National Institute of Standards & Technology

Certificate

Standard Reference Material® 2461

Standard Cartridge Case

This Standard Reference Material (SRM) is intended primarily for use as a check standard for crime laboratories: first, to help verify that the computerized optical equipment for cartridge case imaging acquisition and correlation is operating properly; second, to establish ballistics measurement traceability and quality assurance; and third, to facilitate laboratory assessment and accreditation [1–3]. A unit of SRM 2461 consists of a circular electro-formed nickel plate replicated from the head of a fired master cartridge case, which contains a surface topography signature of a breech face impression, a firing pin impression, and an ejector mark. The electro-formed plate is cemented to a brass cylinder holder (see Figure 1) so that the assembly resembles a real fired cartridge case.

Certified Areal Cross Correlation Function Maximum ($ACCF_{max}$) and Signature Difference (D_s): $ACCF_{max}$ and D_s are the two properties of the surface topography used to characterize the similarity of the cartridge case surfaces and obtain the certified values in SRM 2461 [1]. A NIST certified value is a value for which NIST has the highest confidence in its accuracy in that all known or suspected sources of bias have been investigated and taken into account [4]. The certified values are obtained from statistical correlations between the surface topography of breech face, firing pin, and ejector mark regions of 137 SRM 2461 standard cartridge cases and those of the reference standard to determine their degree of similarity. When two correlated cartridge case signatures are exactly the same (point by point), the lower limit of D_s equals 0 % and the upper limit of $ACCF_{max}$ equals 100 %. The certified values for the degree of similarity in Table 1 are reported as one-sided intervals, each with 95 % confidence [4].

Table 1. Certified Areal Cross Correlation Function Maximum ($ACCF_{max}$) and Signature Difference (D_s)

	$ACCF_{max}$ [(a)] (%)	D_s [(a)] (%)
Breech Face	>94.3	<11.2
Firing Pin	>98.0	<4.0
Ejector Mark	>93.7	<12.2

[(a)] The one-sided interval with 95 % confidence represents the measurement uncertainty in similarity in SRM 2461. The measurement uncertainty is the range covered from the lower or upper limits to perfect similarity or zero difference respectively. Two surfaces cannot have a similarity better than perfect ($ACCF_{max}$ = 100 %) or a difference less than nothing (D_s = 0).

Expiration of Certification: The certification of **SRM 2461** is valid, within the measurement uncertainty specified, until **30 September 2021**, provided the SRM is handled and stored in accordance with the instructions given in this certificate (see "Notice and Warning to Users"). The certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

Maintenance of SRM Certification: NIST will monitor this SRM over the period of its certification. If substantive surface changes occur that affect the certification before the expiration of this certificate, NIST will notify the purchaser. Registration (see attached sheet) will facilitate notification.

Coordination of the production and the technical measurements leading to the certification of SRM 2461 were performed by A. Zheng, T.B. Renegar, S. Montalvo-Delgado, C. Janicki, J. Villanova, J. Song, T.V. Vorburger and R. Silver of the NIST Semiconductor and Dimensional Metrology Division and R.M. Thompson of the NIST Law Enforcement Standards Office (OLES).

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The master cartridge case was fired at the National Laboratory Center of the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF) [1]. The master cartridge case and the acquisition of reflection optical microscopy images were provided by M.G. Ols of the ATF's National Laboratory Center, Ammendale, MD. SRM 2461 standard cartridge cases were manufactured by Rubert & Co. Ltd., United Kingdom[(1)].

Statistical consultation and evaluation were provided by J. Yen of the NIST Statistical Engineering Division. The programs in the MATLAB [5] software that were used to calculate $ACCF_{\max}$ and D_s were developed by L. Ma and W. Chu, Guest Researchers at NIST.

Support aspects involved in the issuance of this SRM were coordinated through the NIST Measurement Services Division.

NOTICE AND WARNING TO USERS

Storage and Handling: The cartridge cases must be used and kept in a dry and clean environment at temperatures between 10 °C and 30 °C. Touching the surface of the cartridge case with bare hands may cause corrosion on the surface and may damage the topography signatures, and therefore should be avoided. See the Appendix for a "Handling and Cleaning Procedure".

Use: The cartridge cases are circular electro-formed replicas of a cartridge case head with about a 1 mm thickness of pure nickel, cemented to a brass cylinder holder (see Figure 1). Three topography signatures are included on each SRM standard cartridge case surface: breech face impression, firing pin impression, and ejector mark. In order to protect the outer surface of the cartridge case, the diameter of the brass cylinder (about 12.7 mm) is made larger than the diameter of the cartridge case (about 9 mm). The NIST topography measurements were performed with a confocal microscope, and topography images were obtained for the three areas. On the breech face and firing pin areas, the cylindrical axis of the cartridge case was parallel to the optical axis of the microscope. However, for the topography measurement of the ejector marks, the cartridge case was tilted approximately 30° so that the principal surface of the ejector mark was aligned perpendicular to the microscope optical axis as well as possible.

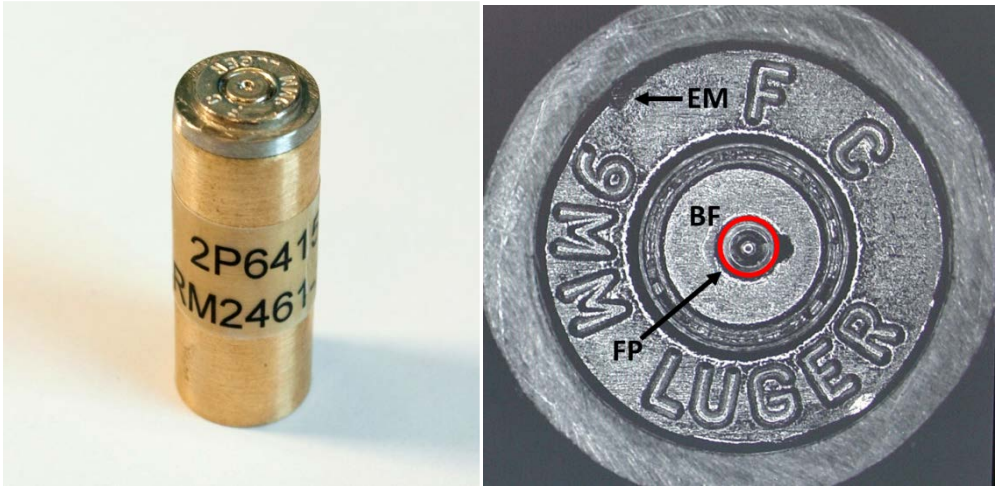


Figure 1. Left – a NIST SRM 2461 Standard Cartridge Case mounted on a brass cylinder holder; right – optical micrograph showing the three certified areas of the SRM, breech face impression (BF), firing pin impression (FP), and ejector mark (EM).

A "User Guide for NIST SRM 2461 Standard Cartridge Cases" is available in the Appendix for customers using the cartridge case to check instrument calibration and measurement quality control of an optical imaging instrument, such as the Integrated Ballistics Identification System (IBIS), for cartridge case signature acquisitions and correlations.

(1) Certain commercial equipment, instrumentation or materials are identified in this certificate to adequately specify the experimental procedure. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

PREPARATION AND ANALYSIS

Electro-Formed Replicas from a Fired Master Cartridge Case: The signature reproducibility of SRM 2461 standard cartridge cases depends on the master cartridge case and on the electro-forming process. In order to ensure that the cartridge cases produced from the same master have virtually the same surface topography signatures, it was necessary to test for differences in the replica surfaces [1]. The results showed that the electro-forming process was stable and was capable of producing a large number of identical surfaces.

Standard and Reference Cartridges Cases: Three standard cartridge cases were selected from a total of 175, with serial numbers (S/N) from 104 to 278, to be used as reference standards. The reference standards for topography correlations are breech face, firing pin, and ejector mark. The breech face signature standard was captured from S/N 155; the firing pin signature standard was captured from S/N 153; and the ejector mark signature standard was captured from S/N 260. In order to evaluate the uniformity and reproducibility of the cartridge case signatures between the distributed standard cartridge cases and the reference standards, two parameters are used to quantify the similarity of a pair of cartridge case topography signatures [1]. One of these is the $ACCF_{\max}$, the maximum value of the areal cross correlation function defined as

$$ACCF_{\max} = \frac{\sum_m \sum_n (\mathbf{A}_{mn} - \overline{\mathbf{A}_{mn}})(\mathbf{B}_{mn} - \overline{\mathbf{B}_{mn}})}{[\sum_m \sum_n (\mathbf{A}_{mn} - \overline{\mathbf{A}_{mn}})^2 \ \sum_m \sum_n (\mathbf{B}_{mn} - \overline{\mathbf{B}_{mn}})^2]^{1/2}}, \tag{1}$$

where the sets of points, A_{mn} and B_{mn}, exclude any data dropouts and outliers [5]. The $ACCF_{\max}$ is the maximum value of the areal cross correlation function *ACCF* [6], which occurs when the image B of the SRM standard cartridge case and the image A of the reference standard are registered at their maximum correlation position.

Before performing the correlation, the topography data are processed by

- locating and interpolating through data dropouts and outliers,
- applying a least squares fit to a second-order polynomial to reduce form error,
- applying a long-wavelength Gaussian filter to further reduce any remaining form and waviness error and applying a short-wavelength Gaussian filter to reduce noise,
- removing the data dropouts and outliers from further analysis,
- registering the two topography images by allowing *x*-*y* translation and *z*-rotation of the compared image until the position of maximum correlation is achieved.

At the maximum correlation position, a difference image Z_{mn} is calculated, which equals the difference between the compared and reference images, B_{mn} and A_{mn}, respectively:

$$Z_{mn} = B_{mn} - A_{mn}. \tag{2}$$

The second parameter, the signature difference, D_s [1], is defined as a ratio of the areal mean-square roughness (Sq^2) [7] of the signature difference image Z to the areal Sq^2 of the reference image A:

$$D_s = Sq^2_{(Z)} \ / \ Sq^2_{(A)}. \tag{3}$$

When the compared image B is exactly the same as the reference image A (point by point), D_s is equal to 0 and $ACCF_{\max}$ must be equal to 100 %.

The $ACCF_{\max}$ and D_s values from the measurements of the 172 standard cartridge cases were statistically analyzed. The results were reported with a confidence level of $\alpha = 95$ % [4]. A total of 137 standard cartridge cases were selected for their high surface quality in all three regions, serial numbers: 106–107, 109–134, 136–137, 140–144, 146–147, 149–152, 156–164, 166, 168, 170, 174–176, 178–179, 181–182, 186–188, 190, 194–197, 199, 201–205, 207–212, 214–216, 218, 220–221, 224–259, 261–263, 266–274, 276–278. For all three regions of the 137 SRM standard cartridge cases being distributed, the lower limit for $ACCF_{\max}$ and upper limit for D_s, each with a 95 % confidence level ($\alpha = 95$ %) are reported in Table 1. To facilitate quantitative comparisons, both the measured topography data and the processed, filtered data for all three regions on the reference standards are available at http://pml.nist.gov/srm2461.

Sources of measurement uncertainty include those from instrument noise, instrument calibration and measurement setup, topography digitization including both the quantization level and sampling interval, image distortion caused by the optical system, errors due to the stitching of three images used for ejector mark and nine images for breech face, and variations from environment and operation setup. All these uncertainty components result in Type A variations in the topography images and result in Type A variations when the cartridge case topography images are correlated with the reference images. Hence, all the uncertainties in the measurement system result in variations of the $ACCF_{\max}$ and D_s parameters for the 137 SRM 2461 standard cartridge cases and are judged to be directly estimated by the observed Type A variations of those parameters.

The NIST measurement system uses a confocal microscope to measure the topography signatures of the breech face impressions, firing pin impressions, and ejector marks. The standard cartridge cases were measured before the processing and registration were applied.

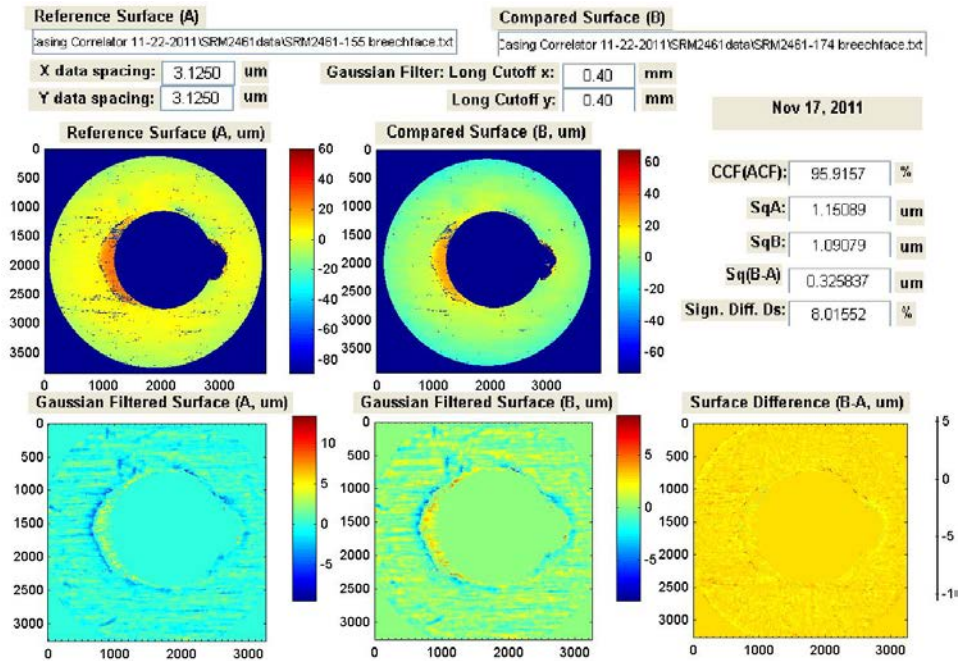


Figure 2. Topography correlation between the breech face images of S/N 155 and S/N 174.

Figure 2 shows a cross correlation between the topography images of the breech face impressions of the reference cartridge case S/N 155 (top, left) and the compared standard cartridge case S/N 174 (top, right). The cutoff filters were moving-average summations representing close approximations to Gaussian weighting functions. The long-wavelength nesting index [8] (cutoff) was 0.4 mm, and the short-wavelength nesting index was 2.5 µm. At the maximum correlation position, the $ACCF_{\max}$ is calculated to be 95.9 %. The topography difference Z is also calculated (see bottom, right), and from it, the signature difference D_s is calculated to be 8.0 %.

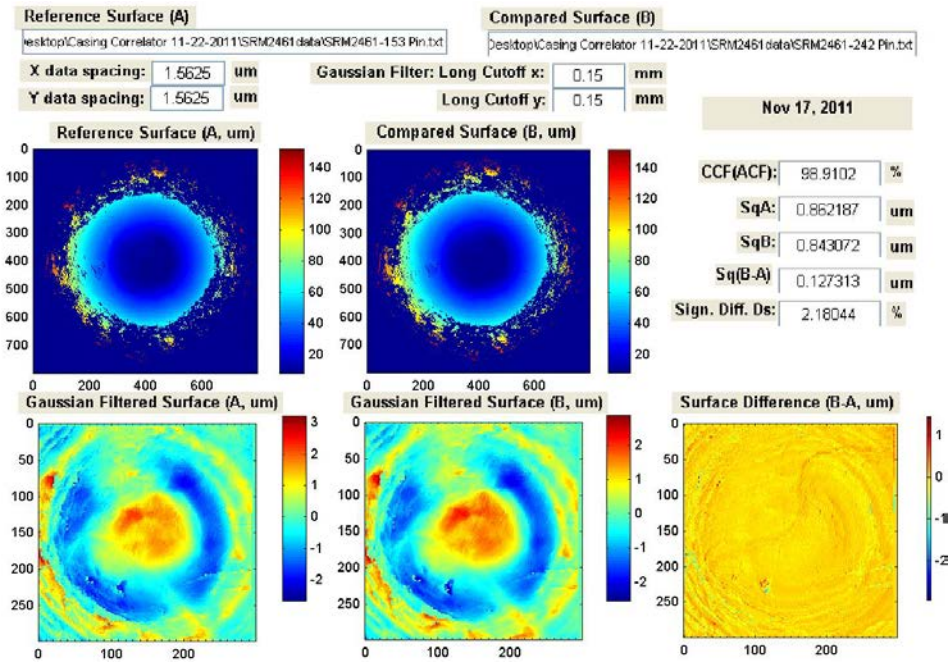


Figure 3. Topography correlation between the firing pin images of S/N 153 and S/N 242.

Figure 3 shows a cross correlation between the topography images of the firing pin impressions of the reference cartridge case S/N 153 (top, left) and the compared standard cartridge case S/N 242 (top, right). The cutoff filters used were moving-average summations representing close approximations to Gaussian weighting functions. The long-wavelength nesting index (cutoff) was 0.15 mm, and the short-wavelength nesting index was 2.5 µm. At the maximum correlation position, the $ACCF_{\max}$ is calculated to be 98.9 %. The topography difference Z is also calculated (see bottom, right), and from it, the signature difference D_s is calculated to be 2.2 %.

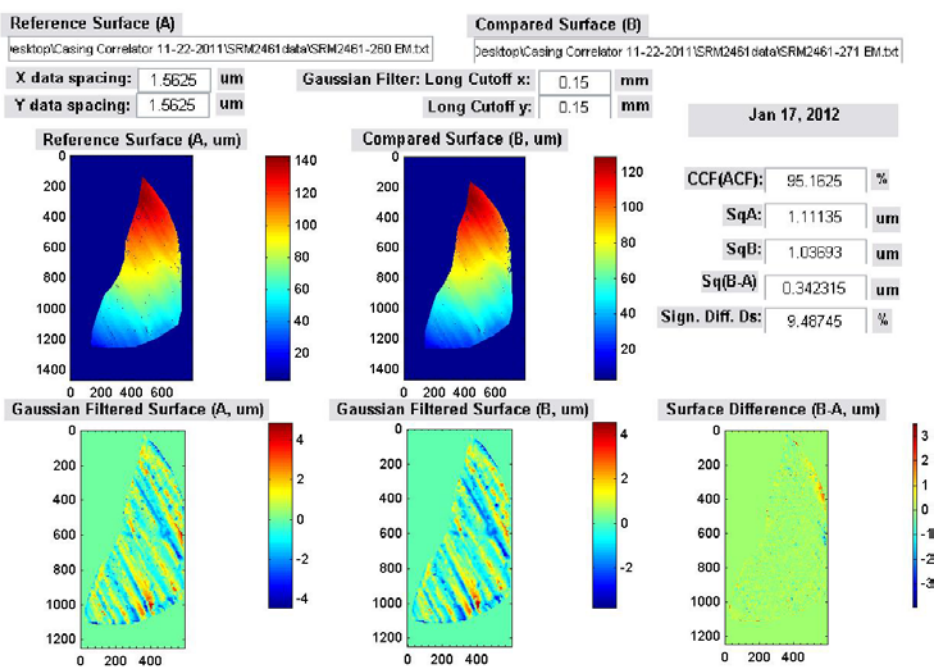


Figure 4. Topography correlation between ejector mark images of S/N 260 and S/N 271.

Figure 4 shows a cross correlation between the topography images of the ejector marks of reference cartridge case S/N 260 (top, left) and the compared standard cartridge case S/N 271 (top, right). The cutoff filters used were moving-average summations representing close approximations to Gaussian weighting functions. The long-wavelength nesting index (cutoff) was 0.15 mm, and the short-wavelength nesting index was 2.5 µm. At the maximum correlation position, the $ACCF_{\max}$ is calculated to be 95.2 %. The topography difference Z is also calculated (see bottom, right), and from it, the signature difference D_s is calculated to be 9.5 %.

REFERENCES

[1] Song, J.; Rubert, P.; Zheng, A.; Vorburger, T.; *Topography Measurements for Determining the Decay Factors in Surface Replication*; Meas. Sci. Technol., Vol. 19**,** 084005 (2008); doi: 10.1088/0957-0233/19/8/084005.

[2] Vorburger, T.V.; Song, J.; Chu, W; Renegar, T.B.; Zheng, A; Yen, J; Thompson, R.M.; Silver, R.M.; Bachrach, B; Ols, M; *Topography Measurements for Correlations of Standard Cartridge Cases*; Proc. SPIE, Vol. 7729, 77291D (2010); doi: 10.1117/12.859918.

[3] Song, J.; Vorburger, T.V.; Ballou, S.; Thompson, R.M.; Yen, J; Renegar, T.B.; Zheng, A; Silver, R.M.; Ols, M; *The National Ballistics Imaging Comparison (NBIC) Project*; Forensic Sci. Int., Vol 216, pp. 168–182 (2012); doi: 10.1016/j.forsciint.2011-09-016.

[4] JCGM 100:2008; *Evaluation of Measurement Data - Guide to the Expression of Uncertainty in Measurement*; (ISO GUM 1995 with Minor Corrections), Joint Committee for Guides in Metrology (JCGM) (2008); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf (accessed June 2012); see also Taylor, B.N.; Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*; NIST Technical Note 1297, U.S. Government Printing Office: Washington, DC (1994); available at http://www.nist.gov/pml/pubs/index.cfm (accessed June 2012).

[5] MATLAB [computer software]; *Function corr2( )*; MathWorks, Inc.; www.mathworks.com (accessed June 2012).

[6] Vorburger, T.V.; Yen, J.; Bachrach, B.; Renegar, T.B.; Filliben, J.J.; Ma, L.; Rhee, H.-G.; Zheng, A.; Song, J.; Riley, M.; Foreman, C.D.; Ballou, S.M.; *Surface Topography Analysis for a Feasibility Assessment of a National Ballistics Imaging Database*; NISTIR 7362; National Institute of Standards and Technology, Gaithersburg, MD (2007); available at http://www.nist.gov/pml/div683/grp02/upload/nistir2007-7362.pdf (accessed June 2012).

[7] ASME B46.1-2009; *Surface Texture (Surface Roughness, Waviness, and Lay)*; Am. Soc. Mech. Eng., New York, NY (2010).

[8] ISO 25178-2:2012; *Geometrical Product Specifications (GPS) — Surface Texture: Areal — Part 2: Terms, Definitions and Surface Texture Parameters*; International Organization for Standardization, Geneva, Switzerland (2012).

Users of this SRM should ensure that the Certificate in their possession is current. This can be accomplished by contacting the SRM Program: telephone (301) 975-0220; fax (301) 948-3730; e-mail srminfo@nist.gov; or via the Internet at http://www.nist.gov/srm.

APPENDIX

USER GUIDE FOR NIST SRM 2461 STANDARD CARTRIDGE CASES

A Draft Data Acquisition Procedure for the Integrated Ballistics Identification System (IBIS)

1. The NIST SRM standard cartridge case is intended for quality testing of automated ballistics signature acquisitions. It is recommended that an acquisition of the standard cartridge cases be entered into IBIS once a month to verify the proper operation of the system. However, you should refer to your own laboratory's policy and procedure guidelines (PPG's) for the frequency of acquisition. The cartridge case should also be entered into the system during each software and hardware upgrade as well as after any scheduled or unscheduled maintenance. All entries and results should be documented.

2. Follow standard procedures from the manufacturer for maintenance and setup of the system and for calibration check at turn on.

3. Procedure for establishing Case Maintenance:
   (EXAMPLE)
   Case ID: Smith/QA/2012-07
   Event Type: Test Fire "TF"
   Law Agency: Unknown
   Date of Occurrence: Date entered into system
   (All other categories may be left blank.)

   Under Case ID, the "Smith" represents the last name of the IBIS user, the "QA" indicates that it is a Quality Assurance test and the "2012-07" represents the year and month that the case is entered into the system. The rest of the case information should be self explanatory.

   Procedure for establishing an Exhibit:
   (EXAMPLE)
   Exhibit ID: SRM 2461-103/TF
   Caliber: 9 mm Luger
   Event Type: "TF"
   (All other categories can be left blank.)

   Under Exhibit info "SRM 2461" indicates the SRM Model, the "103" represents the three-digit serial number associated with the SRM 2461 cartridge case and the "TF" indicates that it is a test fire.

4. Follow the manufacturer's procedure for acquiring a cartridge case. For most conditions, use the same procedure as that for automated imaging of ordinary cartridge cases. However, the following actions are recommended:

5. **Breech Face:**

   - Make sure that the breech face images are optimally focused. Images out-of-focus will likely cause the correlation to drop.

   - The inner and outer diameters of the rings need to be within 0.001 inch (0.0254 mm) of the corresponding diameters for the Golden Image, which are 0.062 inch (inner red ring in Figure A1) and 0.146 inch (outer blue ring), respectively. The ring centering with respect to the inner and outer circumferences is also important.

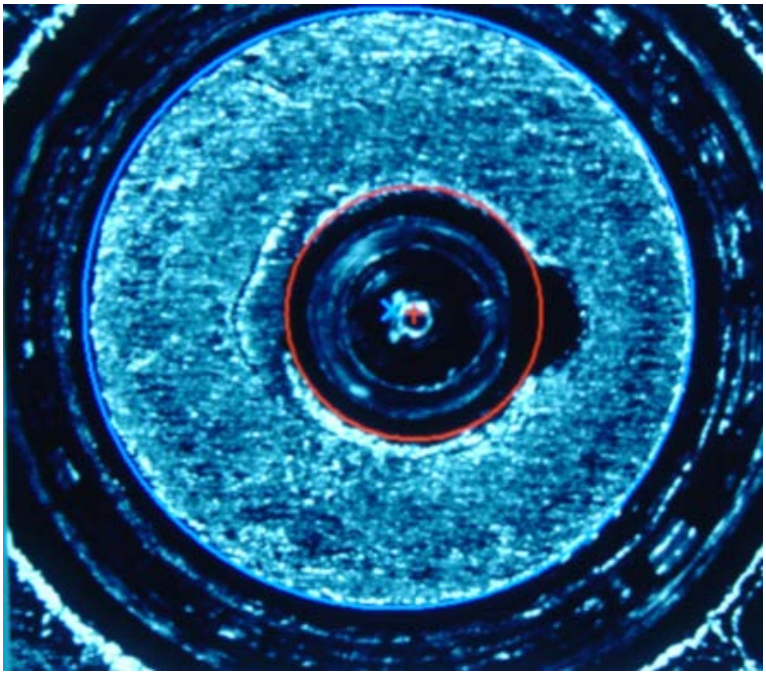


Figure A1. Suggested outer and inner ring placement for breech face. Golden Image ring diameters: Outer ring: 0.146 inch, inner ring: 0.062 inch.

Firing Pin:

- The diameter of the selected area needs to be within 0.001 inch of the corresponding diameter for the Golden Image ring placement, which is 0.062 inch (see Figure A2), that is, in the range 0.061 inch to 0.063 inch. Avoid the mismatch in sizes shown in Figure A3.

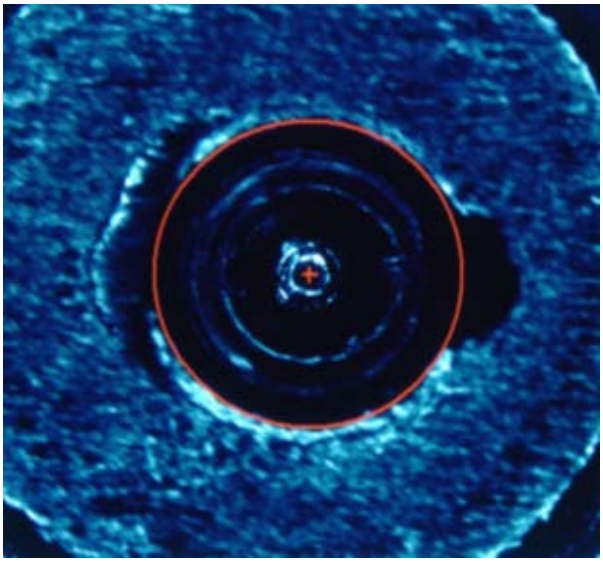
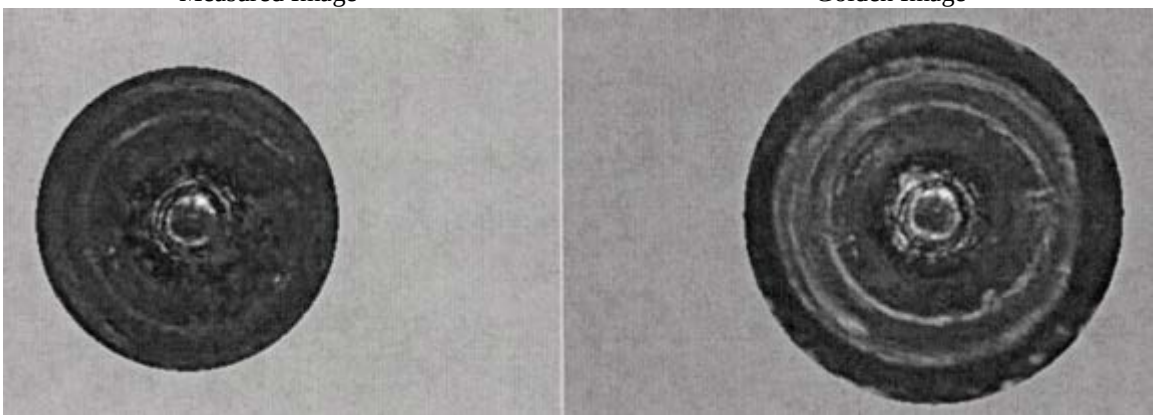


Figure A2. Suggested ring placement for firing pin; diameter: 0.062 inch ± 0.001 inch.

Measured Image | Golden Image



D = 0.051 inch | D = 0.062 inch

Figure A3. Diameter difference in the firing pin correlation may result in a low correlation score.

Ejector Mark:

- Make sure the ejector mark is vertically centered during the measurement and that the rotation is correct. In Figure A4, the ejector mark in the left hand image is positioned too low.

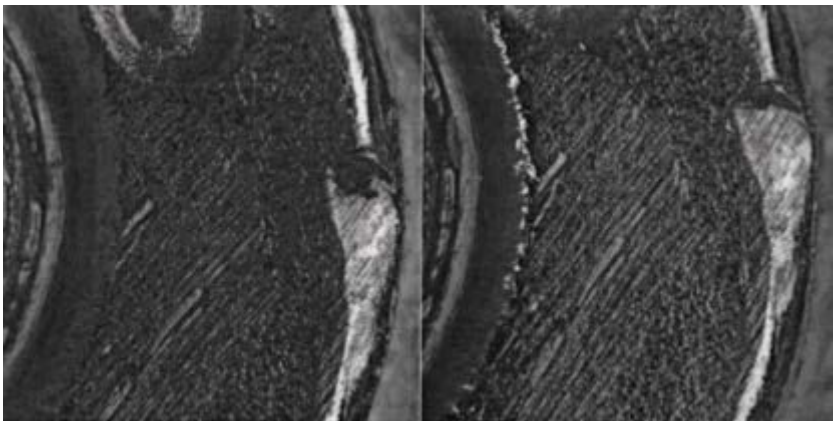


Figure A4. The image on the left shows an ejector mark that is not positioned in the center.

- After acquisition, follow as reasonably closely as possible the outline shown below (see Figure A5).

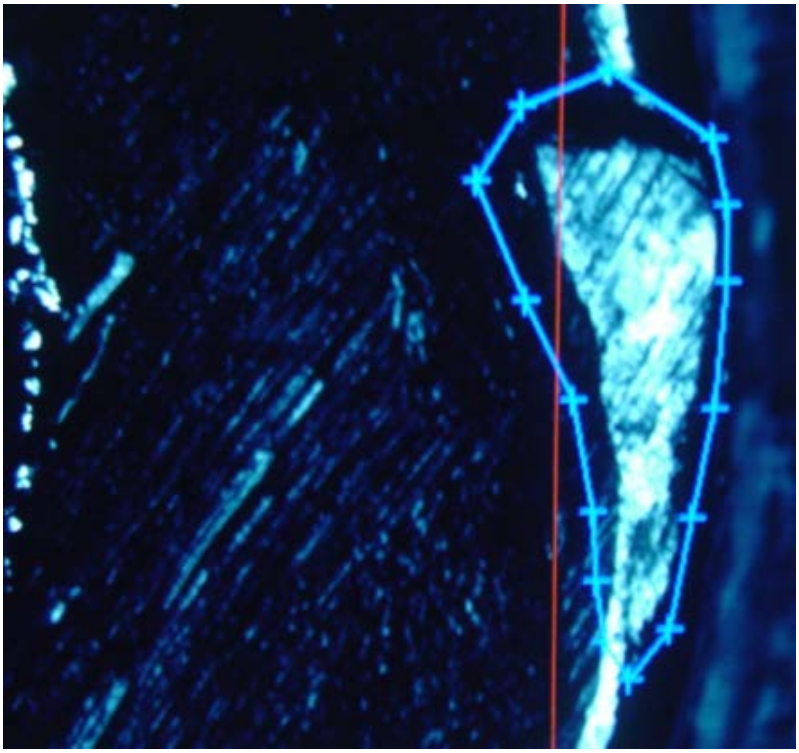


Figure A5. Ejector mark Golden Image.

- Try to set the focus position in the middle of the ejector mark (see Figure A6).

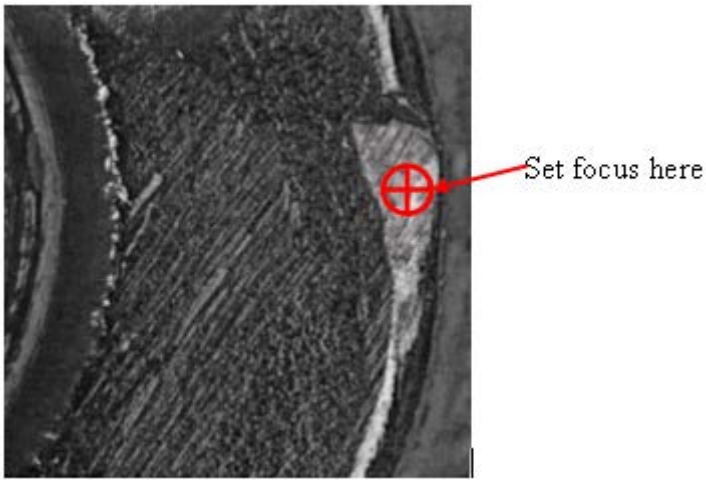


Figure A6. Focus point for ejector mark imaging.

- Make sure to pull the stopper back when measuring the ejector mark (Figure A7).

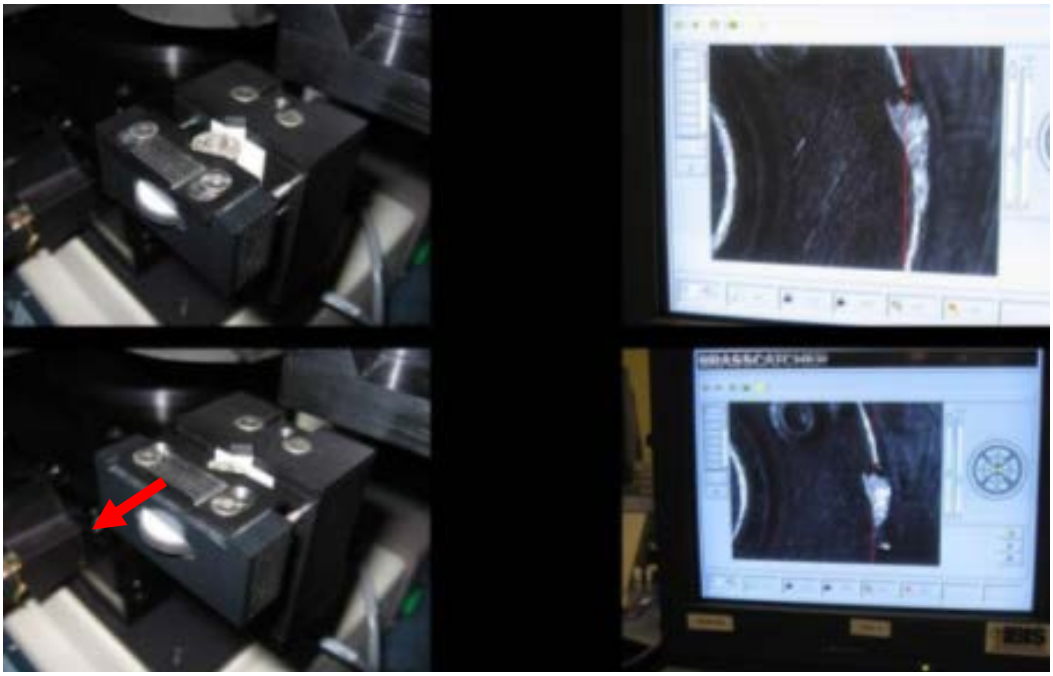


Figure A7. The image on the right, bottom shows the shadowed portion. The stopper needs to be pulled back in this case. The image on the right, top shows the Golden Image with the stopper pulled back and no shadowing.

7. Once the acquisition is completed, a manual correlation of that exhibit needs to be conducted with the region 6 server, where the "Golden Image" resides. Once the correlation has been completed, record the result in the archival records for the laboratory. Once that has been done, delete the Case ID from the system. This will ensure that your case does not get correlated against any future evidence-type cases entered into the system.

8. The correlation scores for the breech face impression, firing pin impression, and ejector mark must all be higher than minimum control values, C_{BF}(SRM 2461), C_{FP}(SRM 2461), C_{EM}(SRM 2461), when compared with the master entry, as calculated with IBIS Software Rev. 3.6. The control value may change in the future as the IBIS software or hardware changes. Start with trial common control values of 214 for breech face, 171 for firing pin, and 400 for ejector mark. Once the local laboratory has established a history of control values, the user may wish to set a control value that is higher than these, consistent with, for example, a 95 % confidence level of achieving the control value.

9. Plot the correlation scores on control charts along with previous scores to indicate the uniformity of the high correlation. If any of the correlation scores drops below the *C* value, flag the results and the date, then double check the alignment and reacquire the cartridge case images.

10. If the correlation score still remains below the *C* value, you may want to have another trained IBIS user enter the cartridge case into the system. If the cartridge case scores at or above the *C* value, then you may have a user issue. If the score is still low, then you may be observing a change in the system performance that needs to be diagnosed. Check the image acquisition procedure. This may include checking the calibration of the IBIS system, as well as the alignment of the cartridge case.

Handling and Cleaning Procedure

The standard cartridge cases are expected to be robust and maintain their quality over many years. However, it is a good procedure to avoid handling the surface of the head in order to avoid unnecessary scratches and finger contamination from marring it. Likewise, cleaning should also be avoided as much as possible because the cleaning process itself can introduce irreversible changes in the surface topography of the cartridge case. If it is clear that contamination has been introduced on the surface to the extent that it has been visibly changed, then a mild cleaning procedure may be used. The suggested procedure is to clean only the contaminated area with a lab swab/cotton tip applicator moistened with ethyl alcohol.