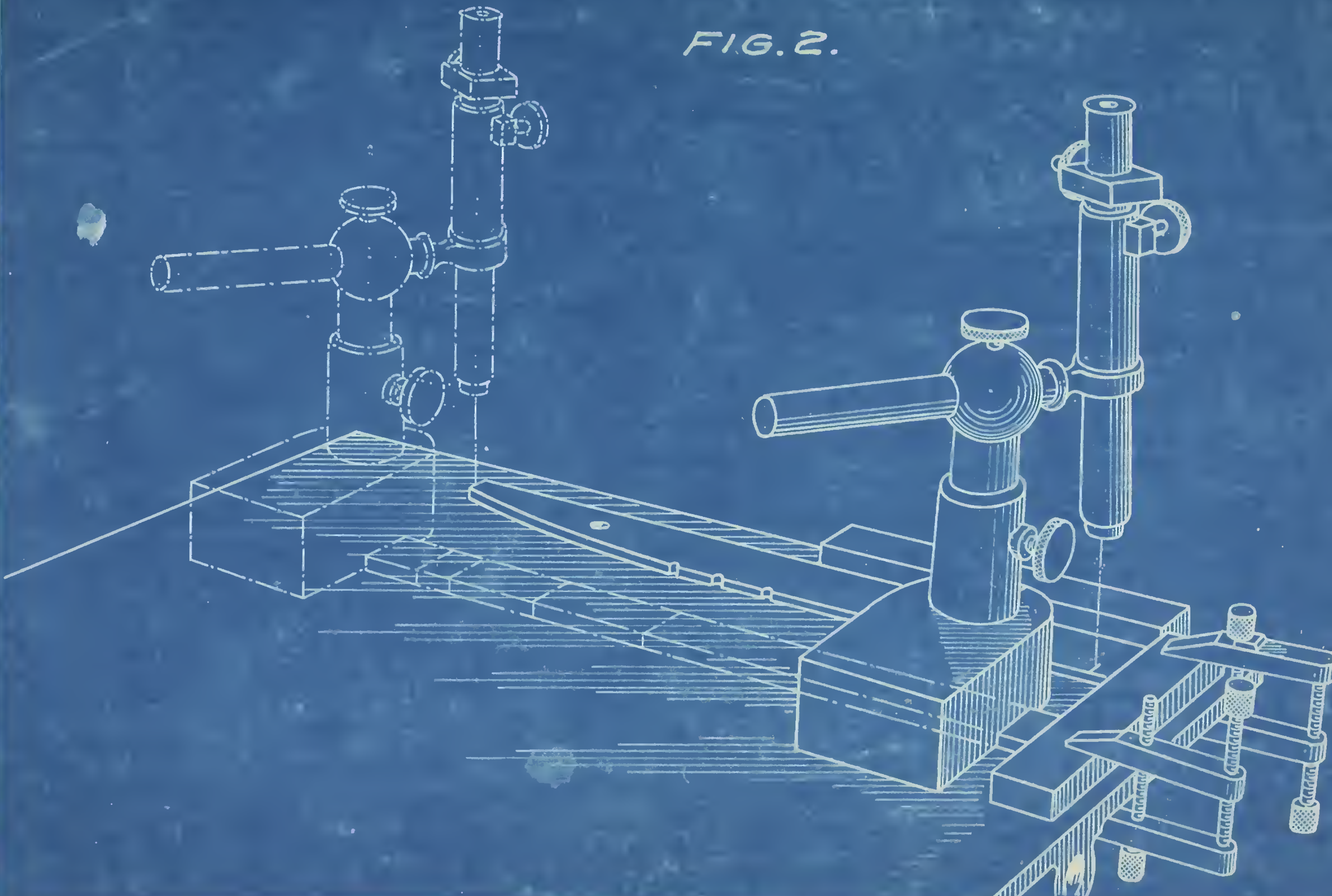
For the measurement of the various elements of screw thread gages the microscope has been applied to various types of machines for that purpose. Such machines have various forms but in general they consist of a bed-plate on which the microscope and gage are mounted and adjustments are provided for moving the gage or the microscope in a lateral and an axial direction by means of a compound slide rest or similar means. These movements are measured either by means of micrometer screws, precision gage blocks, or end standards. When inspecting a screw thread the microscope should be inclined so that its axis is in line with the helix instead of being perpendicular to the axis of the thread; this is necessary in order that a correct view of the profile of the thread may be obtained. Owing to the tangential position of the microscope it is difficult to focus on the plane of the profile which passes through the axis of the screw. For this reason it is the usual practice to first focus on the uppermost part of the thread by noting the clearness and sharpness of the thread. The microscope is then moved downward in a direction perpendicular to the axis of the screw a measured distance equal to half the major diameter (full diameter) of the screw which brings it in proper focus with the profile of the thread. Special illuminating arrangements are provided on such machines so that the profile under observation is clearly defined.

The elements of a screw thread are measured by these means as follows: To measure the major diameter of a thread plug a cross-wire is set to coincide with the crests of the thread and the reading of the micrometer is noted; the position of the screw is then adjusted until the crests on the opposite side coincide with the cross-wire. The difference between the micrometer readings for the two positions represents the major diameter. In measuring the

pitch of the thread, the intersection of the two cross-wires is set to coincide with the side or slope of the thread and, after the screw is accurately located, it is traversed axially until the intersection of the cross-wires again coincides with the side of the adjacent thread. The pitch is determined by the difference between the micrometer readings for the two positions. In order to determine the pitch diameter of a screw thread the intersection of the cross-wires is set to coincide with the thread in the same manner and the screw is adjusted laterally until the cross-wires intersect the slope of the thread on the opposite side; the difference between the two micrometer readings represents the pitch diameter. For measuring the thread angle either the cross-wires or the microscope itself are mounted in such a way that they may be revolved and the angle of rotation measured by a graduated dial and vernier. Thread angles may be measured with a high degree of accuracy by this method and its use is recommended when an optical projection lantern is not available. Some of the methods above outlined for the measurement of screw thread gages were applied by the Gage Section of this Bureau before its present equipment was available. However, they have now been entirely superseded by other methods.

Applications With Gage Blocks. Within the past few years the use of the micrometer microscope as an index or indicator for determining the location of ruled lines and points of intersection of surfaces on profile gages by means of precision gage blocks has been developed. At one of the government arsenals a special fixture has been designed and built for checking profile gages on which the microscope is located laterally, transversely, and radially by means of gage blocks. In Fig. 2 is illustrated a common application of the microscope and gage blocks in this way. The gage shown is a check for the profile of a shell and the dimension to be determined is the distance from the left hand end of the gage to a limit line marked on the gage near the other end. One side of the base of the microscope is lapped flat so that it may be used as a locating surface. The gage is placed firmly and squarely against a parallel bar clamped to a surface plate as shown. The cross-wire of the microscope is set on the line to obtain the first setting and gage blocks are inserted between the parallel bar and machined side of the microscope base. The distance from the base of the microscope to the parallel bar is thus determined. The operation is repeated with the cross-wire set over the end of the gage. The difference in length between the two combinations of gage blocks is the required dimension. To avoid the necessity of trying various combinations of gage blocks to obtain the settings it is convenient to locate the microscope approximately in the correct position and use the eyepiece micrometer to make the final setting; the difference of course is measured by the micrometer head. The length which may be measured by this method is only limited by the size of the surface plate and the length and number of accurate standards available.

FIG. 2.



It frequently is convenient to set a gage in an upright position for inspection. In such a case the microscope is sighted horizontally on the etched line of the gage so that by looking through it the point of a scriber can be set in the middle of the line. The height of this line above the surface plate is then determined directly from the dimensions of the gage blocks used in bringing the scriber up to the line.

If it is desired to measure the distance between two points lying in different planes, the accuracy of measurement will depend on the accuracy of the perpendicularity of the microscope to its direction of travel since it is necessary to refocus for the second point.

Applications In The Tool Room. In the setting up and inspection of work in the tool room there are certain cases in which it is more convenient to use the microscope rather than the usual measuring devices. For the accurate centering of irregular work on a face plate the microscope is set with its axis perpendicular to the face plate and the intersection of the cross-wires is focused on the center of rotation of the plate. The work is then clamped to the face plate with the point of intersection of the scribed lines on the work coinciding with the intersection of the cross-wires. When the work is centered there should be no motion of the point of intersection of the scribed lines relative to the intersection of the cross-wires. In checking the lead of a lathe screw the microscope is attached to the carriage and sighted on a standard scale fastened to the back of the lathe bed parallel to the lead screw. The cross feed screw may be checked in a similar manner. Some manufacturers have found it convenient to use a microscope attached on a swivel arm to grinders and other machine tools for the inspection of small parts and cutting tools.

The microscope has been used to advantage in laying out master plates and profile gages and affords a means for performing such work with a high degree of precision. In general, the applications to which a microscope may be put in the tool room and instrument shop are of a special nature but at times this instrument fulfills requirements which are not met by any other measuring device.

BUREAU OF STANDARDS.