

FEU 13 – Estimation of Uncertainty of Measurement

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1. Scope

- 1.1 This Standard Operating Procedure (SOP) provides the steps required to complete a study designed to determine reproducibility, repeatability, and resolution of measurement data using specific equipment in the laboratory.
- 1.2 This SOP also provides from that study guidance to be used by all FEU personnel to calculate and report the estimation of expanded uncertainty of measurement for barrel and overall firearm length measurements.

2. Background

- 2.1 The FEU reports calculated estimation of uncertainty of measurement for barrel and overall firearm length measurements in circumstances in which the contributor has specifically requested these measurements.
- 2.2 By developing this SOP the FEU will have a standard approach to calculate and report uncertainty of measurement, and comply with the Department of Forensic Sciences Quality Assurance Program, ISO/IEC 17025:2017 and Supplemental Requirements.

3. Safety

- 3.1 Not applicable

4. Materials Required

4.1 Not applicable

5. Standards and Controls

5.1 Not applicable

6. Calibration

6.1 Not applicable

7. Procedures

7.1 Measurand and traceability of measuring equipment

7.1.1 The measurand for this study will be the barrel length and overall length of a firearm (in inches).

7.1.2 NIST-traceable steel rulers and digital calipers that are serialized and have been calibrated, and T squares that have been uniquely identified, are used for barrel and overall length measurements, and will be used to collect measurement data for the estimation of uncertainty of measurement.

7.1.3 The measurement traceability of both the steel rulers and the digital calipers is established through calibration. The traceability of the T squares is established through direct comparison to calibrated steel rulers.

7.2 Uncertainty components

7.2.1 Components contributing to the Type A standard uncertainty that are considered significant include the reproducibility, repeatability, and resolution of measuring equipment.

7.2.1.1 Reproducibility for this study is the ability of different examiners to measure the same item, using the same method and equipment, and get the same result. It is dependent on the specificity of measuring procedures and their consistent employment by examiners, and is addressed by only including qualified examiners in the study.

7.2.1.2 Repeatability for this study is the ability of the same examiner to measure the same item on different days, using the same method and equipment, and get the same result. It is dependent on the training and competence of the examiners to employ the measuring methods consistently, and is addressed by taking measurement data over the course of ten days.

7.2.1.3 Resolution for this study is the ability of a type of measuring equipment to provide precise measurements, and is addressed by using digital rather than analog measuring equipment when possible.

7.2.2 Components considered insignificant to Type A standard uncertainty include, but are not limited to, environmental conditions within normal laboratory operations. Changes to the contributing components listed in Section 7.2.1 that result in less than 10% of the total will be considered insignificant. Sampling is not practiced by the FEU and is not considered a component of uncertainty in this study.

7.2.3 Type B standard uncertainty is reported by the manufacturer, or provided in calibration certificates by the calibration laboratory, for each item of equipment.

7.3 Study Procedure and Measurement Data Collection

7.3.1 All qualified firearms examiner employees will participate in the study. Trainees and contractors will not participate in the study and will not report uncertainties.

7.3.2 Five firearms will be selected from the Firearms Reference Collection with a variety of barrel and overall lengths, including sawed off barrel(s) if possible. If a firearm selected has multiple barrels, one barrel will be selected to measure unless determined otherwise.

7.3.3 Each examiner will take barrel and overall length measurements for each firearm every day for ten days. Measurements must be taken according to methods listed below. Equipment will be selected for use in the study, and all equipment needed to complete the measurements will be available for use.

7.3.4 Daily answer sheets will be provided that include the name, date, firearm tag number, type and serial number of equipment used, and measurements. Measurements will be in inches, and be reported in decimal, not fractional, form. Answer sheets will be collected daily and retained.

7.3.5 Methods for barrel length measurements

7.3.5.1 The depth bar of the digital caliper will be used when the barrel length of a pistol to be measured is less than 6".

7.3.5.1.1 Make sure that the power is on by moving the body of the caliper. Close the jaws of the caliper and press the zero button.

7.3.5.1.2 Ensure that the action of the pistol is closed. Place the bottom of the fixed scale to the muzzle end of the pistol to be measured.

7.3.5.1.3 Move the slider of the digital caliper and adjust the depth bar inside the area to be measured till it bottoms out. Be aware of possible interference by the firing pin aperture, extractor and or ejector. Press the hold button on the caliper.

7.3.5.1.4 Remove the caliper from the measured item and record the indicated measurement.

7.3.5.2 The outside jaws of the digital caliper will be used when the barrel length of a revolver to be measured is less than 6".

- 7.3.5.2.1 Swing or remove the cylinder of the revolver away from the barrel.
- 7.3.5.2.2 Make sure that the power is on by moving the body of the caliper. Close the jaws of the caliper and press the zero button.
- 7.3.5.2.3 Put the outside jaws (longer pair) of the digital caliper on the outside of the forcing cone and muzzle end of the barrel to be measured. Slowly slide the outside jaws closed until both of the jaws tighten against the outside surfaces of the barrel perfectly. Press the hold button on the caliper.
- 7.3.5.2.4 Remove the caliper from the measured item and record the indicated measurement.
- 7.3.5.3 The combination of the certified steel ruler and rod will be used when the length of the barrel to be measured is greater than 6" and less than 12".
 - 7.3.5.3.1 Insert the rod into the barrel as one would the depth bar from the digital caliper. Do not try to keep the rod in the center of the barrel. Keep the rod against one side of the barrel.
 - 7.3.5.3.2 Extend the rod inside the barrel until it bottoms out. Be aware of possible interference by the firing pin aperture, extractor and or ejector. Indicate where the top of the measured area is in relationship to the rod by marking the rod with a sharp point marker.
 - 7.3.5.3.3 Remove the rod and place it on the certified steel ruler over the desired measuring unit. Align one end of the rod with the zero end of the certified steel ruler. Ensure the rod is parallel to the ruler.
 - 7.3.5.3.4 Record the reading from the certified steel ruler that aligns with the indicated marked area on the rod.
- 7.3.5.4 The combination of the T square, certified steel ruler and rod will be used when the length of the barrel to be measured is greater 12".
 - 7.3.5.4.1 Insert the rod into the barrel as one would the depth bar from the digital caliper. Do not try to keep the rod in the center of the barrel. Keep the rod against one side of the barrel.
 - 7.3.5.4.2 Extend the rod inside the barrel until it bottoms out. Be aware of possible interference by the firing pin aperture, extractor and or ejector. Indicate where the top of the measured area is in relationship to the rod by marking the rod with a sharp point marker.
 - 7.3.5.4.3 Remove the rod and place it on the T square over the desired measuring unit. Align one end of the rod with the zero end of the T square. Ensure the rod is parallel to the T square.
 - 7.3.5.4.4 Record the reading from the T square that aligns with the indicated marked area on the rod.

- 7.3.5.4.5 Align the portions of the T square used for measurement with the certified steel ruler to ensure that measuring units are the same, and that an equivalent measurement would be determined from the certified steel ruler.

7.3.6 Methods for overall length measurements

- 7.3.6.1 The certified steel ruler will be used when the overall length of the firearm to be measured is less than 12".

- 7.3.6.1.1 Place the firearm (with the action closed) to position the barrel parallel with certified steel ruler. Align the farthest extension of the grip or backstrap end of the firearm with the zero end of the certified steel ruler.

- 7.3.6.1.2 Record the reading from the certified steel ruler that aligns with the farthest extension of the muzzle end of the firearm.

- 7.3.6.2 The combination of the T square and certified steel ruler will be used when the overall length of the firearm to be measured is greater than 12".

- 7.3.6.2.1 Place the firearm (with the action closed) to position the barrel parallel with T square. Align the farthest extension of the grip or backstrap end of the firearm with the zero end of the T square.

- 7.3.6.2.2 Record the reading from the T square that aligns with the farthest extension of the muzzle end of the firearm.

- 7.3.6.2.3 Align the portions of the T square used for measurement with the certified steel ruler to ensure that measuring units are the same, and that an equivalent measurement would be determined from the certified steel ruler.

7.4 Calculations

- 7.4.1 The raw measurement data and resulting calculations from Section 9 of this procedure will be recorded and retained in the UoM Study Calculations spreadsheet in the FSL network drive.

7.5 Reporting

- 7.5.1 Uncertainty of measurement is reported for barrel and overall length measurements when these measurements are requested in writing by the contributor. If not requested by the contributor, these measurements will not be reported, and any measurements recorded in examination notes are considered approximations.
- 7.5.2 No quantitative measurements that impact the evaluation of a specification limit will be reported without including estimated uncertainty of measurement.
- 7.5.3 Estimations of uncertainty of measurement will be reported as "y [measured value] +/- U [expanded uncertainty] inches, with a 95% confidence interval coverage factor". Expanded uncertainties will be reported to two significant digits, and measured values will be reported to the number of decimal places indicated by the

relevant expanded uncertainty. An example may be referenced in the Firearms Analysis report template.

7.6 Study review schedule

7.6.1 The Uncertainty of Measurement study will be reviewed for the need to re-calculate estimations when:

7.6.1.1 New equipment used in the measuring methods is added or equipment included in the study is removed from service

7.6.1.2 Measuring methods are revised for better precision

7.6.1.3 Updated calibration certificates containing new values for Type B standard uncertainty are obtained for equipment sent for annual calibration

7.6.1.4 Qualified examiners are added to or removed from the FEU.

7.6.2 Re-calculation of estimations will be determined necessary when:

7.6.2.1 The number items of equipment of a given type (ie: rulers, calipers) changes by more than 10%

7.6.2.2 New types of equipment are incorporated into procedure and measuring methods are revised

7.6.2.3 The new value for Type B standard uncertainty of any item of equipment used in the study has changed by more than 10%

7.6.2.4 The number of qualified examiners changes by more than 10%.

8. Sampling

8.1 Not Applicable

9. Calculation

9.1 The Type A standard uncertainty (u_a) is calculated using the following Equation 1:

$$u_a = \frac{\text{standard deviation}}{\text{sqrt}(n)} \quad n = \text{number of measurements}$$

9.2 The combined uncertainty (u_c) is calculated using the following Equation 2:

$$u_c = \text{sqrt}(u_a^2 + u_b^2) \quad \begin{array}{l} u_a = \text{Type A standard uncertainty (measured)} \\ u_b = \text{Type B standard uncertainty (reported)} \end{array}$$

9.3 The expanded uncertainty (U) is calculated using the following Equation 3:

$$U = z \cdot u_c \quad z = 1.96 \text{ (coverage factor for 95\% confidence interval)}$$

10. Uncertainty of Measurement

- 10.1 This procedure provides the approach to calculate and report uncertainty of measurement estimations.

11. Limitations

- 11.1 Uncertainty of measurement estimation is not calculated and will not be reported for trigger pull measurements because it does not impact the evaluation of a specification limit. The free weight measuring equipment used is not calibrated and does not provide for more precise measurement increments than one quarter pound, resulting in measurement resolution that does not allow for practical estimations of uncertainty. Due to the method by which these measurements are determined, these measurements are approximations and are recorded in case notes as a range.

12. Documentation

- 12.1 Firearms Analysis Report template
- 12.2 UoM Study Calculations spreadsheet

13. References

- 13.1 ISO/IEC 17025:2017 – General Requirements for the Competence of Testing and Calibration Laboratories, International Organization for Standardization, Geneva, Switzerland.
- 13.2 ANAB Supplemental Requirements for Forensic Testing, ANSI-ASQ National Accreditation Board, Milwaukee, WI, (Current Version).
- 13.3 FSL Quality Assurance Manual (Current Version).