Charlotte Mecklenburg Crime Lab Firearms Section
Determination of Uncertainty of Measurement for Barrel and Overall Lengths of Long Firearms

The measurements of long guns' barrel length and overall length are the only two measurements where "the testing contains measurement results that are quantitative, reported and may reasonably be expected to be used, by an immediate or extended customer (anyone in the judicial process) to determine, prosecute or defend the type or level of criminal charge(s)" that we report in our laboratory reports. Therefore these are the only measurements deemed necessary to have an uncertainty value determined for them.

Test Method Information:

- Three examiners perform these measurements
- All of the examiners use the same equipment for measuring

Measurement Traceability:

The traceability for this measurement process is established through the calibration of the equipment used to perform the measurements.

- The calibration of the equipment was determined to be a significant factor in the accuracy of a test result.
- The calibration of the measuring equipment was performed by the manufacturer.
- The laboratory posses a certificate of calibration that certifies the traceability of the measuring instrument.

Measurement Assurance:

- The laboratory has determined that since the measuring equipment is stationary and the rule is locked in place, that no intermediate checks beyond visual inspection of the equipment are necessary to maintain confidence in the calibration of the equipment in the interval between external calibration checks.
- The laboratory has a procedure to ensure that the equipment is functioning properly, which includes a visual inspection. (Firearms SOP Appendix B, Section G).

THE MEASUREMENT PROCESS

Measurand 1 – The barrel length of a firearm (other than a revolver) using a steel ruler with 1/32 inch scale markings in an aluminum measuring box

Current Test Method – Firearms Identification SOP for Barrel & Overall Length Measurement, Revision Date: 5/15/13

Summary of Measurement – A measured line which is parallel to the axis of the barrel that runs from the breech face in a closed and locked and cocked position to the muzzle.

Range of Measurement – up to approximately 30 inches

A single measurement is made.

Measurand 2 – The overall length of a firearm using a steel ruler with 1/32 inch scale markings in an aluminum measuring box

Current Test Method – Firearms Identification SOP for Barrel & Overall Length Measurement, Revision Date: 5/15/13

Summary of Measurement – A measured line which is parallel to the axis of the barrel that runs from a perpendicular line which touches the rearmost point of the butt end of the firearm to the muzzle.

Range of Measurement – up to the length that will fit in the measuring box (approximately 34 inches)

A single measurement is made.

EQUIPMENT USED FOR DETERMINING BARREL AND OVERALL LENGTH

The equipment used for determining barrel and overall length consists of the following:

- Measuring box (DM-36) containing a NIST traceable steel rule
- Three metal rods of varying diameters with collets that screw tight

IDENTIFICATION OF UNCERTAINTY COMPONENTS

Following are factors that we considered in the determination of uncertainty:

Calibration of the measuring rule
The readability of the measuring rule

- at zero
- at the measurement end

Reproducibility of the measuring process - factors are accounted for in the repeatability study

- Different examiners
- Examiners' visual acuity
- Time of day
- Slippage in the measuring box
- Angle of the firearm relative to the measuring box/rule
- Straightness of cut on barrels or stocks
- Whether the firearm is cocked (firing pin affecting measuring rod)
- Available light
- Examiners following method differently

The uncertainty due to environmental factors such as temperature and humidity were deemed to be so small as to not affect the measured lengths of firearms/ barrels. Since the amount the firearms and the measuring rule expand and contract is well below the measurable limit that we can perform. Also, there is a very small change in environmental factors within the laboratory.

QUANTIFICATION OF UNCERTAINTY COMPONENTS

Measuring Rule
(Type B Evaluation)
The uncertainty of the measuring rule, based on the certificate of calibration = 0.005" per foot in each scale length

Readability/Reading
(Type B Evaluation)
The smallest value readable on the rule = 0.03125" (1/32")
This would be the same value for both the zero end and the measurement end

Measuring Rule Resolution
(Type B Evaluation)
Laboratory procedure requires that the value be rounded up to the nearest 1/32 inch rule mark, therefore *no resolution will be done*.

Repeatability
(Type A Evaluation)
A laboratory study was performed to evaluate the repeatability of results of the measurement process across all three examiners. The study utilized firearms from the laboratory's reference collection. Firearms included in the study covered the full range of long guns that might be encountered in cases submitted to the laboratory. These included firearms with sawed off barrels and stocks. It included a variety of different long gun/stock designs. Only long guns were used since there is no necessity to measure handguns for this type of examination.
The study was conducted by having each examiner measure the barrel and overall length of ten different firearms four different weeks beginning on 11/15/13 and ending 12/06/13. The firearms were measured no more than once per week. Some measurements were done in the morning and some in the afternoon on any given day so that the experiment covered a variety of examiner physical and mental conditions. Each set of measurements

was recorded on separate forms and then dropped into a box to avoid any bias involved with seeing the previously recorded measurements.

The following firearms (all from the Firearms Section Reference Collection) were used in the experiment:

Ref #	Description
257	a sawed off bolt-action Remington 22 LR caliber rifle
263	a sawed off Stevens single-shot 16 Gauge shotgun with a loose butt stock and burrs on the barrel cut
347	a sawed off Harrington & Richardson 12 Gauge shotgun
576	a sawed off Universal M-1 Carbine 30 caliber rifle
543	a KelTec Sub2000 40 S&W caliber carbine
447	a Hi-Point model 995 9mm Luger caliber rifle with missing rear sight and a flash suppressor
494	a Hi-Point model 995 9mm Luger caliber rifle with rear sight
448	a Maverick by Mossberg model 88 12 Gauge shotgun with a pistol grip
97	an Ithaca model 48 22 caliber lever action rifle
575	a Calico model M-900 9mm Luger caliber carbine

The laboratory has procedures that address the use of the measuring equipment (as listed above) and requires periodic visual inspection of the equipment (Appendix B).

The number of measurements from the study is greater than 100 (120).

Because the length of each firearm measured varied, the data of interest is not the nominal length, but the variation of each measurement from the mean of the measurements made by all three examiners on a single measureand.

The repeatability values were determined separately for barrel length and overall length since there is a slight difference in the method used (a rod is used in barrel length determination). The values and final calculations are located on the spread sheet print out attached.

CONVERSION OF QUANTITIES TO STANDARD UNCERTAINTIES

#257	BBL	X-mean	X-mean squared		OAL	X-mean	X-mean squared
1	11.9375	0.005208	2.71267E-05	1	20.75	0.015625	0.000244141
2	11.9375	0.005208	2.71267E-05	2	20.75	0.015625	0.000244141
3	11.9375	0.005208	2.71267E-05	3	20.78125	0.046875	0.002197266
4	11.9375	0.005208	2.71267E-05	4	20.75	0.015625	0.000244141
5	11.9375	0.005208	2.71267E-05	5	20.75	0.015625	0.000244141
6	11.9375	0.005208	2.71267E-05	6	20.71875	-0.015625	0.000244141
7	11.9375	0.005208	2.71267E-05	7	20.71875	-0.015625	0.000244141
8	11.9375	0.005208	2.71267E-05	8	20.71875	-0.015625	0.000244141
9	11.9375	0.005208	2.71267E-05	9	20.71875	-0.015625	0.000244141
10	11.9375	0.005208	2.71267E-05	10	20.71875	-0.015625	0.000244141
11	11.90625	-0.02604	0.000678168	11	20.71875	-0.015625	0.000244141
12	11.90625	-0.02604	0.000678168	12	20.71875	-0.015625	0.000244141
Mean	11.93229		0.001627604	Mean	20.73438		0.004882813

#263

	BBL	X-mean	X-mean squared		OAL	X-mean	X-mean squared
1	14.0625	-0.00852	7.26046E-05	1	22.84375	0.019729167	0.00038924
2	14.0625	-0.00852	7.26046E-05	2	22.8125	-0.011520833	0.00013273
3	14.0625	-0.00852	7.26046E-05	3	22.8125	-0.011520833	0.00013273
4	14.09375	0.022729	0.000516615	4	22.8125	-0.011520833	0.00013273
5	14.09375	0.022729	0.000516615	5	22.90625	0.082229167	0.006761636
6	14.09375	0.022729	0.000516615	6	22.8125	-0.011520833	0.00013273
7	14.09375	0.022729	0.000516615	7	22.83475	0.010729167	0.000115115
8	14.0625	-0.00852	7.26046E-05	8	22.83475	0.010729167	0.000115115
9	14.0625	-0.00852	7.26046E-05	9	22.8125	-0.011520833	0.00013273
10	14.03975	-0.03127	0.000977865	10	22.8125	-0.011520833	0.00013273
11	14.0625	-0.00852	7.26046E-05	11	22.78125	-0.042770833	0.001829344
12	14.0625	-0.00852	7.26046E-05	12	22.8125	-0.011520833	0.00013273
Mean	14.07102		0.003552557	Mean	22.82402		0.010139557

#347

	BBL	X-mean	X-mean squared		OAL	X-mean	X-mean squared
1	18.125	0.002604	6.78168E-06	1	26.4375	-0.005208333	2.71267E-05
2	18.125	0.002604	6.78168E-06	2	26.4375	-0.005208333	2.71267E-05
3	18.125	0.002604	6.78168E-06	3	26.4375	-0.005208333	2.71267E-05
4	18.125	0.002604	6.78168E-06	4	26.46875	0.026041667	0.000678168
5	18.125	0.002604	6.78168E-06	5	26.4375	-0.005208333	2.71267E-05
6	18.125	0.002604	6.78168E-06	6	26.5625	0.119791667	0.014350043
7	18.125	0.002604	6.78168E-06	7	26.4375	-0.005208333	2.71267E-05
8	18.125	0.002604	6.78168E-06	8	26.34375	-0.098958333	0.009792752
9	18.125	0.002604	6.78168E-06	9	26.46875	0.026041667	0.000678168
10	18.125	0.002604	6.78168E-06	10	26.4375	-0.005208333	2.71267E-05
11	18.09375	-0.02865	0.000820584	11	26.40625	-0.036458333	0.00132921
12	18.125	0.002604	6.78168E-06	12	26.4375	-0.005208333	2.71267E-05
Mean	18.1224		0.000895182	Mean	26.44271		0.027018229

#576

	BBL	X-mean	X-mean squared		OAL	X-mean	X-mean squared
1	18.03125	-0.01302	0.000169542	1	27.5625	0.015625	0.000244141
2	18.03125	-0.01302	0.000169542	2	27.53125	-0.015625	0.000244141
3	18.03125	-0.01302	0.000169542	3	27.5625	0.015625	0.000244141
4	18.0625	0.018229	0.000332303	4	27.5625	0.015625	0.000244141
5	18.0625	0.018229	0.000332303	5	27.5625	0.015625	0.000244141
6	18.0625	0.018229	0.000332303	6	27.5625	0.015625	0.000244141
7	18.0625	0.018229	0.000332303	7	27.5625	0.015625	0.000244141
8	18.0625	0.018229	0.000332303	8	27.53125	-0.015625	0.000244141

9	18.03125	-0.01302	0.000169542	9	27.53125	-0.015625	0.000244141
10	18.03125	-0.01302	0.000169542	10	27.53125	-0.015625	0.000244141
11	18.03125	-0.01302	0.000169542	11	27.53125	-0.015625	0.000244141
12	18.03125	-0.01302	0.000169542	12	27.53125	-0.015625	0.000244141
Mean	18.04427		0.002848307	Mean	27.54688		0.002929688

#543

	BBL	X-mean	X-mean squared		**OAL**	X-mean	X-mean squared
1	16.375	0.036458	0.00132921	1	29.46875	0.002604167	6.78168E-06
2	16.375	0.036458	0.00132921	2	29.5	0.033854167	0.001146105
3	16.375	0.036458	0.00132921	3	29.46875	0.002604167	6.78168E-06
4	16.375	0.036458	0.00132921	4	29.46875	0.002604167	6.78168E-06
5	16.0625	-0.27604	0.076199002	5	29.46875	0.002604167	6.78168E-06
6	16.375	0.036458	0.00132921	6	29.46875	0.002604167	6.78168E-06
7	16.375	0.036458	0.00132921	7	29.46875	0.002604167	6.78168E-06
8	16.375	0.036458	0.00132921	8	29.5	0.033854167	0.001146105
9	16.375	0.036458	0.00132921	9	29.4375	-0.028645833	0.000820584
10	16.3125	-0.02604	0.000678168	10	29.40625	-0.059895833	0.003587511
11	16.3125	-0.02604	0.000678168	11	29.46875	0.002604167	6.78168E-06
12	16.375	0.036458	0.00132921	12	29.46875	0.002604167	6.78168E-06
Mean	16.33854		0.089518229	Mean	29.46615		0.006754557

#447

	BBL	X-mean	X-mean squared		**OAL**	X-mean	X-mean squared
1	18.625	0.013021	0.000169542	1	33.21875	-0.0078125	6.10352E-05
2	18.59375	-0.01823	0.000332303	2	33.25	0.0234375	0.000549316
3	18.59375	-0.01823	0.000332303	3	33.25	0.0234375	0.000549316
4	18.625	0.013021	0.000169542	4	33.25	0.0234375	0.000549316
5	18.625	0.013021	0.000169542	5	33.21875	-0.0078125	6.10352E-05
6	18.625	0.013021	0.000169542	6	33.25	0.0234375	0.000549316
7	18.625	0.013021	0.000169542	7	33.21875	-0.0078125	6.10352E-05
8	18.625	0.013021	0.000169542	8	33.21875	-0.0078125	6.10352E-05
9	18.59375	-0.01823	0.000332303	9	33.21875	-0.0078125	6.10352E-05
10	18.59375	-0.01823	0.000332303	10	33.21875	-0.0078125	6.10352E-05
11	18.59375	-0.01823	0.000332303	11	33.1875	-0.0390625	0.001525879
12	18.625	0.013021	0.000169542	12	33.21875	-0.0078125	6.10352E-05
Mean	18.61198		0.002848307	Mean	33.22656		0.004150391

#494

	BBL	X-mean	X-mean squared		OAL	X-mean	X-mean squared
1	16.65625	0	0	1	31.25	0.015625	0.000244141
2	16.65625	0	0	2	31.25	0.015625	0.000244141
3	16.65625	0	0	3	31.25	0.015625	0.000244141
4	16.65625	0	0	4	31.21875	-0.015625	0.000244141
5	16.65625	0	0	5	31.25	0.015625	0.000244141
6	16.65625	0	0	6	31.21875	-0.015625	0.000244141
7	16.65625	0	0	7	31.21875	-0.015625	0.000244141
8	16.65625	0	0	8	31.25	0.015625	0.000244141
9	16.65625	0	0	9	31.21875	-0.015625	0.000244141
10	16.65625	0	0	10	31.25	0.015625	0.000244141
11	16.65625	0	0	11	31.21875	-0.015625	0.000244141
12	16.65625	0	0	12	31.21875	-0.015625	0.000244141
Mean	16.65625		0	Mean	31.23438		0.002929688

#448

	BBL	X-mean	X-mean squared		OAL	X-mean	X-mean squared
1	18.625	-0.01042	0.000108507	1	28.1875	0	0
2	18.625	-0.01042	0.000108507	2	28.1875	0	0
3	18.625	-0.01042	0.000108507	3	28.21875	0.03125	0.000976563
4	18.625	-0.01042	0.000108507	4	28.1875	0	0
5	18.625	-0.01042	0.000108507	5	28.1875	0	0
6	18.65625	0.020833	0.000434028	6	28.1875	0	0
7	18.65625	0.020833	0.000434028	7	28.1875	0	0
8	18.65625	0.020833	0.000434028	8	28.1875	0	0
9	18.625	-0.01042	0.000108507	9	28.15625	-0.03125	0.000976563
10	18.625	-0.01042	0.000108507	10	28.1875	0	0
11	18.625	-0.01042	0.000108507	11	28.1875	0	0
12	18.65625	0.020833	0.000434028	12	28.1875	0	0
Mean	18.63542		0.002604167	Mean	28.1875		0.001953125

#97

	BBL	X-mean	X-mean squared		OAL	X-mean	X-mean squared
1	18.15625	0.018229	0.000332303	1	34.34375	-0.018229167	0.000332303
2	18.25	0.111979	0.012539334	2	34.34375	-0.018229167	0.000332303
3	18.125	-0.01302	0.000169542	3	34.375	0.013020833	0.000169542
4	18.125	-0.01302	0.000169542	4	34.3125	-0.049479167	0.002448188
5	18.125	-0.01302	0.000169542	5	34.34375	-0.018229167	0.000332303
6	18.125	-0.01302	0.000169542	6	34.375	0.013020833	0.000169542
7	18.125	-0.01302	0.000169542	7	34.5	0.138020833	0.01904975
8	18.125	-0.01302	0.000169542	8	34.40625	0.044270833	0.001959907

9	18.125	-0.01302	0.000169542	9	34.28125	-0.080729167	0.006517198
10	18.125	-0.01302	0.000169542	10	34.375	0.013020833	0.000169542
11	18.125	-0.01302	0.000169542	11	34.28125	-0.080729167	0.006517198
12	18.125	-0.01302	0.000169542	12	34.40625	0.044270833	0.001959907
Mean	18.13802		0.014567057	Mean	34.36198		0.039957682

#575

	BBL	X-mean	X-mean squared		**OAL**	X-mean	X-mean squared
1	16.1875	0	0	1	28.875	-0.033854167	0.001146105
2	16.1875	0	0	2	28.90625	-0.002604167	6.78168E-06
3	16.1875	0	0	3	28.90625	-0.002604167	6.78168E-06
4	16.1875	0	0	4	28.90625	-0.002604167	6.78168E-06
5	16.1875	0	0	5	28.9375	0.028645833	0.000820584
6	16.1875	0	0	6	28.9375	0.028645833	0.000820584
7	16.1875	0	0	7	28.90625	-0.002604167	6.78168E-06
8	16.21875	0.03125	0.000976563	8	28.90625	-0.002604167	6.78168E-06
9	16.1875	0	0	9	28.90625	-0.002604167	6.78168E-06
10	16.1875	0	0	10	28.90625	-0.002604167	6.78168E-06
11	16.1875	0	0	11	28.90625	-0.002604167	6.78168E-06
12	16.15625	-0.03125	0.000976563	12	28.90625	-0.002604167	6.78168E-06
Mean	16.1875		0.001953125	Mean	28.90885		0.002848307

Variances Squared	BBL	OAL
257	0.001628	0.004883
263	0.003553	0.01014
347	0.000895	0.027018
576	0.002848	0.00293
543	0.089518	0.006755
447	0.002848	0.00415
494	0	0.00293
448	0.002604	0.001953
97	0.014567	0.039958
575	0.001953	0.002848
Sum of V sq	0.120415	0.103564
Sum V Sq/n-1	0.001012	0.00087
Sqrt (V Sq/(n-1))	0.03181	0.029501

BBL Standard Deviation = 0.03181

OAL Standard Deviation = 0.029501

Type A evaluation of components:

Reproducibility data for Measurand 1 (barrel length):

The standard deviation for reproducibility data for barrel length is 0.03181 inch

Reproducibility data for Measurand 2 (overall length):

The standard deviation for reproducibility data for barrel length is 0.029501 inch

Type B evaluation of components:

The readability of the measuring tool is 1/32 inch = 0.03125 inch
This readability is appropriate at both the zero end and the measurement end, so it will be used twice in the computation for standard uncertainty. It does not change for type of measurand.

The uncertainty for the calibration of the measuring instrument as determined by the manufacturer is 0.005 inch. The uncertainty from the calibration certificate was divided by the coverage factor (2) to arrive at a standard uncertainty. Therefore the standard uncertainty from the calibration of the measuring instrument is 0.0025 inch.

CALCULATION OF THE COMBINED STANDARD UNCERTAINTY

$UM_{total} = SQRT [(reproducibility)^2 + (reading- zero)^2 + (reading- measurement)^2 + (measuring\ rule)^2]$

Where:
SQRT = square root
Reproducibility = The average difference in readings across examiners/ days / firearms
Reading = the smallest value able to be read on the measuring rule
Measuring Rule = the uncertainty of the calibration of the measuring rule

For the measurement of barrel length:

Uncertainty Component	Value	Units	Distribution	Type	Divisor	Degrees Freedom (n-1)	Standard Uncertainty	Component Contribution %
Repeatability	0.03181017	inch	A	normal	1.00	119	0.031810169	46
Readability at zero	0.03125000	inch	B	rectangular	1.73	infinite	0.018041684	26
Readability at measurement	0.03125000	inch	B	rectangular	1.73	infinite	0.018041684	26
Measuring Rule Uncertainty	0.00250000	inch	B	rectangular	1.73	infinite	0.001443335	2
Combined Standard Unc	u_c						0.040804102	100
Expanded Unc	U (k=2)						0.081608205	
Expanded Unc	U (k=3)						0.122412307	
Reported Uncertainty:	**0.082**		**k=2**					

The combined standard uncertainty is 0.040804102 inch.

For the measurement of overall length:

Uncertainty Component	Value	Units	Distribution	Type	Divisor	Degrees Freedom (n-1)	Standard Uncertainty	Component Contribution %
Repeatability	0.02950061	inch	A	normal	1.00	119	0.029500611	44
Readability at zero	0.03125000	inch	B	rectangular	1.73	infinite	0.018041684	27
Readability at measurement	0.03125000	inch	B	rectangular	1.73	infinite	0.018041684	27
Measuring Rule Uncertainty	0.00250000	inch	B	rectangular	1.73	infinite	0.001443335	2
Combined Standard Unc	u_c						0.039030423	100
Expanded Unc	U (k=2)						0.078060846	
Expanded Unc	U (k=3)						0.117091269	
Reported Uncertainty:	**0.078**		**k=2**					

The combined standard uncertainty is 0.039030423 inch.

EXPANSION OF UNCERTAINTIES FOR COVERAGE FACTOR OF K=2

The expanded uncertainty for barrel length is: 0.081608205 inch.

The expanded uncertainty for overall length is: 0.078060846 inch.

EVALUATION OF THE EXPANDED UNCERTAINTIES

The uncertainties were evaluated and determined to be acceptable. There were no calculation errors found and the amounts will meet the needs of the customers.

REPORTING OF UNCERTAINTIES

For barrel length:
The uncertainty of measurement of barrel length will be reported as the measured barrel length +/- 0.082 inches at K=2 (95.45%) which will be converted and rounded up to the nearest 32nd inch (which is 3/32 inch). So, for the purposes of writing reports, the reported measurement will be the measured barrel length +/- 3/32 inch at K=2 (95.45%).

For overall length:
The uncertainty of measurement of barrel length will be reported as the measured barrel length +/- 0.078 inches at K=2 (95.45%) which will be converted and rounded up to the nearest 32nd inch (which is 3/32 inch). So, for the purposes of writing reports, the reported measurement will be the measured barrel length +/- 3/32 inch at K=2 (95.45%).

SCHEDULE FOR REVIEW & RECALCULATION

The study of uncertainty as listed above will be reviewed every three years or any time there is a change in equipment or personnel.