An Improved Vacuum Casting Method for the Replication of Reference Bullets

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Outline

- Introduction
- Motivation
- Casting procedure overview
- Validation of process - correlation analysis
- Decay factor study & durability testing
- Possible evidentiary uses

Introduction

- Casting of impressions, toolmarks, and firearm surfaces is employed as a means to transport evidence and preserve surface features.
- Casts are routinely used as primary evidence for analysis and comparison where direct examination would be impractical or impossible.

Introduction

- The NIST SRM 2460 Standard Bullet was developed to be used as a quality control standard in forensic laboratories
- The bullet surfaces are well characterized & validated using surface profile analysis.

Motivation

- A total of 40 NIST SRM2460 Standard Bullets were produced.
- Due to the complex manufacturing process, they are expensive ($2120 ea.) and time consuming to manufacture.
- Almost sold out.

Motivation

- Need an inexpensive and less time consuming method to replenish the Standard Bullet.

- Requirements:
  - Needs to retain the same surface topography quality as the original standard bullets
  - Color/translucency properties must be compatible with microscope imaging
  - Durable

Polymer replication using vacuum casting technique could potentially be used to restock the Standard Bullets

European Research

“Vorrichtung zum Abformen von Hülsen und Geschossen unterschiedlicher Kaliber”

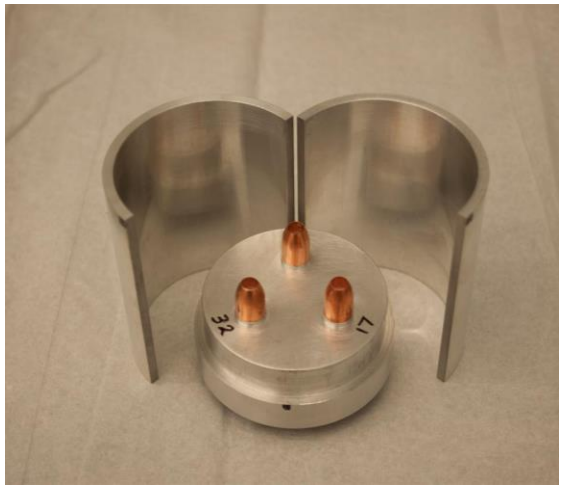
Alfons Koch, 2010

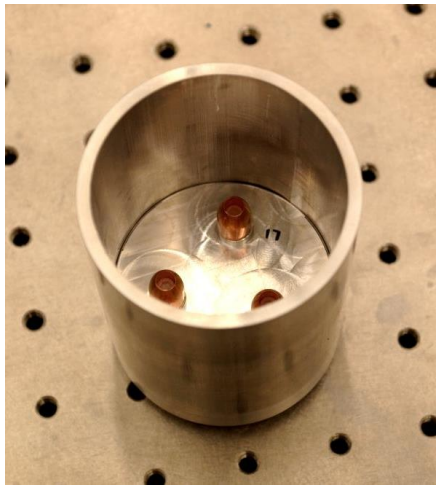
(Patent application DPMA DE 10 2005 039 823.5-15)

BKA/NIST signed MOU in 2011

Vacuum Casting Technique
- Replication container

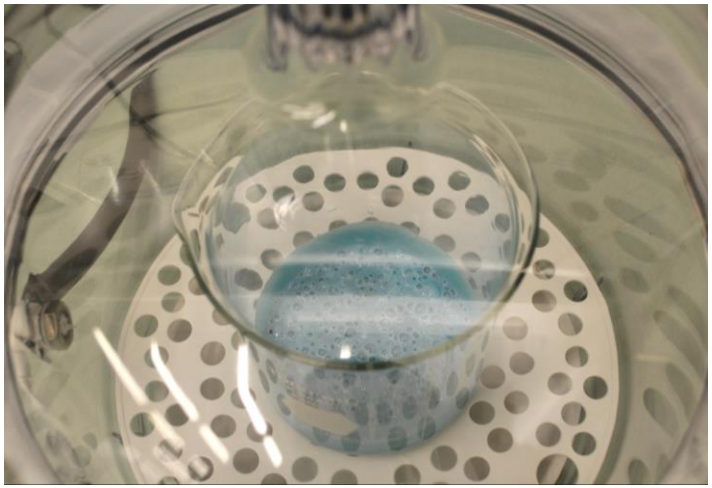
A replication container was fabricated to house the master bullets during the silicone molding phase.



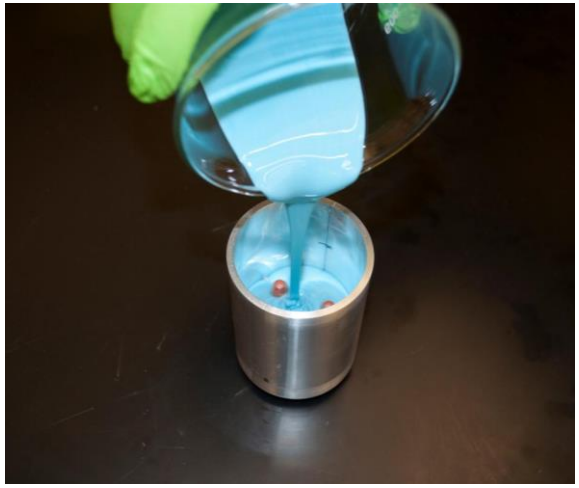


Vacuum Casting Technique
- Step 1: Silicone Mold

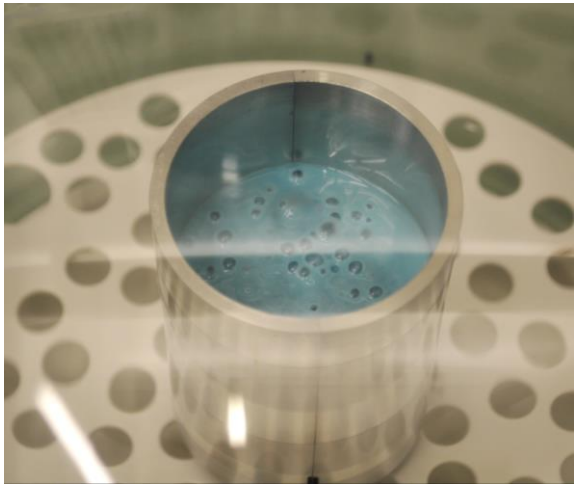
Mixing silicone



Vacuum-degassing in desiccator



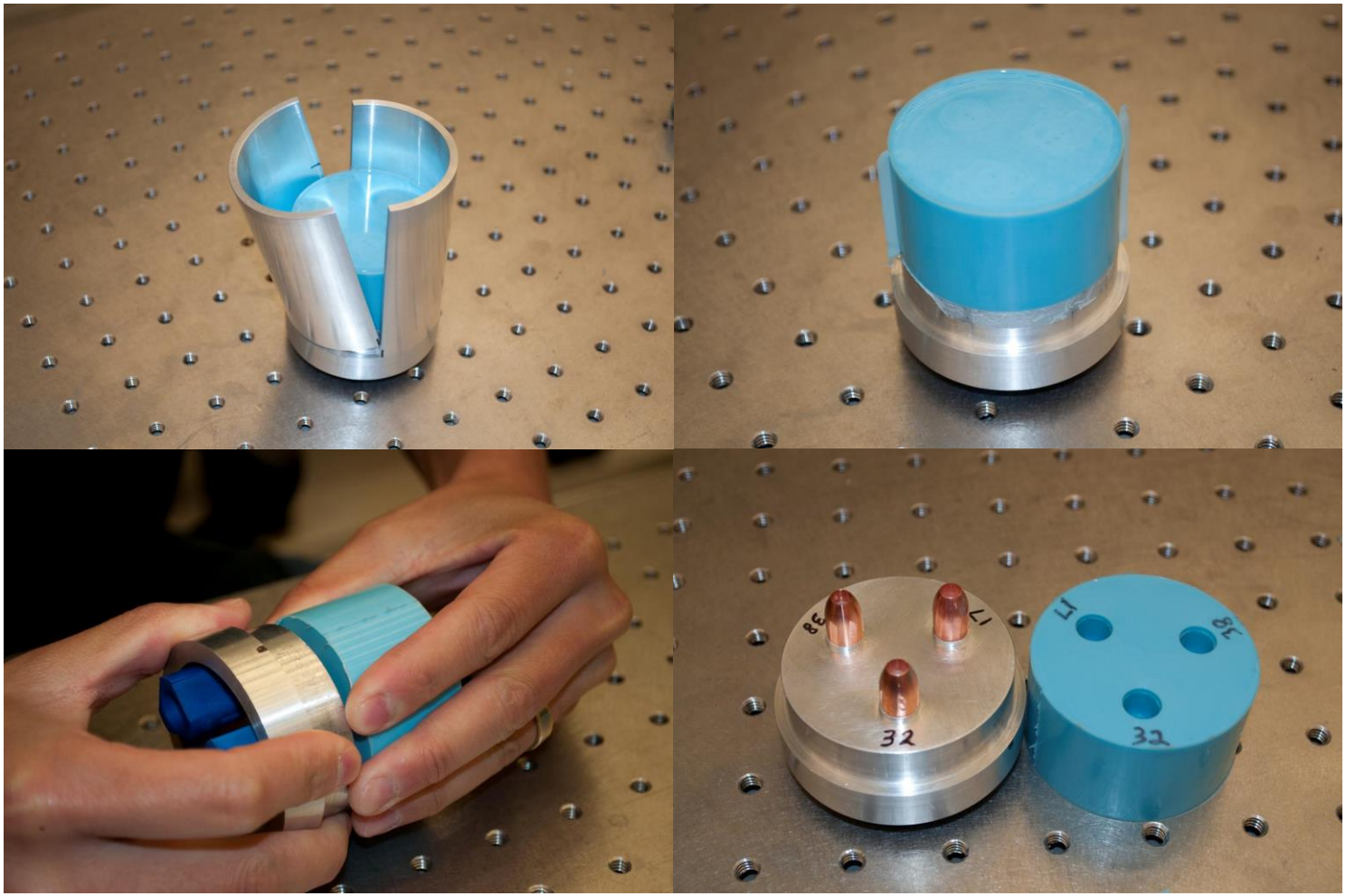
Pouring silicone into replication rig



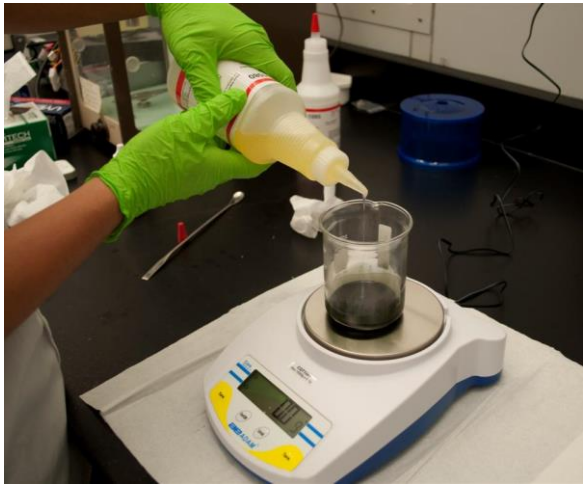
2nd vacuum-degas

Vacuum Casting Technique

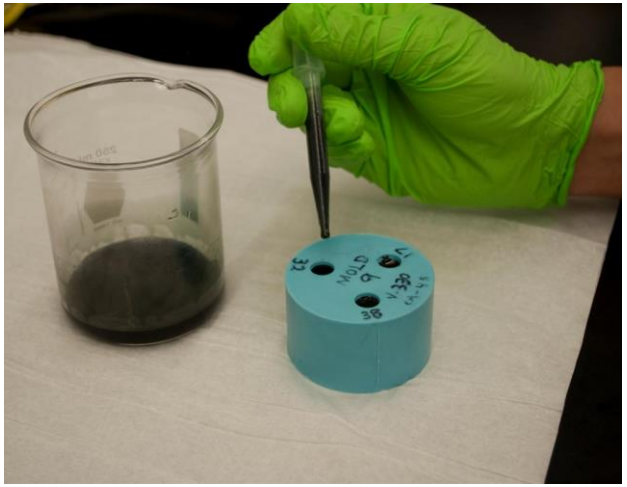
- Removing the silicone mold from the replication rig

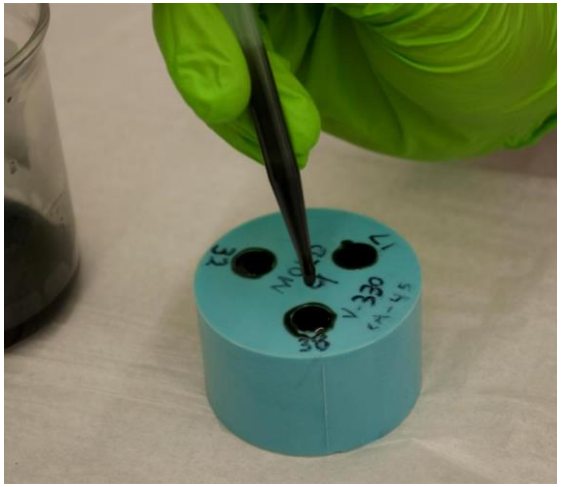


Vacuum Casting Technique
- Step 2: Polyurethane Replica



Mix two-part polyurethane and coloring dye. Then vacuum-degas.

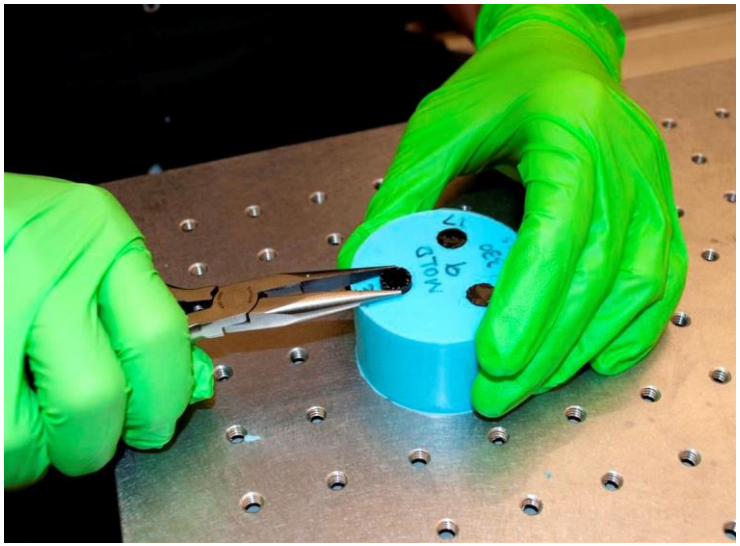


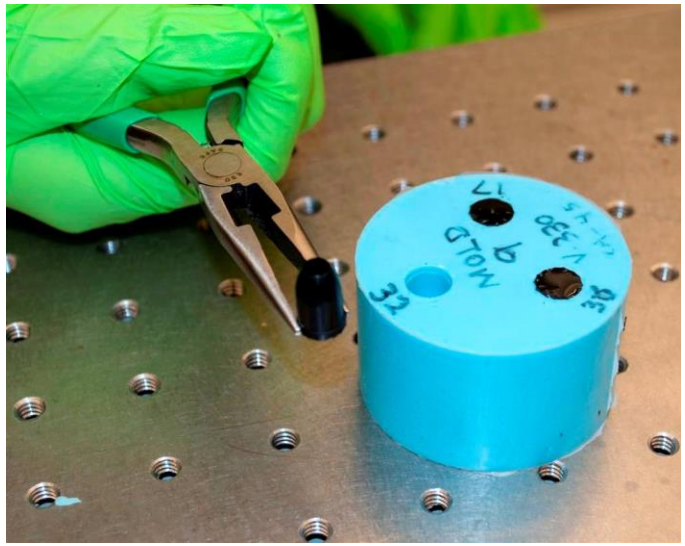


Use a dropper to fill mold with polyurethane. Vacuum-degas again and let cure.

Vacuum Casting Technique

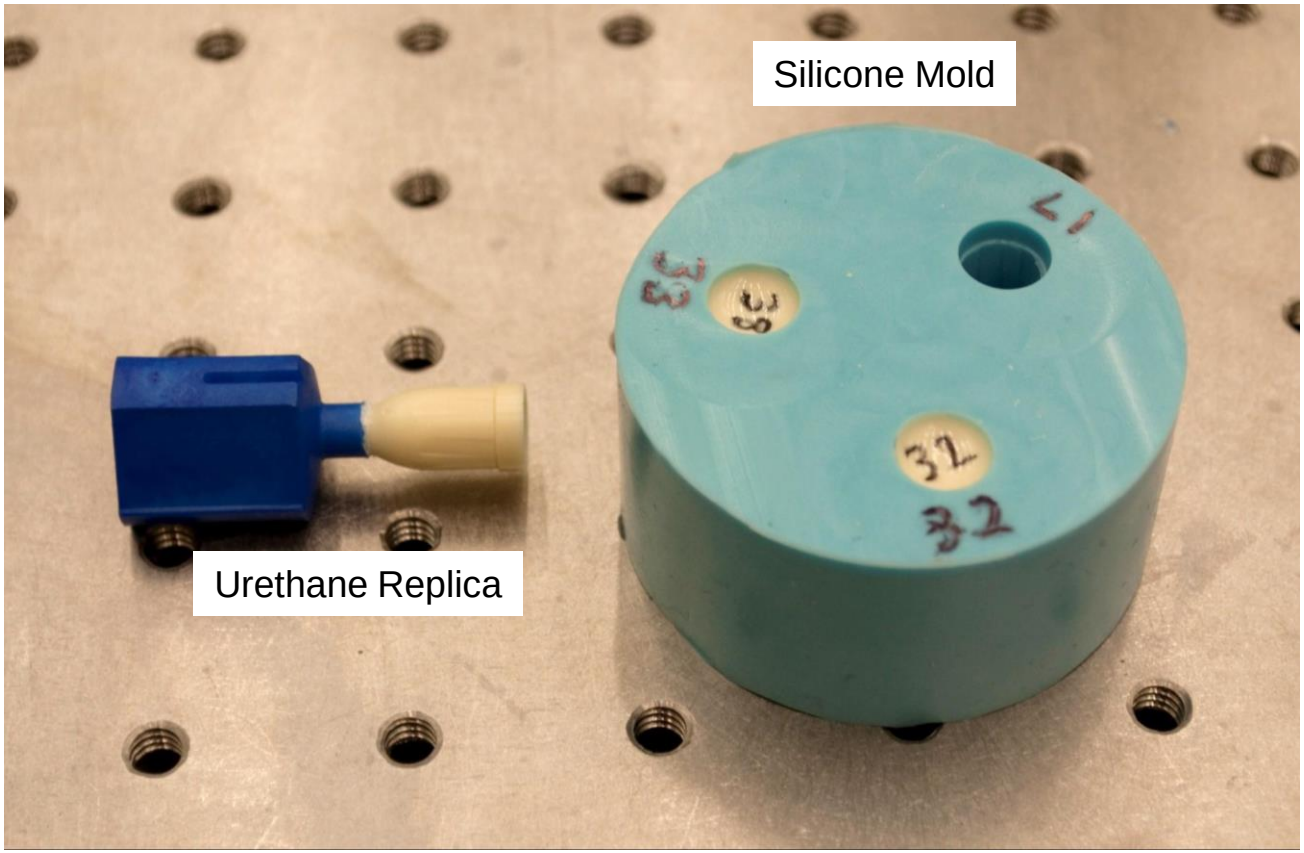
- Removing the cured polyurethane replica bullets from the silicone mold



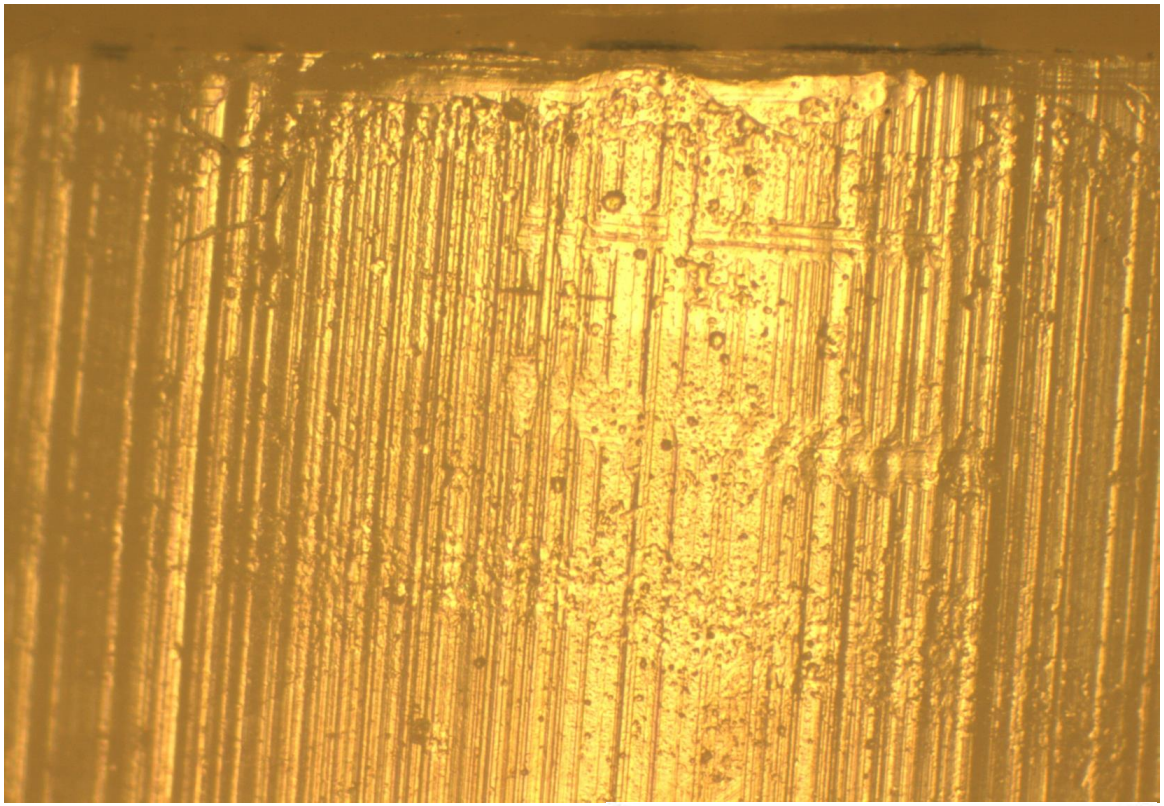


Carefully separate the silicone from the urethane replicas and then remove the replicas with needle nose pliers. The bullet standoff in the replication rig will avoid contact with the striated regions of the bullets, avoiding any damage.

First Replication
(before vacuum degassing was implemented)



First Replication
(before vacuum degassing was implemented)



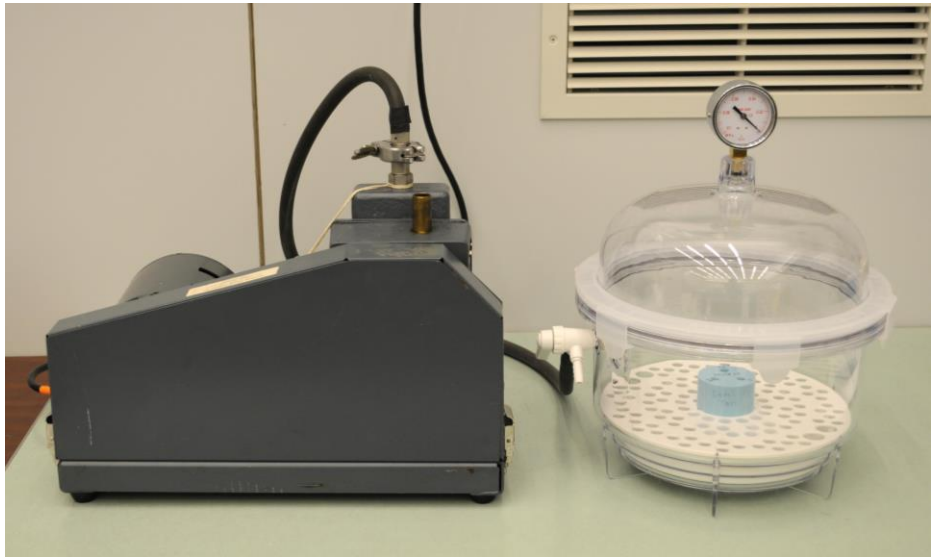
(5X Optical Image)

Quality control of micro-bubbles needs to be addressed

Improvements to process

- Vacuum / degassing using a belt driven “roughing” pump during mixing process

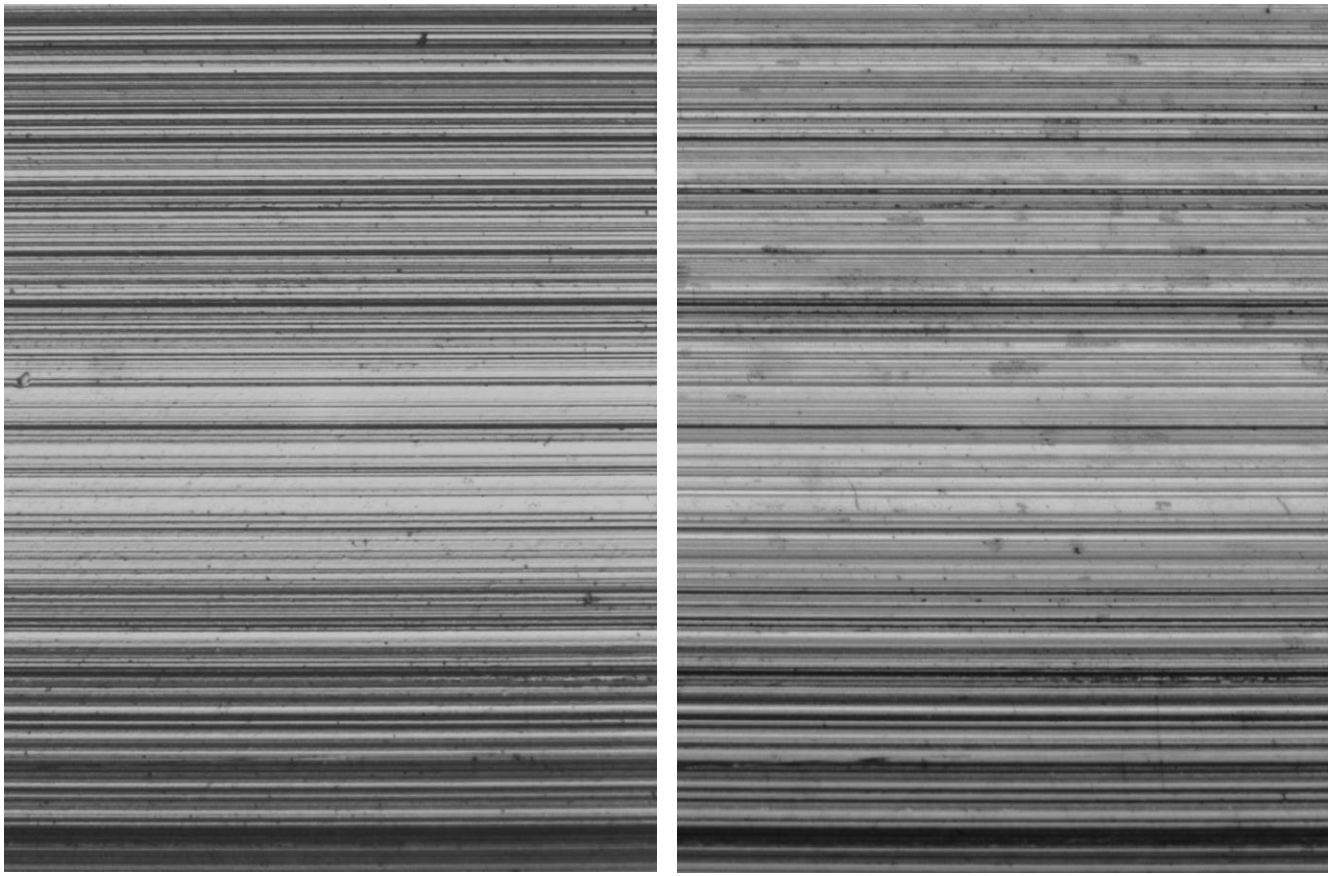
  5 x 10^{-2} Torr
  (6.5 x 10^{-5} atmosphere)



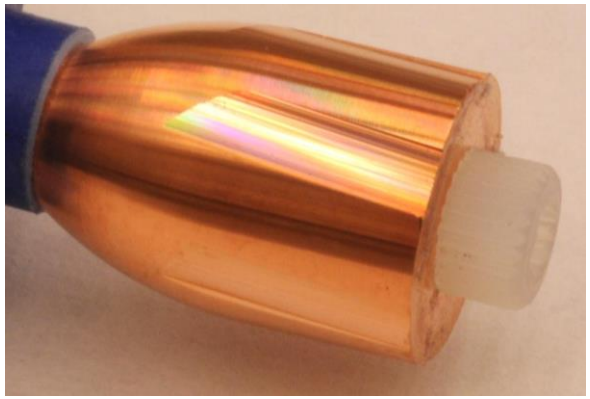
- Changes to silicone & polyurethane materials
  - Reduced viscosity (pours better)
  - Longer working time before curing

Improved Procedure

Replica from Mold # 13a **Original SRM 2460-038**



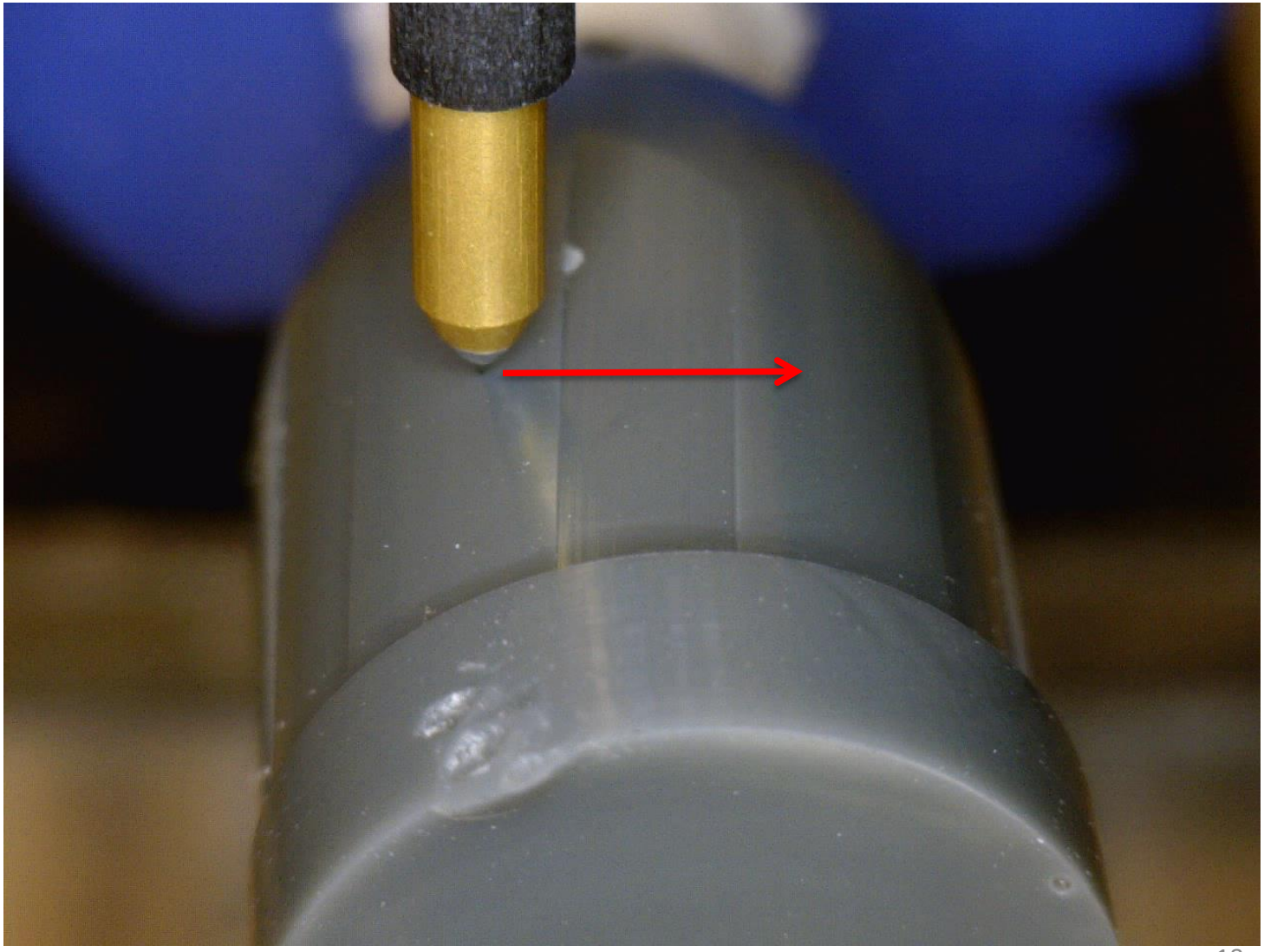
(5X Optical comparison)



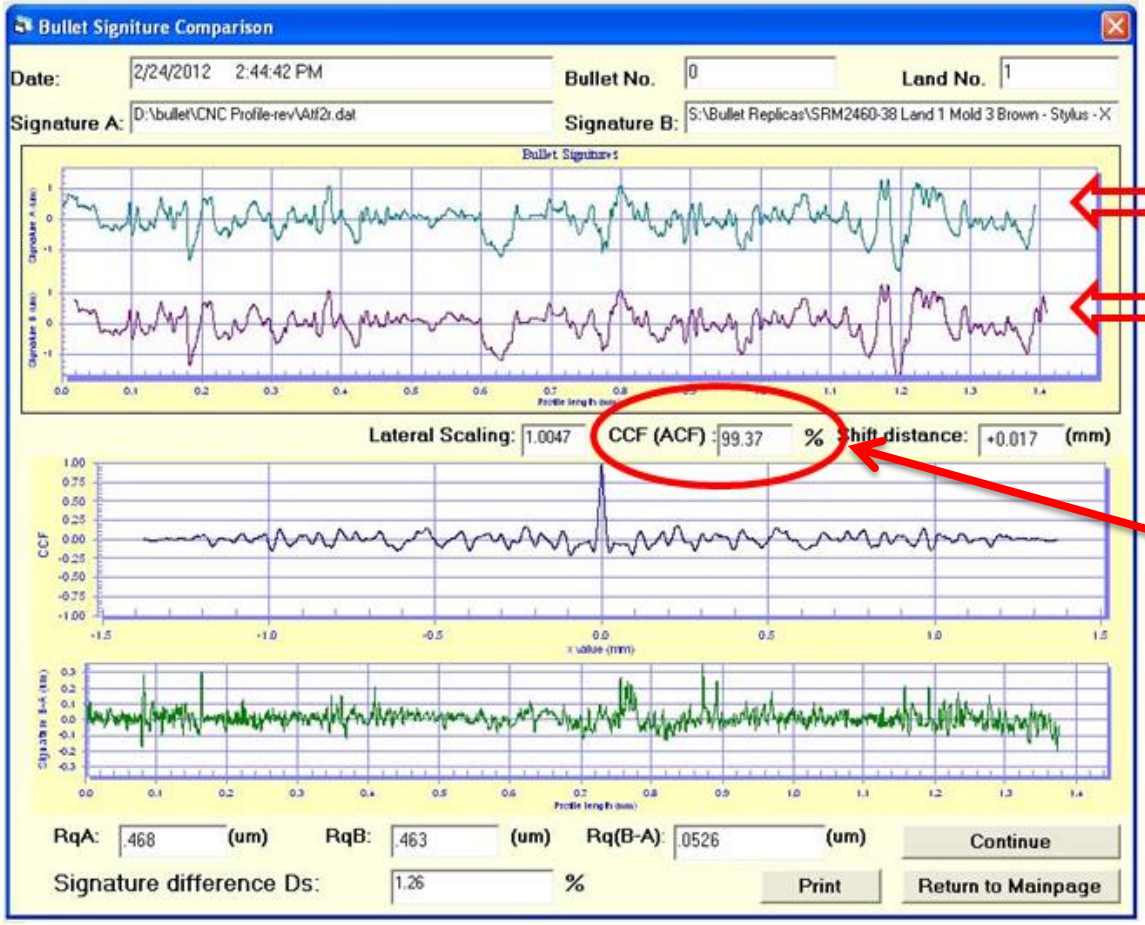
SRM 2460-038

Close-up images of Standard Bullet replicas

Stylus Measurement of the Replica Bullets



Example of CCF Correlation Program



Virtual Signature Standard

Brown Replica from Mold #3

99.37%

Stylus profile comparison of virtual signature to Replica

VERY High CCF value of 99.37% indicates that the Replica is virtually identical to the Master Bullet

Decay Factor: Time

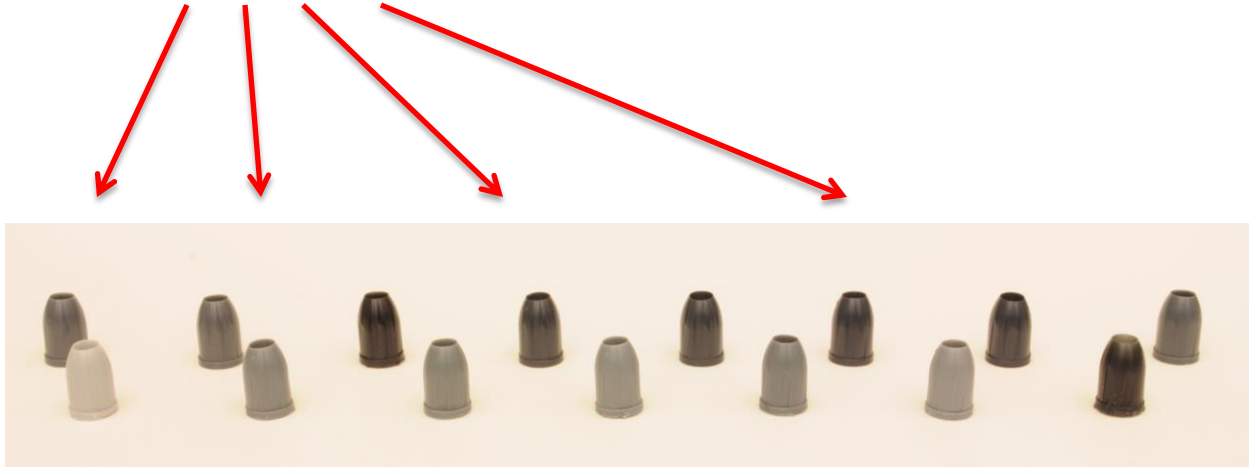
Mold 10, Bullet # 15 – Consecutive measurements vs. Virtual Standard

Measurement Date	*CCFmax %*	Lateral Scaling
5/29/2012	99.37	1.0055
5/30/2012	99.41	1.0060
5/31/2012	99.47	1.0050
6/1/2012	99.50	1.0055
6/4/2012	99.39	1.0055
6/5/2012	99.41	1.0050
6/6/2012	99.45	1.0050
6/7/2012	99.46	1.0055
6/11/2012	99.48	1.0055
6/12/2012	99.51	1.0055
…		
11/26/2012	**99.41**	**1.0050**
…		
02/14/2014	**99.44**	**1.0055**

High CCF% 6 months & 1 ½ years later

Decay Factor: Sibling Replications

Multiple replicas made from a single mold.

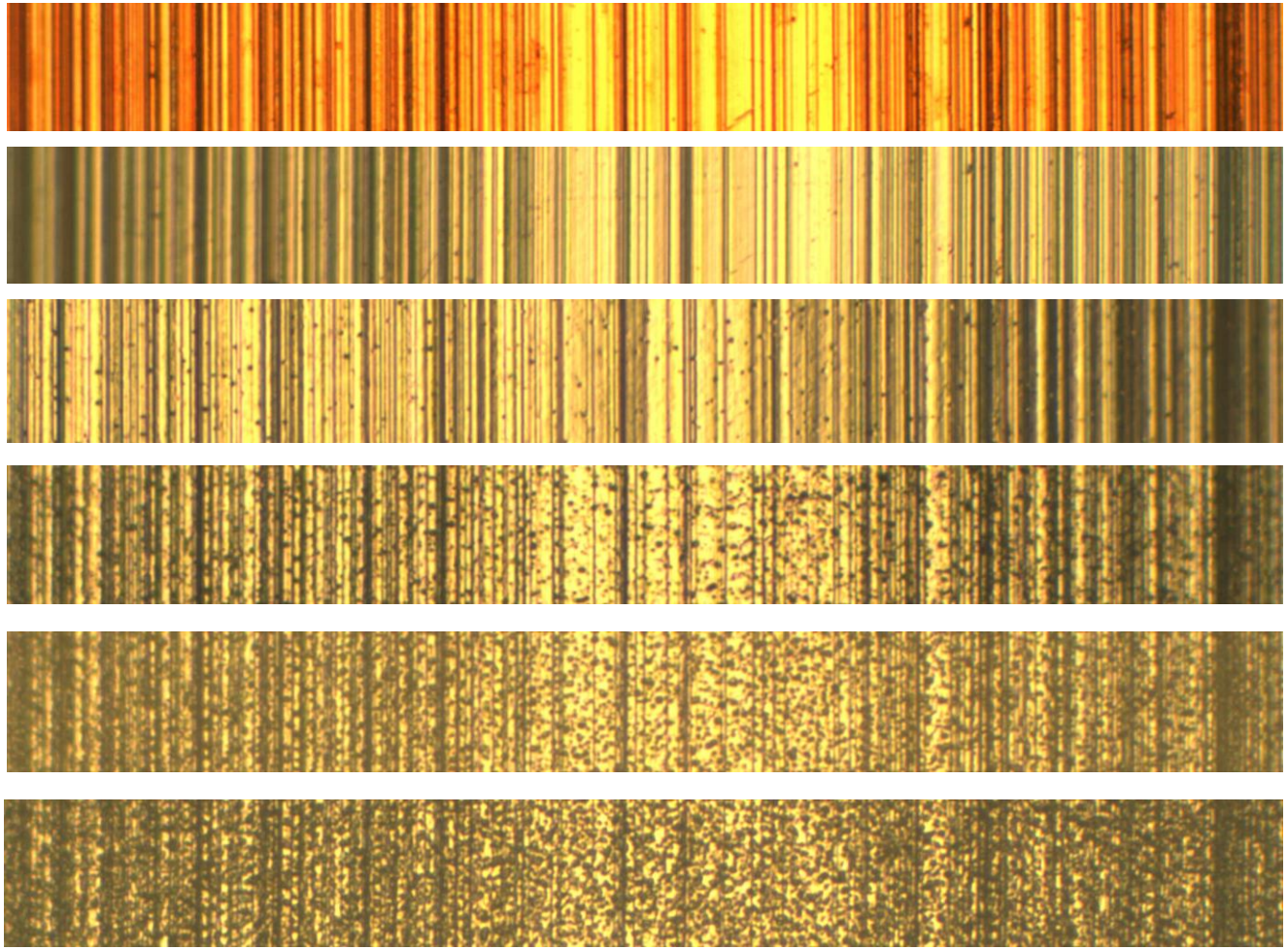


Decay Factor: Sibling Replications - CCF Results

Replicas from Mold # 9, Bullet 038, Land 1

Sibling Replication #	*CCFmax* %	Lateral Scaling
1	99.30	1.0045
2	99.32	1.005
3	99.41	1.005
4	99.16	1.005
5	99.20	1.0045
6	99.25	1.003
7	98.72	1.004
8	98.22	1.004
9	98.38	1.0045
10	97.98	1.0045
11	97.45	1.005
12	97.39	1.005
13	97.17	1.0045
14	97.09	1.0045
15	93.42	1.0035

Sibling Replications – Optical Comparisons



2460-038
Master

Mold #9
1st Replica

Mold #9
3rd Replica

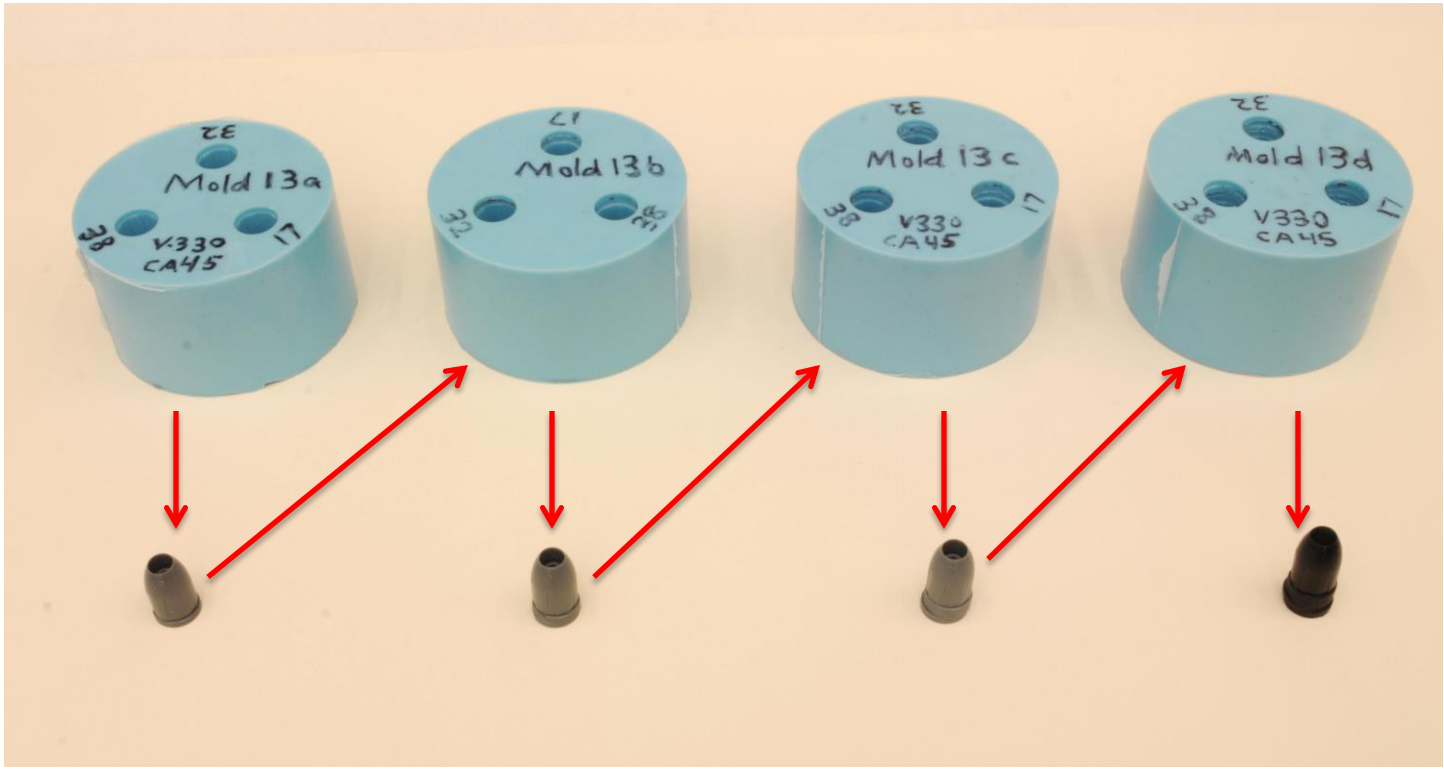
Mold #9
6th Replica

Mold #9
9th Replica

Mold #9
12th Replica

Decay Factor: Generation Test

Each replica is used to create a new mold



Master Bullet #'s 17, 32, & 38 used to create first mold (13a)

Decay Factor: Generation Test

Close-up of Generation Replicas
From Master Bullet # 038

Note: Standoff in replication rig reproduces itself during each casting cycle

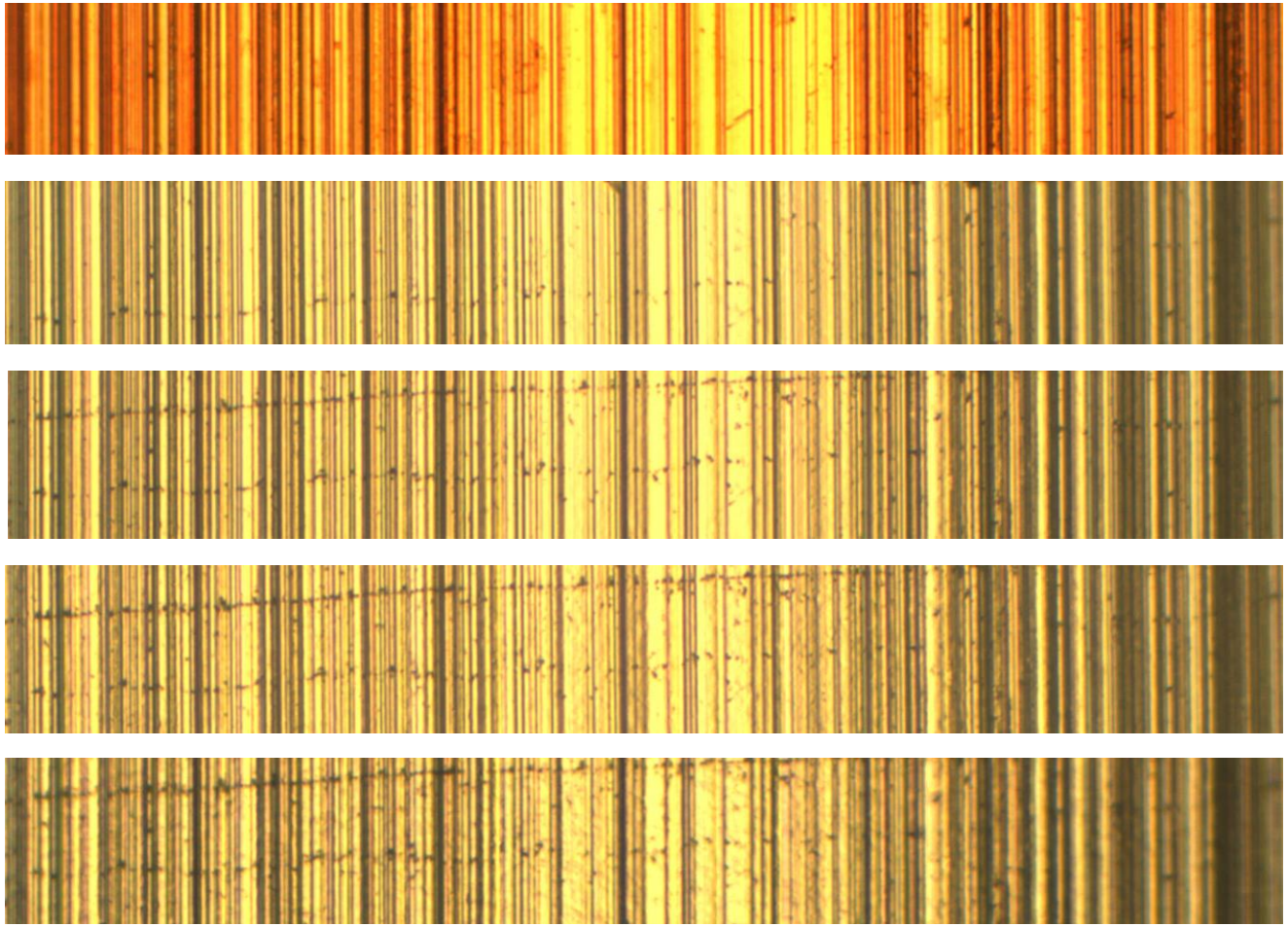
Decay Factor: Generation Test – CCF Results

Replicas from Molds 13_, Bullet 038, Land 1

Generation #	*CCFmax* %	Lateral Scaling
1 (Mold 13**a**)	99.59	1.004
2 (Mold 13**b**)	99.41	1.0095
3 (Mold 13**c**)	99.45	1.014
4 (Mold 13**d**)	99.43	1.019

Note: Each urethane replica shrinks by 0.4 - 0.5%.
This is a compounding effect from generation to generation.

Generation Test – Optical Comparisons



2460-038
Master

Mold #13a
(1st Generation)

Mold #13b
(2nd Generation)

Mold #13c
(3rd Generation)

Mold #13d
(4th Generation)

Durability Testing

Real world “stress tests” are conducted on polymer replica bullets to ensure their durability, and suitability to be used as reference masters.

- High Temperature – Replica # M15-38-1 heated to 55ºC (130ºF) for 3.5 hours
- Low Temperature – Replica # M15-32-1 cooled to -12ºC (10ºF) for 8 hours
- Handling – Replica # M15-38-3 handled with bare hands on land impressions and dropped 1.5 meters to hard surface 10 times
- Chemical – Replica # M15-38-2 immersed in Ethyl Alcohol for 20 minutes

Durability Testing

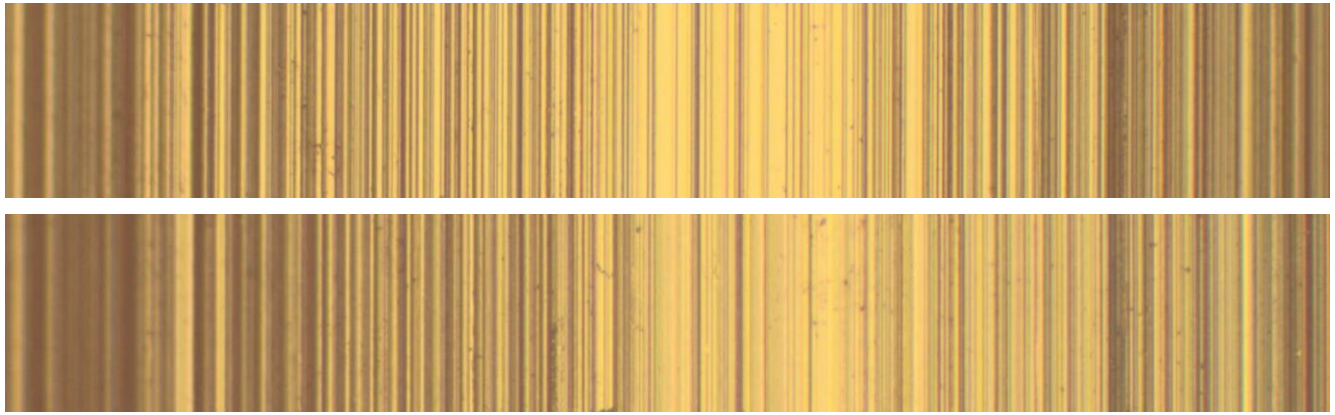
Replica bullets are measured/analyzed before and after "stress tests" using stylus profilometer

Test Type	*Control CCF% (Before Test)*	*After Test CCF%*
High Temperature	99.42	99.51
Low Temperature	99.36	99.42
Handling	99.48	99.35
Chemical	99.37	98.74

Correlations compared to Virtual Standard

Durability Testing

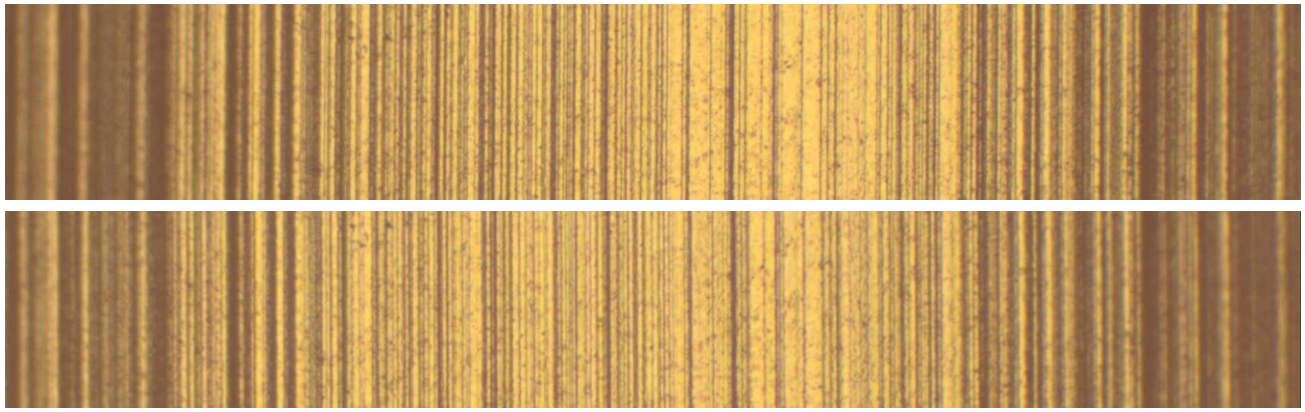
High Temperature (replica # M15-38-1)



Before

After

Low Temperature (replica # M15-32-1)

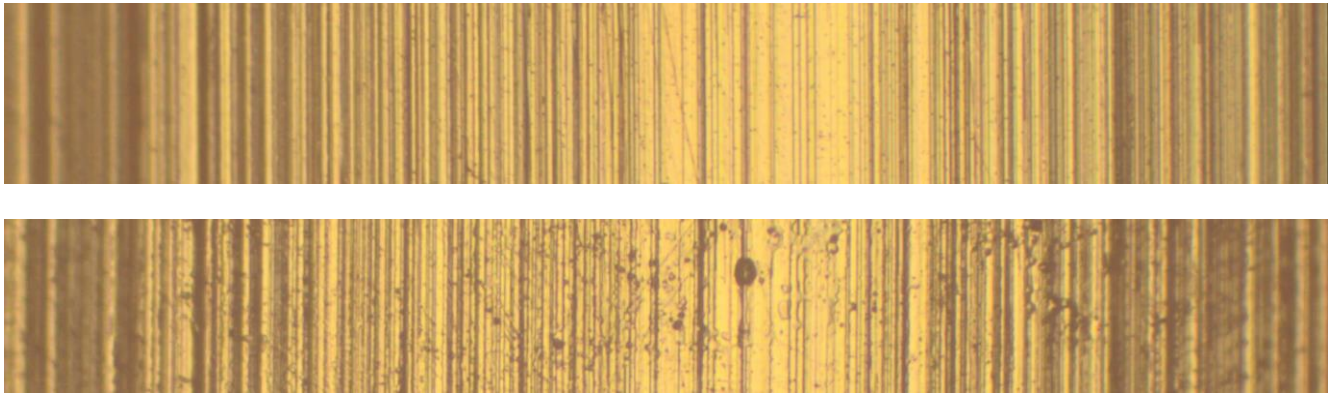


Before

After

Durability Testing

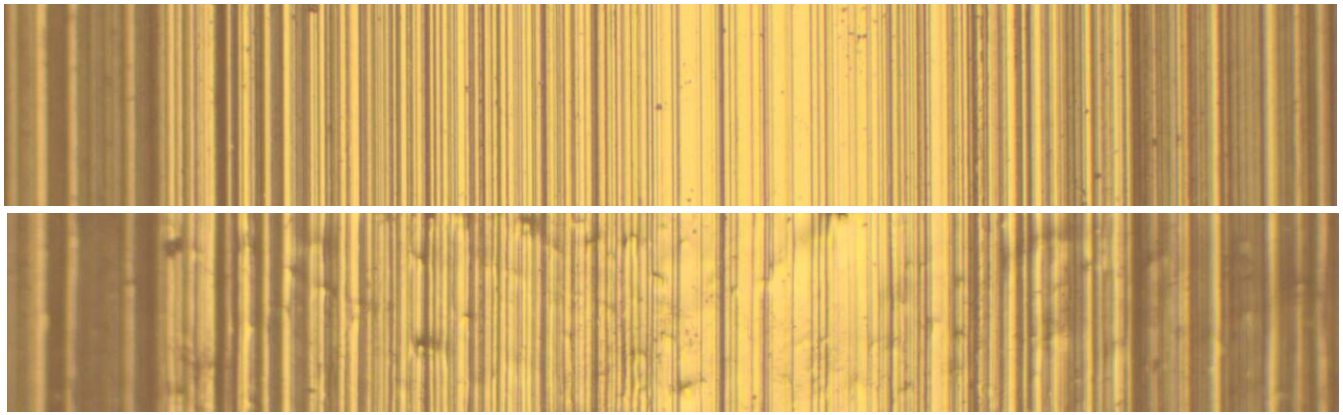
Handling & drop test (replica # M15-38-3)



Before

After

Chemical immersion (replica # M15-38-2)



Before

After

Possible Evidentiary Uses

- Inter-laboratory transfer of bullet (and cartridge case) evidence for comparisons.

  Logistics and chain of custody issues with transferring actual evidence are alleviated

- International evidence transfer.

- Large proficiency test production
  - Eliminates sample variation in production runs.
  - Pre-evaluated samples representative of casework difficulty can be produced.

Future Work

- Improve Bullet Replicas
  - Testing of release agents, hydrophobic coatings, etc. to reduce mold tearing from successive replications. -currently underway
  - Utilize pressurization in conjunction with vacuum-degassing during silicone/urethane curing.
  - Continue durability testing of polymer replicas (include abrasives, oil, humidity, etc.)
- Replication of Cartridge Cases

Acknowledgements

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Thank you!

Questions?

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Previous Research

- "The Production of Replicas of Bullets and Cartridges", by Geradts, Kreijzer, & C. Van Brakel, Netherlands Forensic Science Laboratory.
  - Developed procedures to counter shrinkage effects using modern casting materials.
  - Potential transfer of evidence in EU.

  Reference: AFTE Vol 28, No1 Jan 1996

- "Casting of Complex Stereometric Samples for proficiency Tests in Firearm & Toolmark Examinations" Kock & Katterwe, BKA Germany.
  - Technique described in the production of a large inter-laboratory proficiency test for bullet identification.
  - Evaluated new materials and adapted procedures.

  Reference: AFTE Vol 39 No4 Fall 2007

- **"**Topography measurements for determining the decay factors in surface replication" Song, Rubert, Zheng & Vorburger; NIST.
  - Developed procedures to test and measure the decay factor in the replication of surface topography.

  Reference: Proceedings of ISMTII 2007 MST11

- "Topography Measurements and Performance Comparisons between NIST SRM 2460 Standard Bullet Masters and BKA Bullet Replicas", Song, J., Vorburger, T.V., Thompson, R., Ballou, S., Zheng, A., Renegar, T.B., Silver, R., Ols, M., W. Wenz, A. Koch, M. Braune, A. Lohn, AFTE Journal, **44**, 3, 2012, pp.201-217.