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TWO NEW INSTRUMENTS FOR THE MEASUREMENT OF "CLASS" CHARACTERISTICS OF FIRED BULLETS

CHARLES M. WILSON†

In an orderly process for the identification of fired bullets two distinct groups of bullet characteristics must be considered. One group may be designated as "class" characteristics; that is, those characteristics of a fired bullet which are common to all bullets of similar ammunition fired in a particular type, caliber, and make of firearm.¹ The other group may be termed "accidental," and considered as "individual" characteristics which are peculiar to bullets fired from a particular weapon. Although in the final analysis the identification of a bullet as having been fired from a certain weapon depends principally upon a consideration of "accidental" characteristics, the "class" characteristics are of importance, and particularly so in the preliminary examination.

The practical difficulties encountered in the accurate measurement of certain "class" characteristics have already been referred to by Goddard,² Souder,³ Kraft,⁴ Mezger, Heess, and Hasslacher,⁵ Wiard,⁶ Burrard,⁷ Hatcher,⁸ and Gunther.⁹ To the end of eliminat-

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¹ See Hatcher, J. S., "Textbook of Firearms Investigation, Identification and Evidence (1935) 254; Gunther, J. B., C. O., "The Identification of Firearms" (1935), 29-31, 74, 78, 83. (Both books cited hereafter merely as Hatcher or Gunther.)

² Goddard, C. H., "The Identification of Projectiles in Criminal Cases," *Military Surgeon* 58 (2), 149-151 (1926); "Forensic Ballistics," *Army Ordnance* 6 (33), 196-200 (1925); "Scientific Identification of Firearms and Bullets," *J. Crim. Law* 17 (2), 254-263 (1926); "Firearms as Evidence," *J. Crim. Law* 2 (1) 3-7; "Arms Identification—Its Story," *Police '13-13'* 10 (139), 10-13 (1935), and 10 (140), 18-19 (1935); "A Bullet Classification Formula," *Police '13-13'* 9 (125), 17, 31 (1934).

³ Souder, W., "Firearms Identification," *Army and Navy Jour.* 49 (29), 675 (1932).

⁴ Kraft, B., "Critical Review of Forensic Ballistics," *Am. J. Police Sci.* 2 (1) 52-66, (1) 125-142 (1931); *ibid.*, "A Central Registry Office for Forensic Firearms Identification," *Am. J. Police Sci.* 2 (3) 268-270 (1931); *ibid.*, "Apparatus Used in Forensic Ballistics," *Am. J. Police Sci.* 2 (5), 409-418 (1931). (Reprinted from *Archiv für Kriminologie*.)

⁵ Mezger, O., Hess, W., Hasslacher, F., "Determination of the Type of Pistol Employed from an Examination of Fired Bullets and Shells," *Am. J. Police Sci.* 2 (6), 473-500 (1931), 3 (1) 124-146 (1932). (Reprinted from *Archiv für Kriminologie*.)

⁶ Wiard, S., "The Preliminary Identification of Fired Bullets," *Am. J. Police Sci.* 3 (1) 14-21 (1932).

⁷ Burrard, G., "The Identification of Firearms and Forensic Ballistics" (1934) 142-147, 199-207.

⁸ Hatcher, at pp. 48-51, 54, 191-194, 258, 288-293.

⁹ Gunther, at pp. 19, 47, 108, 111.

ing some of the difficulties discussed by these authors, the writer designed and constructed two instruments, herein described, which give promise of simplifying and possibly increasing the accuracy of the measurements of certain "class" characteristics.

There are two distinct methods applicable to the problem of micrometric measurement of diameters, land and groove widths, and depth of rifling evident on the surface of many fired bullets: (a) mechanical,¹⁰ and (b) optical.

The mechanical methods include the use of the micrometer caliper as suggested by Hall,¹¹ Goddard,¹² and Hatcher,¹³ for the measurement of diameters and lengths of unfired bullets and essential overall measurements of cartridge cases, which provides a simple and accurate means of measurement. The same is true of the application of the dial micrometer as suggested by Goddard,¹⁴ and Kraft.¹⁵ These mechanical measuring devices should not, however, be used in the measurement of fired bullets, and particularly lead bullets, since it is necessary to clamp the object being measured between the hardened steel jaws of the measuring device in order to make the desired determinations. Obviously this is poor practice where fired bullets are concerned since there is a great probability that the surface thereof may be mutilated.

Gunther,¹⁶ has suggested the use of the fixed ocular micrometer or eyepiece micrometer to be utilized in conjunction with the comparison microscope. This device consists of a focusing ocular arranged with a ruled glass reticule which is superimposed over the virtual image produced by the optical system of the compound microscope. Calibration is necessary for each setting of the drawtube. The use of this arrangement is not recommended because measurements to fractions of the minor divisions of the eyepiece

¹⁰ The first recognition of the importance to the firearms identification technician of the objective determination of maximum diameter, and of land and groove widths evident on the surface of many fired bullets submitted for examination is that given by Hall. See Hall, A. S., "The Missile and the Weapon," *Am. J. Police Sci.* 2 (4), 311-322 (1931). (Reprinted from *Buffalo Medical Journal*, June, 1900.) See in this connection the early case of *Dean v. Commonwealth*, 311 Gratt (Va.) 912. (1879), referred to by Inbau, F. E., "Scientific Evidence in Criminal Cases: I. Firearms Identification—Ballistics," *J. Crim. Law* 24 (4), 830 (1933).

¹¹ *Op. cit. supra* note 10, at p. 312, *et seq.*

¹² Goddard, C. H., "Forensic Ballistics," *Army Ordnance* 6 (33), 196-200 (1925).

¹³ Hatcher, at pp. 54,, 158, 160-164.

¹⁴ Goddard, C. H., "The Identification of Projectiles in Criminal Cases," *Military Surgeon* 58 (2), 145-154 (1926).

¹⁵ Kraft, B., "Apparatus Used in Forensic Ballistics," *Am. J. Police Sci.* 2 (5), 415 (1931).

¹⁶ Gunther, at p. 18.

reticule are purely a matter of guesswork and in addition its use incurs the disadvantages to be referred to in connection with the application of the filar micrometer.

Robinson,¹⁷ Van Amburgh,¹⁸ Goddard,¹⁹ Gunther,²⁰ and Hatcher,²¹ refer to the use of the filar micrometer ocular for the measurement of diameters and land and groove widths of fired bullets. This instrument, since its use in 1921 by Robinson and Van Amburgh, has continued to be used almost universally in firearms identification work, the exceptions being in the case of Kraft, Mezger, Heess and Hasslacher, whose special instruments will be referred to later.

Filar micrometers are available having stated magnifications ranging from 10x to 25x and are used in place of the regular ocular of the compound microscope. The filar micrometer is arranged with a fixed glass scale divided into ten equal major divisions, each of which is equal to .01 mm. Provision is made for a slide which carries a cross-hair and can be moved across the field by a lead screw the pitch of which is such that one revolution of the screw will move the cross-hair a distance equal to one major division. Attached to this lead screw is a drum divided into 100 equal parts. Thus it is possible to set the cross-hair to approximately 1/100th of .01 mm. or .0001 mm. or 1 micron. Optically the fixed glass scale with movable cross-hair arrangement is superimposed over the virtual image produced by the microscope. Calibration of this instrument is necessary for a particular setting of the microscope draw tube with a given objective. This calibration is accomplished by adjusting the microscope draw tube length so that the virtual image of the reference standard, the stage micrometer (or some even sub-multiple) coincides with the ten major divisions of the filar scale. Obviously, the slightest movement of the draw tube length after it has once been calibrated will affect the accuracy so that measurements cannot be depended upon. For this reason the calibration should be checked at the completion of each series of observations.

What might be referred to as a "mental hazard" exists when using the filar micrometer. A confusingly large numerical error is

¹⁷ See transcript of trial court's record in the Sacco-Vanzetti case, portions of which may be found quoted in Gunther, *op. cit. supra* note 1, at p. 239, *et seq.*

¹⁸ *Ibid.*, p. 137, *et seq.*

¹⁹ *Supra* note 2.

²⁰ Gunther, at pp. 18-20.

²¹ Hatcher, at pp. 158, 191-193, 258-260.

present when making measurements of land and groove widths or when averaging maximum diameters of fired bullets when the bullet form is not cylindrical. For purposes of discussion we shall assume the filar eyepiece arrangement has been calibrated so that each micrometer division is equal to .0001 inch. In the measurement of land and groove widths we seldom have sharply defined edges to set the cross-hair to; therefore, the best we can do is to estimate a particular setting which may fall at any point between say thirty and fifty-five divisions on the micrometer head. Often the same conditions exist in the setting to the other limit and therefore we are not sure of our measurement to closer than the sums or differences of the readings, or to within several ten-thousandths of an inch. This confusing numerical error, together with the fact that the calibration is easily thrown out, constitutes the principal objection to the use of the filar micrometer for this purpose.

There are several special microscopes which incorporate a micrometer feed moving the entire optical system and focusing arrangement a measured distance. These are referred to by Mezger, Heess and Hasslacher,²² and Kraft.²³ There are also two special microscopes manufactured in this country admirably suited to such applications. These are manufactured by the Bausch and Lomb Optical Company (Figure 1) and the Gaertner Scientific Instrument Company (Figure 2) but, to the writer's knowledge, they have never been used for this purpose. Bausch and Lomb's Tool-makers' Microscope does incorporate, however, stage micrometer feeds which would permit measurements to be made in much the same manner as is possible with the variable stage micrometer described in this paper.

Variable Stage Micrometer

The calibrated variable stage micrometer (illustrated in Figures 3 and 4) was designed and constructed to overcome many of the practical difficulties previously described. It appears to be of particular value in the measurement of the following "class" characteristics: (1) Maximum diameters of fired bullets; (2) Widths of land and groove impressions on fired bullets; (3) Dimensions of unfired bullets and shells, *i. e.*, widths, depths, and relative posi-

²² *Op. cit. supra* note 5, at pp. 499, 126-135.

²³ Kraft, B., "Apparatus Used in Forensic Ballistics," *Am. J. Police Sci.* 2 (5) 412-414 (1931).

tions of cannellures, crimps, and diameters of primer cups, etc. The instrument is so arranged that it can be clamped into position on the stage of any one of several microscopes. The calibration is direct and positive. A one inch Brown and Sharpe micrometer head No. 294, calibrated to .001 inch is used to provide measured lateral movement of the bullet stage. For this particular type of barrel the manufacturer's stated accuracy is .0001 inch from thread to thread or from one end of the lead screw to the other.

In the measurement of the foregoing "class" characteristics it has been found in practice that the variable stage micrometer possesses the following advantages over the filar micrometer: (1) No calibration is necessary; (2) The device is accurate to .001 inch and measurements to .0005 inch may be approximated; (3) Measurements are independent of magnification of the optical system and for that reason the microscope may be equipped with a swivel objective nose-piece containing several objectives, and changes of overall magnification may be rapidly made; (4) Wider range of overall magnifications are possible; and (5) Elimination of the numerical error previously referred to.

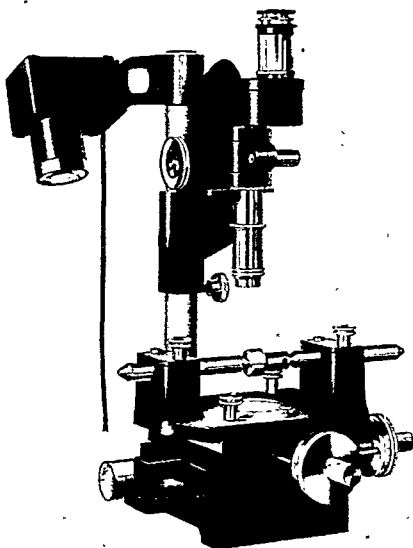


FIGURE 1
Bausch & Lomb Optical Co.
Toolmakers Microscope, Type E4900.

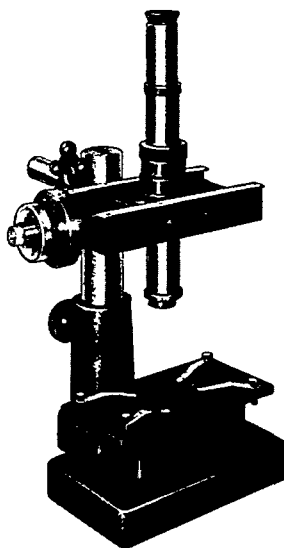


FIGURE 2
Gaertner Scientific Corp.
Comparator, Type 1150.

The instrument should be used with a focusing ocular having a stated magnification of 10x. The ocular is equipped with a cross-hair reticule (two lines set at 90°).²⁴ The bullet to be measured is

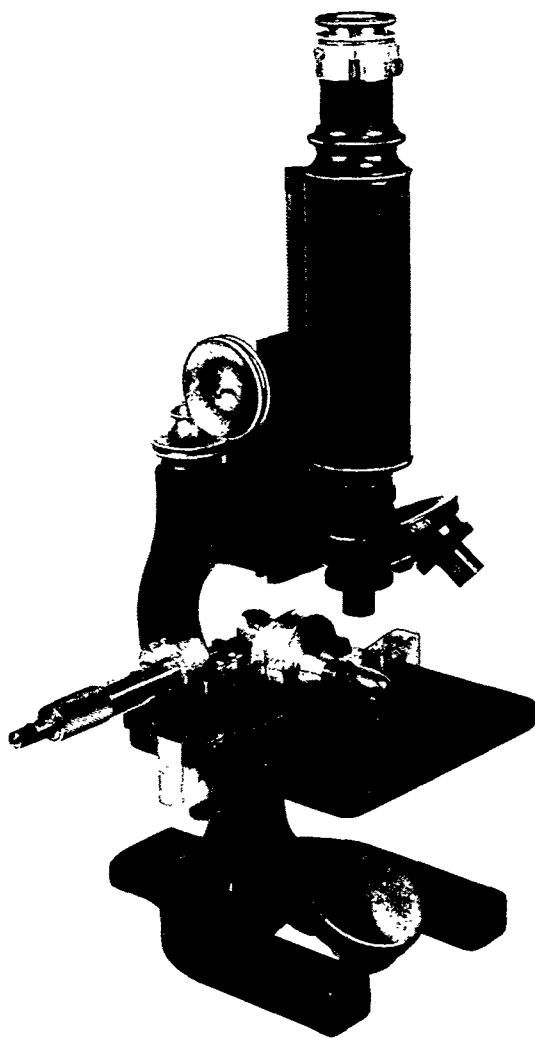


FIGURE 3
Variable Stage Micrometer Mounted on Microscope.

²⁴ An alternative for the solid line cross hair reticule which has been found to possess certain advantages is a special cross hair disc made by the Gaertner

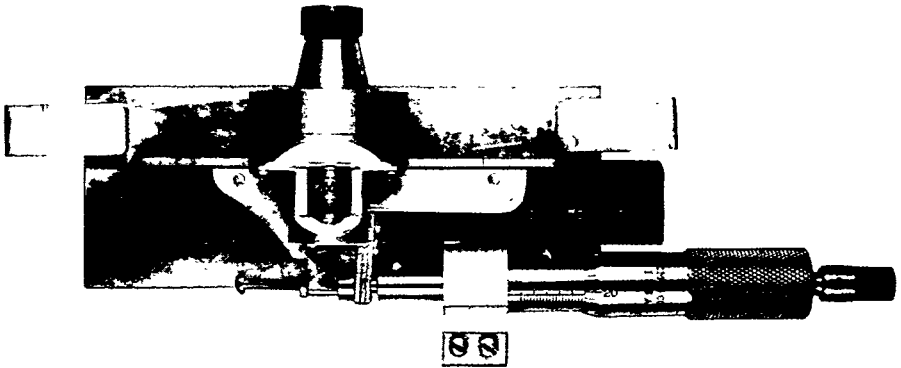


FIGURE 4
Variable Stage Micrometer.

placed on plasticine in the revolving mount and the instrument is adjusted on the stage until the bullet is brought into the optical field. The set screws are then tightened, locking the instrument in place. The micrometer spindle is adjusted until either one side of the bullet or a land edge coincides either with one of the cross-hairs or the point of intersection of the two cross-hairs. The micrometer readings on both barrel and thimble are then noted. By means of the micrometer head the bullet mount is then manipulated until the cross-hairs coincide with the other limit of measurement. The barrel and thimble readings are again noted. The difference between these two readings is obviously the lateral travel of the bullet required to align the bullet to that particular limit or line which is of interest.

The methods of illuminating the bullet are the same as have been used previously by other technicians, namely: when measuring land groove widths, a small spotlight equipped with frosted daylight blue filter should be placed above and to either side of axis of bullet; when measuring maximum diameters, illumination is from below the bullet and the cross-hair is set to coincide with "shadow" image on either side of bullet.

The "Inclinometer"

The other type of "class" characteristic to be dealt with here is the measurement of the angle of twist of rifling, or, as it is often referred to, the "rate of twist." Heretofore, several methods have

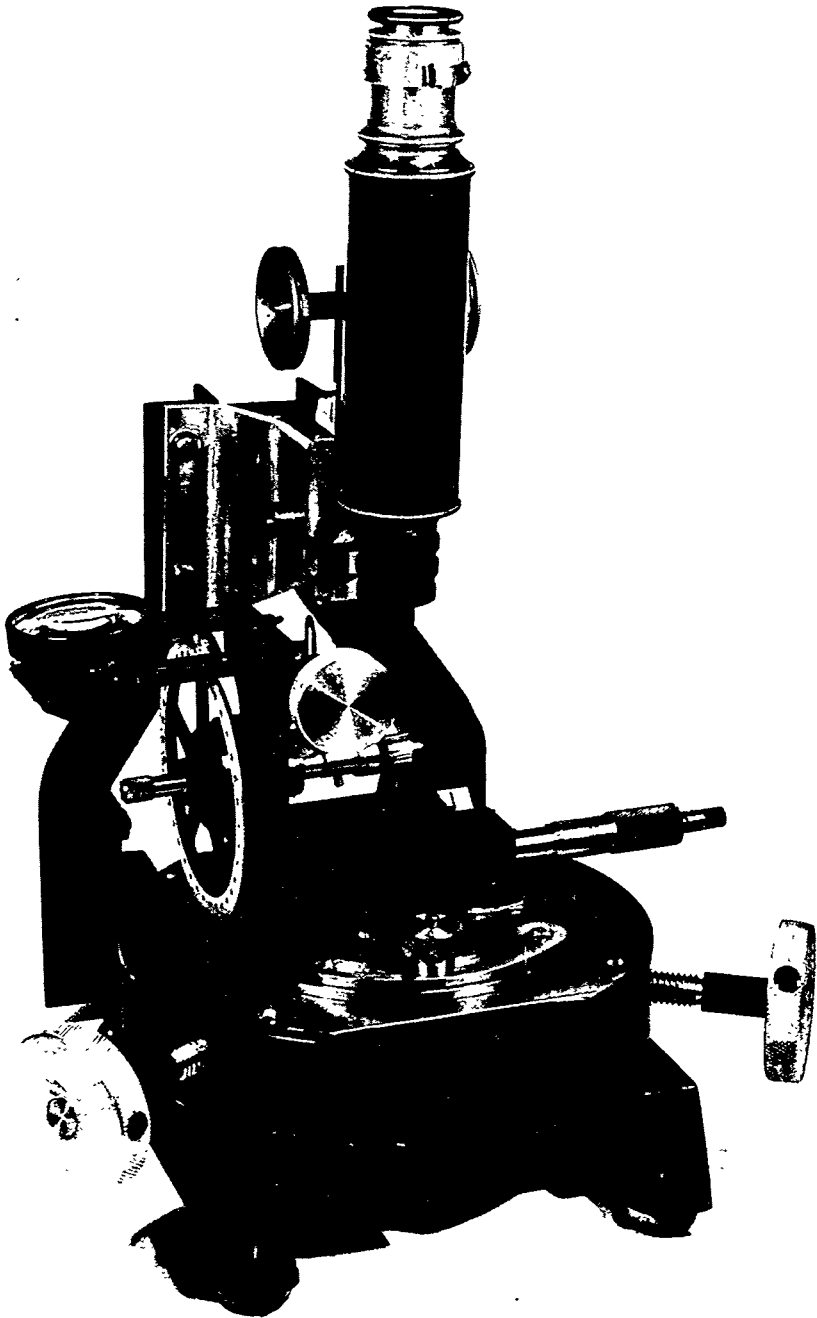


FIGURE 5
"Inclinometer."

been employed with varying degrees of success. The methods published by Goddard, Kraft, Mezger, Heess, and Hasslacher have been used by the writer and each was found wanting in some particular, with the result that the instrument described was designed and constructed. It has been found to possess certain advantages over other methods advocated.

This instrument, which the writer has chosen to refer to as an "Inclinometer" (illustrated in Figure 5), consists of a special compound microscope equipped with special stage so arranged that elements of lateral displacement and rotation may be accurately measured. The bullet holder is mounted on a shaft which can be turned independently of the quadrant so that coarse adjustments can be made. This shaft is mounted inside a second hollow shaft which carries a graduated circle divided into degrees of arc. A vernier is provided so that the rotation of the bullet mount can be read to minutes of arc. This entire assembly is mounted on a carriage which can be moved either to the right or left by manipulation of micrometer spindle of the same type as used in constructing the variable stage micrometer previously described. This assembly is in turn mounted so that the bullet mount and lateral slide can be manipulated to any point within a two inch circle by adjustment of the two screws shown in the foreground of the illustration (Figure 5). In addition, it can be rotated through approximately 30° of arc and locked in position with the knurled thumb screw also shown in the foreground. Thus lateral displacement of the bullet can be accurately determined to .001 inches and approximated to .0005 inches and at the same time rotational elements can be measured to one minute of arc. The ocular used with the microscope is arranged with a cross-hair reticule which is of the same type as referred to previously.

The manipulation is as follows: The bullet being examined is placed on the mount so that the axis of rifling or the unmutilated portion of the bullet coincides, as nearly as possible, with the axis of rotation of the quadrant of the instrument; the entire bullet carriage is moved into the field of the microscope; the driving land edge is turned upward (toward microscope); the quadrant reading is noted and also the micrometer reading; the bullet mount is then displaced laterally the maximum distance consistent with the length of an unmutilated driving land edge; the micrometer readings are again noted; the bullet is then rotated until the original driving land edge previously used again coincides with the cross-hair.

As an illustration, assume that the lateral travel (distance between two micrometer readings) = .220 inches and that the rotational element necessary to realign with the original land edge = $5^{\circ} 0'$. Thus the rifling impression on the surface of the fired bullet being studied has, in traveling along a plane approximating the axis of the bore of the arm through which it was fired, advanced $5^{\circ} 0'$ in moving .220 inches in this plane. Since 5° is $1/72$ nd of one complete revolution ($360/5 = 72$) we may assume $72 \times .220$ inches = 15.85 inches travel required for the rifling impression to make one complete revolution (360°).²⁵

The use of this instrument in determining the rate of twist of rifling obviously dispenses with trigonometric computations involving the use of the tangent of the angle of departure of rifling at extremely small angles. Also, the determination of the rate of twist of the rifling impression is reduced to a simple arithmetical problem which can often be solved by mere inspection of the rotational and lateral displacements so measured.

The method utilized by Goddard,²⁶ and Kraft,²⁷ for determining the rate of twist of rifling involves the use of the filar micrometer arranged with a goniometer attachment so that the angle of departure of rifling impression on bullet being examined could be determined with respect to the side of bullet. Mezger, Heess and Hasslacher²⁸ were able to make the same determination by use of goniometer microscope stage arrangement. In either case the determination of the rate of twist involved the following trigonometric computation:

$$\tan \theta = \frac{D \cdot \pi}{R} \text{ or } R = \frac{D \cdot \pi}{\tan \theta}$$

(D = Bullet diameter in inches; R = Rate of twist in inches; and θ = Angle of departure of rifling impression.)

The limitations imposed upon the measurement of the "class" characteristics, here discussed, by any known method are of three

Scientific Corporation of Chicago and is ruled with two dotted lines set at 90° . This type of ruling does not completely obscure the line or point on the surface of the object which is to be measured, as is true when the solid line ruling is used.

²⁵ See "The Conclusive Link," Spencer Lens Co. catalog for 1934, p. 21. The same principle is employed in the use of the Spencer Helixometer.

²⁶ *Supra* note 2.

²⁷ Kraft, B., "Apparatus Used in Forensic Ballistics," *Am. J. Police Sci.* 2 (5), 412-414 (1931).

²⁸ *Op. cit. supra* note 5., at pp. 499; 131-134.

types: (1) Mutilations or abrasions incurred by bullet after it has left muzzle of firearm; (2) Deformations and mutilations occurring on the surface of the fired bullet as the result of firing from a particular gun and using a particular make and type of ammunition; (3) Production practices and design considerations incidental to manufacture of a particular firearm firing a given type, class, and make of bullet.

Factors (1) and (2) affecting these limitations have been very ably treated by Hatcher.²⁹ Obviously, number (3) includes a mass of material which has never been published and for three reasons probably never will be: (A) In those cases which involve a high class of rifled firearms, such as the products of Colt, Smith and Wesson, Remington, Winchester, Savage, or Government Armories, the fabrication of which is according to strict manufacturing specifications and tolerances, these plants rightfully consider such material as confidential; (B) In those cases involving cheap foreign imitations of these products it is seriously doubted whether any manufacturing specifications or tolerances were drafted; (C) In those cases which involve firearms manufactured by companies now non-existent, it is practically impossible to obtain such material.

In the light we now consider such determinations, 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 measurements.

²⁹ Hatcher, at pp. 49-51, 75, 76, 253-259, 280-282, 288-293. Also see in this connection, Coxe, W. H., "Smokeless Shotgun Powders" (1933) (Published by du Pont de Nemours and Company). In addition to a comprehensive treatment by Coxe of questions concerning interior ballistics, he has included an excellent bibliography upon the subject.