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# Electron-Tube Rifling Depth Micrometer: For the Measurement of Individual Depth of Groove Impressions on Fired Bullets

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# AN ELECTRON-TUBE RIFLING DEPTH MICROMETER

## For the Measurement of Individual Depth of Groove Impressions on Fired Bullets

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In the preliminary examination of fired bullets the firearms identification technician has made little use of the class characteristic known as "the depth of rifling impressions."[1] This has been so principally because of the fact that a suitable instrument has not been available for such measurements.

Attempts have been made to measure the average difference between the depth of two opposite land-to-groove impressions using a micrometer caliper. By this method the groove to groove and land to land diameters are measured, and one-half the difference between these two values is then assigned as the average groove depth on the opposite sides of the bullet in question. This method of measurement would not be possible if the bullet to be examined were distorted or if only a fragment of the jacket material of a fired bullet were available for examination.[2] An alternative method involves the use of either the filar-micrometer or a special stage micrometer.[3] The use of either of these instruments in the measurement of groove depths on fired bullets is accomplished in the following manner: The bullet to be examined is mounted so that its axis is set at right angles to the optical axis of the microscope, and is rotated so that the face of a driving land edge is in a horizontal plane.[4] In this

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[1] In this connection see Wilson, C. M., "Two New Instruments for the Measurement of Class Characteristics." 27 J. Crim. Law and Criminology 97-108 (1936).

[2] The writer was consulted recently in a case involving the fatal shooting of a government agent, in which two of the exhibits submitted for examination were fragments of gilding metal jacket material. One measured approximately 1/8" x 1/4". Evident on its surface was one land impression and a portion of the two adjacent groove impressions. Repeated measurements of the land to groove depth checked by the method described herein checked to within .0003 on both of the fatal fragments and on the test bullets fired from the Remington .35 caliber Model 8 automatic rifle submitted for examination. Subsequently the small fragment was "matched" with the remainder of the jacketed material and also with the test bullets.

[3] *Op. cit.* supra note 1.

[4] For explanation of "driving land edge" see *op. cit. supra* note 1 at p. 105.

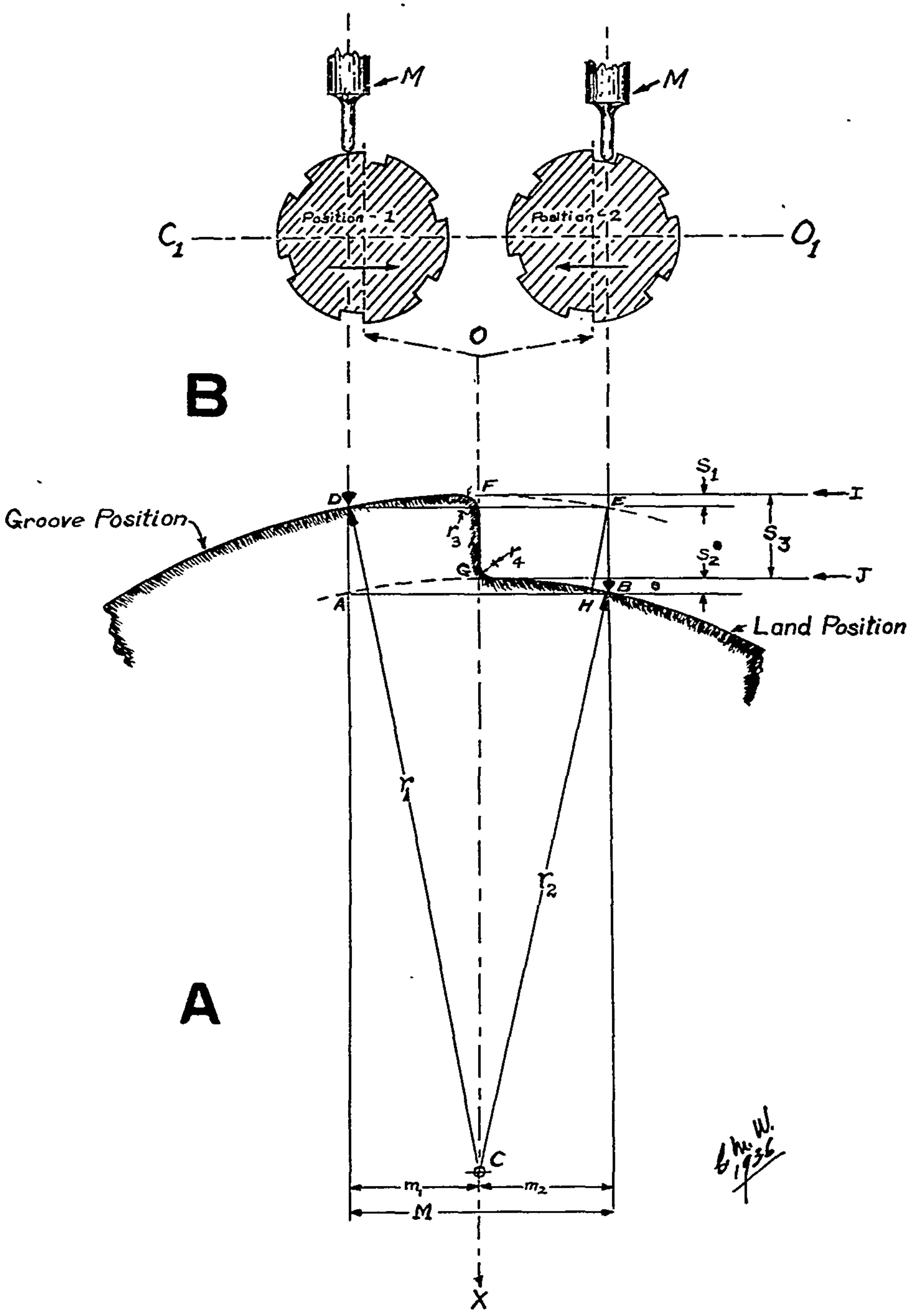


FIGURE 1

Diagramatic Representation of Method Using position the limits of measurement approximately coincide with IF and JG of Figure 1-A. In practice the contour of either edge of the rifling cutter is usually relieved (corresponding to $r_4$ of Figure 1-A) either as the result of the shaping and grinding or as the result of wear incidental to its use in the rifling of barrels. The fillet or relief radius corresponding to $r_4$ of Figure 1-A is attributable to the effects of lead lapping or wear and erosion incidental to use of barrel. In practice it has been observed that this land edge is seldom sharply defined, so that it is impossible to establish the actual limits of measurement which would coincide with IF and JG of Figure 1-A. At best, this method of measurement yields a figure which is only an approximation of the actual individual land-to-groove depths.

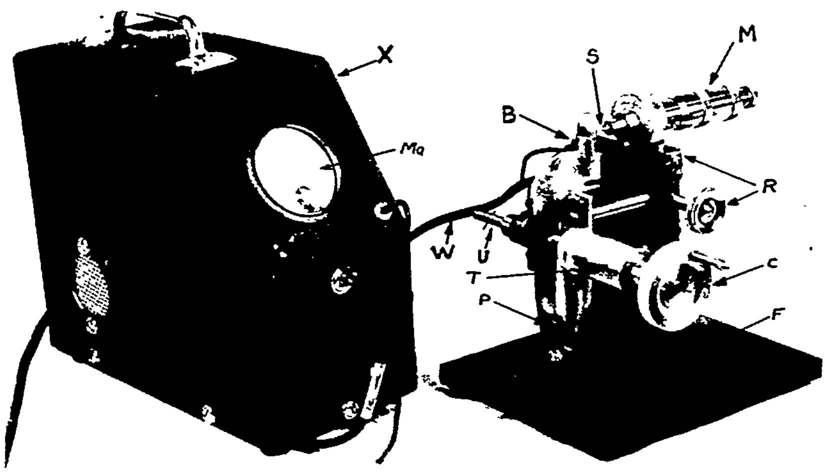


FIGURE 2

Electron-Tube Rifling Depth Micrometer.

To the end of increasing the accuracy of measurement of depth of individual land-to-groove impressions on fired bullets, the writer designed and constructed the electron-tube rifling impression micrometer illustrated in Figure 2. The frame of the measuring instrument was constructed by using one-half inch bakelite (F); thus the bullet mount and the micrometer head assembly are insulated from each other. The micrometer head used in the instrument is a special Brown & Sharpe No. 296-RS micrometer head (M). The tip of the measuring spindle was ground and polished so that for a distance of approximately one-quarter of an inch back from the tip the diameter of the micrometer spindle was reduced to 5/64ths of an inch. The extreme tip was ground and polished so that its contour approximated a hemisphere instead of the conventional plane surface. The barrel was provided with a vernier permitting accurate measurements to .0001 inch.[5] The micrometer may be raised or lowered by manipulation of the rack and pinion. This adjustment was found to be necessary so that bullets of various lengths could be accommodated, and in order to permit the micrometer tip to be adjusted so as to clear grease grooves or cannelures and also to permit successive measurements to be made in the same relative position along the rifling surface of a bullet. The bullet to be measured is placed in the wax contained in the cup at the bottom of bullet mount B.

The cross-feed micrometer spindle C operates against a compression spring contained in tube U. This micrometer cross feed permits the displacement of bullet mount B across measured parts of an arc whose radius is four inches (axis of rotation—P). The cross-feed micrometer thimble T can be rotated independent of the cross-feed spindle C. With this arrangement it is possible to first align the bullet so that the axis of the measuring micrometer spindle coincides with the diameter of the bullet and at the same time coincides with the land-groove edge immediately adjacent to the tip of the micrometer spindle (O-X), Figures 1-A and 1-B). When the bullet is in this position the thimble is rotated so that the "zero" graduation coincides with the index line inscribed on the upper portion of the barrel of the cross-feed micrometer. It is then possible to displace the bullet-mount equal measured distances $M_1$, $M_2$ (Figure 1-A), position 1 and 2 (Figure 1-B), either side of the original position, O-X, which coincides with land-groove face F-G and also with diameter of bullet O-X.

In the manipulation of a micrometer, either the operator's sense of touch is relied upon as the means of determining the position of "contact" or a ratchet stop is provided so that approximately equal tension will be produced between spindle tip, specimen, and anvil in making successive measurements. In making measurements on

[5] A certificate of accuracy for this particular micrometer head was supplied by Brown and Sharpe, the manufacturers, as follows: .100", .200", .300", .400", .500", .600", .700", and .800" were accurate to within ±.000025" at 68° F. .900" and 1.000" were —.00005".

fired bullets this method was found to be impractical for two reasons. In the first place the small area of contact of the special spherical micrometer spindle tip is forced into the surface of lead bullets, without perceptible pressure having been applied, thereby producing inaccurate results and also causing a mutilation of the rifling impressions on the surface of the bullet being measured. Secondly, considerable difficulty is experienced in determining or "feeling" the exact point of contact, thus preventing a duplication of the desired measurements to fractions of thousandths of an inch.

In attempting to overcome these practical difficulties, various electrical methods of indicating the contact position between micrometer tip and bullet were tried, which included the series arrangement of battery and buzzer, or flashlight lamp. They were finally discarded because an "apparent" contact position would be indicated over a range of displacements of from .0003 to .0013 inch of the micrometer spindle tip.[6] This contact error was found to be particularly large where the surface of the bullet being measured was badly decomposed, either as the result of oxidation or of its having remained in contact with body fluids for some period of time. To overcome this contact resistance error, a vacuum tube or electronic contact indicator[7] was arranged in a metal box (see X of Figure 2

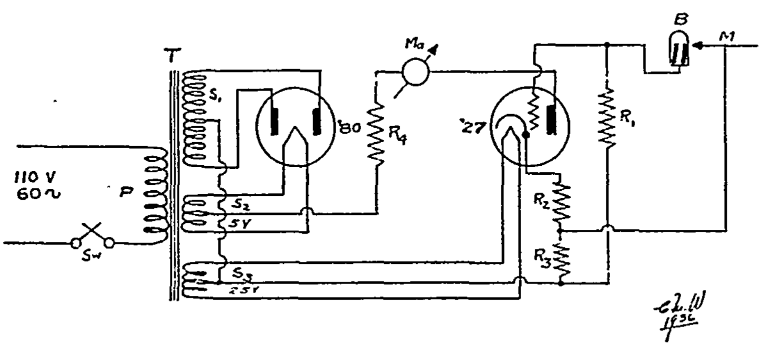


FIGURE 3

Schematic Wiring Diagram of Micrometer "Contact" Indicator.

[6] For a discussion of a series arrangement of buzzer, battery, and large micrometer for the measurement of diameters of heavy ordnance rifle tubes, see Reilly, J. W. and Dunn, B. W., "Report, Chief of Ordnance, 1892," Executive Documents, Vol. 3, appendix 49, pp. 967-972 (U. S. Government Printing Office). See also, Remmers, W. E., "Causes of Cuppy Wire," Proceedings of Mining and Metallurgical Engineers (1929) pp. 109-111, describing pantograph arranged with needle in series with battery and buzzer for indicating contact in tracing on enlarged scale contour of interior of wire drawing dies.

[7] See Henny, K., Electron Tubes in Industry (1934) 116-117; 195-197, describing several electron tube contact methods.

and the schematic wiring diagram shown in Figure 3). This extremely sensitive device operates in the following manner: Operating current is supplied from 110 volt, 60 cycle lighting supply. Plate and grid potentials are supplied from the full wave rectifying system shown. There is applied to the plate of the 27 tube a positive potential of approximately 95 volts. The plate current values are indicated by the Weston 0-2 milliameter Ma of Figures 2 and 3. Negative grid potential is obtained from the voltage drop across $R_3$ and $R_5$. This negative grid charge is adjusted and permanently set so that it maintains the plate current at approximately .5 milliampere. Bullet mount B and measuring micrometer M are connected to the vacuum tube circuit by means of a two-conductor flexible cord W. When M is in contact with the surface of the bullet B, the grid potential is reduced by an amount equal to the EMF developed across $R_5$, due to the fact that M and B being in contact short out a portion of the grid bias network ($R_5$). This results in a reduction of the negative grid charge and causes a sudden increase in the plate current which is indicated by the meter Ma, thus indicating "contact" position between M and B (Figure 2). The value of resistance $R_3$ is adjusted and permanently set so that with M in contact with B the plate current is approximately 2 milliamperes.

The advantage of this arrangement over other electrical methods used lies in the fact that a negligible current flow between M and B (on the order of 2 microamperes) will produce a relatively large change in the plate circuit meter Ma, thus reducing the contact resistance error to a negligible value. Some idea of the sensitivity of this vacuum tube method of indicating contact can be gained from the following. The micrometer thimble was equipped with a belt drive reduction feed acting as a vernier. Using this arrangement, tests were made which indicate that the electronic device would probably be capable of indicating the point of contact with a metallic object from .00001 to .00003 inches. It should be mentioned, however, that precision measurements to the 5th decimal part of an inch would be of little or no practical value in the examination of fired bullets.

In operation, the cross-feed micrometer is adjusted as previously outlined and the cross-feed thimble set at "zero." The bullet mount is then displaced a minimum distance so that the tip of the micrometer spindle will not come in contact with the land-groove shoulder or edge and the cross-feed micrometer thimble reading noted. The measuring micrometer is then rotated so that "contact" is indicated by the sudden upswing of the plate current meter Ma (Position 1 of Figures 1-B, and D, of Figure 1-A). This setting is repeated several times and the average micrometer reading noted. The measuring micrometer spindle is then rotated in the opposite direction or "backed away" from the bullet so as to clear the surface. By manipulation of the cross-feed micrometer the bullet mount is then displaced ar amount equal and opposite to the original setting. The measuring micrometer is again rotated so that "contact" is indicated by the sudden upswing of the meter Ma (Position 2, Figure 1-B, and B of Figure 1-A). The difference between these two measurements (as indicated by the difference between the two "contact" measurements) is approximately equal to the individual land-to-groove impression depth and is expressd in thousandths and ten-thousandths of an inch.

Errors due to the measuring micrometer, temperature corrections, and errors due to contact resistance are sufficiently small as to be disregarded. It might be mentioned in this connection that individual differences which might exist between two bullets fired in succession from the same firearm, using the same type and make of ammunition, would probably be responsible for larger discrepancies than the errors attributable to the variables referred to above.

The largest error introduced by this method of measurement is due to the method employed in making the measurements. In the use of this instrument we are representing the land-groove depth in terms of the differences between the sagittas of two arcs whose radii are $r_1$ and $r_2$ (Fig. 1-A). A sagitta may be described as the distance from the center of an arc to the center of its subtending chord. In Figure 1-A, then, the sagitta of the arc DFE whose radius is $r_1$ (radius of groove to groove diameter of fired bullet) is represented by $S_1$ along OX (diameter of bullet). $S_2$ represents the sagitta of the arc AGB whose radius $r_2$ is equal to one-half the caliber diameter of the fired bullet. If in measuring the depth of land-to-groove impressions on evidence and test bullets, the cross-feed displacements are equal ($\frac{M}{2} = M_1 = M_2$) with respect to OX in Figure 1-A, the measurements so made are identical and we may then assume any error introduced by the method of measurement to be constant and can therefore be disregarded. The cross-feed displacements and ($m_1$ and $m_2$ of Figure 1-A) should be as small as practicable and in the use of the instrument standard displacements for each caliber should be used. Referring to Figures 1-A and 1-B, it will be observed that the axis of the measuring micrometer at B does not coincide with the diameter of the fired bullet but the displacement is along one side of the triangle EBH. The error introduced by this fact was calculated in the case of a bullet having a maximum diameter of .357 inch, a groove depth of .004 inch and a total cross-feed displacement M = .0234 inch to be less than .0001 inch, which, as has been pointed out, can be neglected if the measuring technique is standarized for each caliber. It might be mentioned in discussing the errors incidental to this method of measurement that as the caliber diameter is reduced for a given displacement (M) the error referred to above increases as the chord lengths (DE and AB of Figure 1-A) approach the caliber diameter of the bullet being measured.

In the use of rifling depth micrometer the following possible sources of error, insofar as apparent rifling impression depths are concerned, should be taken into consideration:[8]

1. Where rifling cutter feed was not advanced at uniform rate (producing unequal depths of groove impressions).
2. Hard spots in barrel blank which would produce low areas on the groove surfaces because the rifling cutter would tend to "ride over" these hard spots, thus producing irregular groove depth.
3. Excessive erosion of rifling surface in vicinity of throat of barrel.

Considering the factors which might affect the individual land-to-groove depths on bullets fired from a particular barrel—in addition to the above a consideration of the following would be of importance:

1. Where the unfired bullet diameter was less than the groove to groove diameter of the barrel.
2. Accumulation of rust, corrosion, or products of combustion of propellant or primer mixtures which were allowed to remain in the bore of firearm.
3. "Leading" of the bore of arm.
4. In case of a revolver in which shearing of bullet was excessive due to poor alignment of chamber and barrel throat.
5. Mutilation of rifling impressions on surface after leaving bore of firearm.
6. Effects of "stripping" of rifling impressions on bullet surface.

[8] "Attempts to make precision measurements of fired bullets should only be attempted by those who are thoroughly familiar with practical manufacturing practices as well as with a basic theoretical understanding of factors which may either introduce apparent dissimilarities or points of apparent similarity, and in the final analysis should be attempted only by persons who are conservative in the interpretations they place on such measursements." *Op. cit. supra* note 1 at p. 107.