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A COMPARISON OF CYANOACRYLATE FUMING FOLLOWED BY MBD DYE STAINING AND GUN BLUING FOR DEVELOPMENT OF LATENT FINGERPRINTS ON CARTRIDGE CASES

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by
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ABSTRACT

The development of latent fingerprints on cartridge cases is a desirable ability for the forensic laboratory, offering the potential to provide probative evidence as to the handler of whole ammunition or fired cartridge cases discovered at the crime scene. Previous studies have focused primarily on intentionally-laid fingerprints on cartridge case surfaces, which do not represent samples likely to come across the desk of a forensic analyst. This study focuses on naturally-handled ammunition and the success rates associated with latent fingerprints produced in a more realistic set of circumstances. A comparison was performed of two fingerprint development methods—gun bluing and MBD [7-(p-Methoxybenzylamino)-4-Nitrobenz-2-oxa-1, 3-Diazole] dye staining following cyanoacrylate fuming—on two common ammunition types (brass and nickel-plated cartridge cases, caliber 9mm Luger). MBD dye staining showed a slight advantage over gun bluing based on statistical and observational results. Unfired, brass positive controls processed using MBD achieved statistically higher grades ($p<0.001$) than those processed using gun bluing. Gun bluing also entirely failed to yield central ridge detail on unfired brass cartridge cases. Finally, MBD was able to generate of-value fingerprints (grades 3-4) at higher rates than gun bluing in all testing groups that had a nonzero number of valuable fingerprints. For all naturally-handled, case-like samples, only a single of-value fingerprint was obtained using the MBD method on an unfired nickel-plated cartridge case. Based on the results and observations of this study, it is recommended that laboratories do not process 9mm Luger brass or nickel-plated fired cartridge cases for latent fingerprints using the MBD or Gun Bluing methods, and process unfired nickel-plated cartridge cases using the MBD method.

1. INTRODUCTION

1.1. Fingerprint Basics

Development and analysis of latent fingerprints is a key field of forensic pattern analysis, providing a means of identifying individuals who have touched a surface. Such results can be achieved due to the uniqueness of the human fingerprint, which forms during early fetal development. The unique arrangement of friction ridges—the features that make up a fingerprint—is the result of the random pressure and stresses on developing fingers generating an original pattern of ridges and grooves that is unlikely to ever be replicated exactly [1]. The friction ridges that develop are supported by cells in the basal layer of the skin, between the dermis and epidermis, and fingerprints are thought to remain relatively consistent throughout a person's life, barring any permanent damage that reaches the dermis.

Fingerprints contain three levels of detail that are examined during the analysis phase of the fingerprint identification process [1]. The first level describes the pattern of overall ridge flow, which can be categorized into a few common classifications, known as arches, loops, and whorls. The second level describes the path, pattern, and termination of individual ridges. Specific details of a ridge, including bifurcations, dots, and endings, are known as minutiae and are greatly beneficial to fingerprint identification. The third and final level of fingerprint detail includes details of friction ridges such as the arrangement of pores and ridge edge shape. Level three details are not always reproduced in known fingerprints or, when present, may require a microscope for examination. Taken together, the levels of detail provide points for the comparison of developed fingerprints obtained from a crime scene to those of known individuals.

Unknown, unidentified fingerprints can be searched using the Automated Fingerprint Identification System (AFIS) [2].

Latent fingerprints are those left behind anytime an object is touched by an ungloved hand. They are made up of the matrix that is secreted by the skin, which includes water, salts, lipids, and amino acids. This type of fingerprint is typically invisible to the naked eye, but can be developed for examination and comparison. Techniques for developing latent fingerprints are based on either reaction with the fingerprint matrix or with the substrate beneath it. The differential change in appearance between fingerprint matrix and substrate ideally allows the examiner to visualize the friction ridge detail with sufficient contrast to perform comparisons.

1.2. Development of Fingerprints on Cartridge Cases

Development of latent fingerprints on cartridge cases is an area of interest to the forensic field, particularly with the regularity of recovering spent cartridge cases at shooting scenes. It has long been understood that the firing process, involving high levels of pressure, heat, friction, and gaseous blowback, would be strenuous to latent fingerprints placed on cartridge cases [3,4]. Therefore, a technique for developing this type of evidence must be sensitive enough to distinguish fingerprints that may be incomplete, damaged, or degraded.

There is a wide range of procedures for latent fingerprint development that exist, many of these methods developed for examination of specific surface types, such as porous vs nonporous, rough vs smooth, and surface composition (plastic vs rubber vs wood vs metal). The techniques most commonly associated with latent analysis of cartridge cases include: cyanoacrylate fuming, dye staining, gun bluing, and electrolysis (with several other functional techniques being used less frequently due to cost or effectiveness) [4-7]. One advanced technique of note is known as Vacuum Metal Deposition (VMD), which uses metal that has been heated to evaporation to develop fingerprints [8]. Under vacuum pressure, the metal vapor is prevented from reacting with extraneous molecules and allowed to deposit on a surface. The fingerprint matrix causes this development to occur at a slower rate, allowing contrast to develop between the background and the fingerprint ridge details. This technique is extremely sensitive and has shown success, however, was demonstrated to be the less successful method for nickel-plated cartridge cases when compared to a method known as gun bluing (GB) [8]. This study aims to follow up on those results by comparing the more successful gun bluing to another method commonly used for fingerprint development: cyanoacrylate fuming followed by MBD [7-(p-Methoxybenzylamino)-4-Nitrobenz-2-oxa-1, 3-Diazole] dye staining. Cyanoacrylate (or, superglue) fuming is a popular technique for developing latent fingerprints on nonporous surfaces, such as cartridge cases. When superglue is heated, vapors are generated that react with and coat the fingerprint matrix, allowing it to stand out against the background. Most commonly, this technique is followed up with powder or dye stains in order to further the contrast of the fingerprint.

Popular dye stains for developing latent fingerprints on cartridge cases include Rhodamine 6G, Basic Yellow 40, and MBD [9]. These dyes are able to enhance visualization of cyanoacrylate-fumed latent fingerprints by spraying or submerging the area of interest in the dye solution. The gun bluing technique also involves the application of a specific solution to a latent fingerprint, however, the mechanism of development differs in that it reacts with the background. The gun bluing solution contains oxidizing agents that darken metal surfaces. The rate of darkening will be slower where the fingerprint matrix is present, allowing contrast to form between the background and the latent fingerprint. This technique can also be performed following cyanoacrylate fuming.

Cartridge cases come in a number of different surface materials, with brass being the most common in the United States. Development methods reacting with the fingerprint itself, such as dye-staining techniques, are not expected to vary as much between different cartridge case materials, but techniques that react with the background (ie the cartridge case itself), such as gun bluing or VMD, are likely highly influenced by the material type of the surface of the cartridge case, since it is reacting directly. For this reason, research into development of fingerprints on cartridge cases must take into account that, depending on the cartridge case material, the development method determined to be more successful may vary.

2. OBJECTIVES

The purpose of this study will be to perform a comparison of two techniques for developing latent fingerprints on cartridge cases. Of the common techniques for latent fingerprint processing of cartridge cases, gun bluing and cyanoacrylate fuming followed by MBD dye staining were selected for comparison. Data gathered from this study will be used to support whether a significant difference exists between the success of these methods. Both brass and nickel-plated cartridge cases will be analyzed in order to determine the extent to which cartridge case material affects which development method is more ideal.

A primary focus of this study will be to examine latent fingerprints on naturally handled ammunition. Prior research commonly involves the intentional placement of fingerprints on cartridge cases, which is an improbable scenario for evidence examined in case work. Thus, another purpose for this study will be to determine whether cartridge cases handled naturally will gain and retain fingerprints of suitable detail for comparison.

3. MATERIALS AND METHODS

3.1. Materials

Cartridge cases (450 brass, 450 nickel-plated, 900 total) of a single caliber (9mm Luger) were used. The brass cartridge cases used were Remington, 115 grain copper- and brass-jacketed FMJ (Lot # J19RA2A110, J26RA2A110, L10IBA200); and the nickel-plated cartridge cases used were Federal, 124 grain copper-jacketed HST (Lot # F078QP2-F077U06, F284V51). Cartridge cases were designated for either gun bluing or MBD dye staining, and for one of seven testing groups: negative control (both unfired and fired), positive control (both unfired and fired), load/unload, cycled, and fired. The handling of each of these groups is described in the following sections. The amounts of cartridge cases designated to each group are shown in Table 1.

A SIG Sauer Model 229, caliber 9mm Luger, semiautomatic pistol, SN 55B-006-471, was used for cycling and firing of test ammunition. Cartridge cases were collected into 2.5” x 4.25” kraft coin envelopes from Uline (Lot # 00331). Cyanoacrylate fuming was performed using a Misonix fuming chamber, model CA-3000, SN: CA04430810. Amount of cyanoacrylate glue (Evident) used was measured using a TL-series professional digital mini scale into a VWR metal fuming tray. The control used for cyanoacrylate processing was placed on a Globe Scientific glass microscope slide, Lot # A103867-04-052217. Brownell Formula 44/40 Instant

Gun Blue and MBD solutions were supplied by Birchwood Casey and Evident (Lot # 061220), respectively. Alternate light source (ALS) visualization of MBD samples was achieved using a Crime Lite 42S. Photography was performed using a Nikon SLR camera, D3300, SN: 3308618 and a Vivitar Series 1 +10 close up macro lens. ALS photography additionally utilized a Promaster orange YA2 lens filter, 52 mm.

3.2. Pre-development handling and fingerprint placement

3.2.1. Negative Control

Cartridge cases designated to the 'negative control' group were processed immediately out of the box (2 cases per 50-round box), using gloves and tweezers for handling.

3.2.2. Positive Control

Cartridge cases designated to the 'positive control' group were processed following intentional placement of fingerprints. A donor placed fingerprints by rolling an ungloved finger from nailbed to nailbed over the surface of the cartridge case. No other spiking of the intentionally-laid fingerprints occurred. Fingerprints were placed at the shooting range and cartridge cases were collected into individual labeled manila envelopes.

3.2.1. Negative Control, Fired

Cartridge cases designated to the 'negative control, fired' group were loaded into a magazine with gloves, fired, collected into manila envelopes, and processed.

3.2.2. Positive Control, Fired

Cartridge cases designated to the 'positive control, fired' group were loaded into a magazine with gloves and fired. After firing and collection, a donor placed fingerprints by rolling an ungloved finger from nailbed to nailbed over the surface of the cartridge case. The cartridge cases were then repackaged into manila envelopes and processed.

3.2.3. Test Groups

Cartridge cases designated to the 'load/unload,' 'cycled,' and 'fired' groups were naturally handled without gloves and either loaded and unloaded from the magazine, cycled through the firearm without firing, or fired from the firearm, respectively. The donor did not perform any specified actions prior to handling ammunition, but loading, cycling, and firing were performed around the same time of day for each set. Fifteen cycled rounds and forty-five fired rounds were generated at one time each week (up to the total round numbers as specified in the table above), to be processed by the end of that same week. Loaded/Unloaded samples were added onto the above specified sets, and performed in groups of the same type (i.e. all Br, MBD one day and all Ni, GB another). All dates of collecting and processing were recorded.

3.3. Fingerprint development techniques

3.3.1. MBD Procedure

All cartridge cases to be processed under the MBD method were first developed using cyanoacrylate fuming. The amount of superglue used (target 1g) and the actual time of fuming were recorded. Time of fuming was determined using a control fingerprint, which was placed onto a glass microscope slide, and fuming was stopped once this control print began to appear.

The cyanoacrylate fuming process consists of three steps. The first is bringing the chamber to an ideal humidity for latent fingerprint development (80%) [10]. The second step, which is the time recorded, is the fuming step, in which the superglue is heated to a temperature of 160°C, and the vapors come in contact with the cartridge case surfaces. The final step is a fifteen minute purge to allow all fumes to safely exit the chamber before it is opened.

The MBD procedures used followed the guidelines set forth in Virginia DFS Latent Prints Procedure Manual [11], sections 6 and 7, respectively. Cartridge cases were briefly dipped 2-3 times in MBD dye stain (pre-mixed solution), air dried, and examined and photographed.

3.3.2. Gun Bluing Procedure

The gun bluing solution was prepared using Formula 44/40. Into a small beaker, 40 mL of distilled water and ~1 mL of the Formula 44/40 solution were added and stirred until mixed. Each solution was used to process no more than twenty cartridge cases before being discarded so that a fresh solution could be prepared and used.

Cartridge cases were submerged one at a time in the gun bluing solution, which was agitated until the surface of the cartridge case had blackened sufficiently for the development of fingerprints. The amount of time for development is variable, so visual determination of the stopping point was used, and the actual times used for each cartridge case were recorded.

Following development, cartridge cases were submerged briefly in a second beaker containing only distilled water, then allowed to air dry before examination and photography.

3.4. Photography

All processed cartridge cases were photographed using a Nikon 3300 SLR camera. Camera settings that provided the highest quality image were recorded. Some cartridge cases were photographed additional times to capture all surfaces containing potential ridge detail.

3.5. Print Scoring

Fingerprints were graded using a 0-4 scale as described in Table 2. This table was adapted from a previous study [8]. An experienced, secondary analyst verified each score of 1 or above.

3.6. Data Analysis and Interpretation

The Kruskal-Wallis one-way ANOVA (Analysis of Variance) and Mann-Whitney U test for pairwise comparison were performed in PAST 4 and used to assess whether differences between development methods were significant. These tests were run using the mean grade for each material (brass vs nickel-plated), development type (MBD vs GB), and sample type (control vs cycled vs loaded/unloaded vs fired).

ANOVA comparison works by assessing within-group and between-group variation to determine whether significant differences (ie: differences that are not due to random chance) exist between groups. The Kruskal-Wallis test is a nonparametric ANOVA method, meaning it is able to be used on data with skewed distributions or other features that violate the assumptions of the parametric ANOVA. On its own, Kruskal-Wallis compares all samples at once, with a significant result indicating that at least one group is significantly different than the rest. In order to compare two samples at a time (for example, to compare only fired brass samples processed by MBD vs fired brass samples processed by GB), the Mann-Whitney U test is performed. This assessment determines the likelihood that the data found would be observed if there was no difference between the sample groups. A p-value of 0.01 would indicate a low chance (1%) that the differences in data were due to random chance and not due to actual differences between sample groups, indicating that a statistically significant difference likely exists.

3.7. General Process and Challenges

Cartridge cases were fired (or loaded/unloaded or cycled), collected into individual manila envelopes, and processed in batches, with the development technique alternated each week. Cartridge cases were processed the next day for most sample generation sessions, though timing issues forced a few instances to be performed later (though never more than a week post-collection).

The fingerprint donor in this study had to be changed midway through. A brief analysis was performed to assess any discrepancies between results of different fingerprint donors.

4. IMPACT TO THE FIELD

The ability to obtain latent fingerprints from fired cartridge cases is desirable to forensic laboratories. However, a low success rate in development of fingerprints suitable for comparison poses challenges to crime lab efficiency. This study was undertaken to compare two common techniques used in the analysis of fired cartridge cases in order to provide insight to crime labs on which performs more effectively. By examining naturally handled cartridge cases, this project also better reflects the quality of latent print evidence that can be obtained using either gun bluing or MBD dye staining.

5. RESULTS AND DISCUSSION

5.1. Raw Results

Raw data tables including dates, processing details, camera settings, and fingerprint grades can be found in Appendix A. Figure 1 shows representative results from positive and negative controls. Figure 2 shows representative examples of each grade on the 0-4 grading scale.

Figure 1 is composed of the highest quality developed fingerprints generated on each positive control set. These images demonstrate the variability in quality even when fingerprints are intentionally placed and processed on cartridge cases. Some fingerprints showed strong contrast of ridge detail throughout (Figure 1, row 2, column 3), some showed contrast which varied throughout the fingerprint (Figure 1, row 2, column 3 and row 4, column 2), and some showed minimal contrast (Figure 1, row 4, columns 3 & 4). Notably, Gun Bluing on unfired brass cartridge cases was unable to develop central ridge detail, with ridges only visible on the outline of the fingerprint (Figure 1, row 2, column 2). Additionally, the unfired brass controls processed by MBD, as well as some other early MBD samples, were inadvertently over-fumed, the effect of which is blurring of useful ridge detail, which can be seen in Figure 1, row 2, column 1. Because of over-deposition of cyanoacrylate, the spaces between the ridges begin to narrow and fade, producing a low-contrast and blurry-looking fingerprint. Overfumed fingerprint grades were estimated based on the ridge detail that could have been visualized if properly processed.

Figure 2 demonstrates the variety in results seen in case-like (non-control) samples. As shown, a grade of 0 indicates a lack of any development of ridge detail on the cartridge case surface. The grade 0 photographs also show the lack of a consistent background on developed cartridge cases. Without a background of a consistent color and shade, better contrast of the fingerprint from that variable surface is required for a high-quality fingerprint to be developed. A developed fingerprint grade of 1 can range from one or two short ridges being present to a fair amount of ridge detail being present, but overlapping or short enough that comparable information (minutiae points) cannot be gleaned from it. This phenomenon will be discussed in additional detail later. Grades above a 1 were rare in case-like samples, and appeared mostly in unfired samples (cycled or loaded/unloaded). A grade of 2 showed between two and seven minutiae points. This amount is not considered to be sufficient for identification purposes, and fingerprints of this grade demonstrated large voids (lack of ridge detail) in the fingerprint that interrupted assessment of ridge flow. Fingerprints of a grade 3 consist of higher numbers of minutiae points, to a level that could potentially be useful for comparison to a known suspect fingerprint. These fingerprints still contained voids in ridge detail that may potentially interrupt important ridge pattern or information. Finally, grade 4 fingerprints were complete or near-complete fingerprints with apparent and discernible patterns and ridge detail minutiae points throughout. As will become important in later analyses, it should be noted that only grades of 3 or 4 can be considered ‘of value’ in a forensic laboratory setting.

5.2. Statistical Comparison of Development Methods

For the initial processing method comparison, the mean grade of each testing and positive control group was calculated and compared between the two development methods using an ANOVA hypothesis test, followed by a pairwise examination between each group. As described in the methods section, ANOVA assesses within-group and between-group differences to determine the likelihood that sets of data arose from a single population (ie the likelihood of there not being a difference between sample groups). Pairwise comparison extends this examination to look at specific differences that exist between pairs of data to allow for method comparison. Nonparametric methods were used due to the heavily skewed nature of the data (many groups tended to have either mostly grades of 1 and 0, or mostly grades of 2-4, so grades were not normally distributed). These pairwise results are summarized in Tables 3 and 4.

Table 3 presents the results of the method comparison on brass cartridge cases. MBD-processed cases showed higher-value mean grades in all compared groups except for fired test samples. The p-values for fired positive control and fired test samples did not show a statistically significant difference between the processing methods ($p=0.32$ and 0.24, respectively). This makes sense because the difference in mean grades was 0.375 and 0.056, respectively, which both would round to a 0 increase in average grade obtained. Unfired positive controls, on the other hand, had a difference in average grade of 2.75 ($p<0.001$), presenting a statistically significant advantage of the MBD method over the GB method on unfired brass carriage cases.

Table 4 presents the results of the method comparison on nickel-plated cartridge cases. Once again, many samples did not demonstrate statistical significance (Unfired positive controls: $p=0.35$, cycled samples: $p=0.30$, fired positive controls: $p=0.30$). A statistically significant difference was observed for fired test samples, however, the actual difference between the mean grades was only 0.136, suggesting no real average grade increase was observed. It is possible that MBD generated a significantly higher number of grade 1 than grade 0 compared to GB, however, recall that grades of 1 still do not indicate valuable fingerprints, as they lack comparable minutiae points.

To summarize, statistically significant differences between fingerprint development methods ($p<0.001$) appeared in two sample groups (brass unfired positive control samples and nickel-plated fired samples), and indicated MBD dye staining as the likely superior method. As mentioned previously, all other samples either showed insignificant to no differences, or could not be examined using a hypothesis test. Despite statistical significance, the nickel-plated, fired samples cannot be considered scientifically significant, as the mean grade calculated between the development processes (0.16 and 0.024) would both round to an average grade of 0, or no ridge detail present. The other significant result, brass unfired positive control samples, suggests that the MBD development method is a more suitable method for developing fingerprints on unfired brass cartridge cases.

While hypothesis testing mean grades is potentially helpful in the comparison of the two methods, this mean comparison has minimal direct meaning to latent fingerprint casework, in which fingerprints are simply ranked as either “of value” or “not of value” for comparison. From the grade descriptions used in this project, only values of 3 and 4 would be considered “of value” in a laboratory, so the proportion of samples graded 3-4 to all samples of each group are given in Tables 5 and 6. For brass cartridge cases, of-value fingerprints appeared in 100% of unfired positive control cases and 37.5% of fired positive control cases when processed by MBD, compared to 0% and 12.5% for the same groups, respectively, when processed by GB. All other brass samples showed no of-value fingerprints. For nickel-plated cartridge cases, of-value fingerprints appeared in 50% of unfired positive control cases and 50% of fired positive control cases when processed by MBD, compared to 37.5% and 25% for the same groups, respectively, when processed by GB. Only one additional of-value nickel-plated cartridge case was present (among the twenty-five cycled test samples processed by MBD; a 4% chance). It should be noted that the sample sizes for controls was low (eight of each type of control), so percentages in this study may not be indicative of actual chances of success in the forensic laboratory, and should be used only to compare what results did appear in this study.

Based on this assessment of of-value likelihood, it is clear that MBD outperforms gun bluing for the processing of latent fingerprints on cartridge cases in this study. The percent success of generating of-value fingerprints is between 12.5% (in unfired nickel-plated positive controls) and 100% (in unfired brass positive controls) greater for MBD than gun bluing. Thus, MBD is the superior method between the methods examined here. That said, it must be noted that most success occurs on control samples, which are not representative of cartridge cases expected in forensic laboratory casework. Only a single of-value fingerprint was detected on a case-like sample (nickel-plated, cycled, MBD-processed), which suggests an extremely low success rate. Figure 3 shows the of-value case-like sample that was generated. This fingerprint received a grade of 3, showing central ridge flow and a good number of minutiae points, but sides that have apparently been rubbed or scratched away at some point in the process. Therefore, while MBD holds a clear advantage over Gun Bluing, neither method is truly optimized for use in efficient casework.

5.3. Statistical Comparison of Cartridge Case Material

The same type of statistical tests (Kruskal-Wallis ANOVA followed by Mann-Whitney U) were performed to compare whether cartridge case type impacted success of given development methods. The results are summarized in Tables 7 and 8.

For the MBD dye-staining method (Table 7), no statistically significant difference was observed (all p-values > 0.1) between the cartridge case material types. This makes sense because the MBD dye staining and the cyanoacrylate fuming that precedes it are both interacting with the fingerprint matrix itself, not the cartridge case material. While this does not mean there is no chemical interaction occurring between the cartridge case material and the cyanoacrylate or the MBD dye stain, the lack of a statistically significant difference in results suggests that any effect may be negligible.

The gun bluing method showed more variable, potentially significant results (Table 8). Because the gun bluing solution directly reacts with cartridge case material, it is expected to perform differently when the material is changed. Unfired positive controls suggest the method works more effectively on unfired nickel cartridge cases (difference in average grade of 1.125), though the statistical significance of this is somewhat questionable ($p=0.03$). Fired test samples suggest a statistically significant difference between fired nickel-plated versus fired brass samples ($p<0.001$), with the fired brass samples being processed more effectively. This aligns with observational results that gun bluing on nickel-plated cartridge cases was often difficult and took more time. This preliminary assessment suggests that the gun bluing method works better with nickel-plated samples if those samples are unfired, but work better for brass samples if the samples are fired. However, more data should be obtained to fully assess gun bluing's effectiveness on brass versus nickel-plated cartridge cases.

5.4. Observational Results

During early gun blue processing of unfired brass ammunition, positive controls revealed an inability of the gun bluing method to generate ridge detail in the fingerprint, even when the outline of the fingerprint's location could be visualized (See Figure 4). Ridge detail was present along the outline of the fingerprint (Figure 4, row 2, column 1, 2, 4), and occasionally some sporadic areas of central ridges could be observed (Figure 4, row 1, column 1-2), but often only appeared after a long processing time (from 10 minutes up to 35 minutes; much longer than the 30-60 seconds required for other samples types). Because of this, it was determined that attempting to process loaded/unloaded and cycled samples would be superfluous, and it was forgone. If the results observed in this study for unfired brass samples are repeated in other laboratories or studies, it is recommended that the Gun Bluing method not be used for unfired brass cartridge cases.

Processing and analysis of loaded/unloaded and cycled cartridge cases demonstrate an important point regarding the usefulness of cartridge cases as sources for latent fingerprints. As seen throughout Figure 5, ridge detail may be visualized with either method used in this study; however, this ridge detail was often highly overlapping or nonspecific, and thus usually failed to receive a grade above a 1 or 2. This is an especially crucial finding, because it shows the flaw in fingerprint development on cartridge cases does not necessarily lie in the method being used, but rather in how cartridge cases are obtaining latent fingerprints in the first place. Natural handling of ammunition does not appear to be conducive to the laying of a clear, non-overlapping fingerprint. If no potentially-of-value fingerprint is present on a cartridge case to begin with, no amount of development practices will be sufficient for visualizing a usable fingerprint.

5.5. Method Comparison

As discussed previously, the MBD methodology generates more favorable fingerprints on both brass and nickel-plated cartridge cases compared to Gun Bluing, and Gun Bluing fails to render useful ridge detail for unfired samples. In addition to being a less effective method, the Gun Bluing process is highly destructive. Because the Gun Bluing method functions by corroding the surface of the cartridge case, it may destroy valuable toolmark evidence that could have been examined. Even steps to protect the toolmark-bearing surfaces, such as taping cartridge case heads, retain the risk of leaking or leaving behind adhesives over toolmarks. It is thus recommended that the use of Gun Bluing be limited in the laboratory processing of cartridge cases, particularly of those composed of brass. While MBD has more evidence to support its use, showing higher rates of success and less destruction of other evidence, these high success rates appear mostly in non-case-like samples (controls). In casework-like samples (LU, CYC, FIR), only a single of-value fingerprint was detected across every sample group tested, suggesting a still-low success rate for the method's application in the laboratory. Overall, processing of latent fingerprints on cartridge cases may be better achieved with MBD, but further research is required to assess development methods in other circumstances (alternate cartridge case materials/ calibers, alternate methods of handling/loading ammunition, etc). If the trends founds in this and other studies hold, laboratories that are still processing cartridge cases for fingerprints may want to consider whether such processing is of value, given a potentially low likelihood of obtaining probative fingerprint information, as well as the potential damage to probative toolmark information.

5.6. Challenges and limitations

Due to a timing conflict, the fingerprint donor used in this study had to be changed. The change occurred at the near-end of the testing of brass samples, however, some brass samples were still generated by the second donor. Donor fingerprint grades for the testing groups that had been generated partly by both donors were examined statistically in order to examine whether the change in fingerprint donor was likely to influence final results. The results are summarized in Table 9.

Only the gun blued, fired samples demonstrated a slightly statistically significant difference between donor fingerprints ($p=0.01$; the other samples had high p-values of 0.45 and 0.21, or could not be determined due to lack of variance in a testing group). Even with this statistical difference, however, the actual difference between the means of each donor's samples (-0.20) would not reflect a practical increase or decrease in the grade of the average fingerprint. Therefore, it was determined that the data could still be processed as a whole, despite the change in donors. Further research into the effect of fingerprint donors on the effectiveness of development methods on fired cartridge cases could be an avenue of focus for future research.

Several additional challenges arose due to the limited time available to complete this research. Only a few practice runs of each method were performed prior to running samples. Thus, early samples were processed with a lower familiarity with the techniques used than later samples (for example, ideal time for cyanoacrylate fuming). Future research would be improved by ensuring full training of the individual processing samples prior to initiation of research. Additionally, photography techniques also developed over the course of the project, with the most notable change occurring after the purchase of a photo stand, which allowed for more consistency in the quality of photographs taken.

It should also be noted that, while packaging and transport of cartridge cases was performed carefully in an attempt to minimize destruction of latent fingerprint evidence, some smudging of original ridge detail cannot be ruled out. Any moving contact between the latent fingerprint and the packaging material has the potential to remove or render useless an area of the latent fingerprint.

Finally, the setup of this study was designed around natural handling, which is, by nature, variable. It is known that, as fingerprints are left, the matrix remaining on the skin is decreasing, and requires time before it is replenished. This means that cartridge cases loaded later are less likely to bear the same level of ridge detail as those loaded first. This was partially controlled by the study design: samples were spaced out week-by-week such that no more than 3-5 magazines were loaded at one time, which was considered a "reasonably realistic" scenario by the firearm examiner supervising this study. There are many other features contributing to a varying quality of fingerprints, including how long ago an individual washed their hands, how much they were exercising/sweating prior to handling ammunition, what other surfaces is the person touching throughout the day, how much are they touching them, and are those surfaces clean or dirty. Because these factors would not be known to an examiner while deciding whether or not to process an evidentiary cartridge case, the best method for determining success rates of latent fingerprint development on naturally-handled cartridge cases is the continued compilation of a vast amount of data such that it covers as many potential, but still "natural," situations as possible.

6. CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of this research, natural handling of brass and nickel-plated 9mm Luger ammunition does not appear to leave behind fingerprints suitable for analysis, even if high quality development of ridge detail could be achieved. Despite this, a general method comparison could still be performed, showing that MBD held an advantage over Gun Bluing, in terms of both success and being less destructive to cartridge case evidence.

In the situations examined in this study, the development of latent fingerprints on all cartridge case evidence is suggested to potentially be not worth a laboratory's time or resources. Due to the nature of cartridge case surfaces and how ammunition is naturally handled, valuable latent fingerprint detail seems unlikely to be deposited. In the absence of a well-detailed original fingerprint, even the better of the two development methods compared still failed to generate useful results. Based on these findings, processing that is performed in laboratories would be recommended to occur primarily on unfired ammunition, which may be collected from the magazines of recovered firearms at a scene or from a suspect. It would also appear to be more advisable to use the MBD dye staining method in preference to Gun Bluing (other dye staining techniques may also be suitable; however, none were tested within the scope of this research). The benefits of focusing efforts to unfired ammunition is two-fold. Firstly, unfired ammunition has not undergone the firing process, so less initial damage to latent fingerprints is expected. Secondly, unfired ammunition is less likely to hold toolmark evidence from firing that would be destroyed or impaired by the fingerprint development process.

The research reported here is of high value to the forensic science community. Research into latent fingerprint processing of cartridge cases that centers around naturally-handled and case-like samples is required to help provide conclusive, published evidence that speaks to whether processing cartridge cases for latent fingerprints should be performed. This paper and its findings, along with the results of other similarly-designed studies, may ultimately serve to provide forensic laboratories with a scientifically-backed justification to forgo the latent fingerprint processing of cartridge cases, as well as provide forensic experts a source to support making such a decision in the courtroom. Forensic laboratories become more efficient when unhelpful analyses can be avoided. If the body of research into naturally handled cartridge cases demonstrates a continued failure to observe of-value fingerprints, more limited processing of latent fingerprint on cartridge cases should be considered, as it would both decrease the processing time of cartridge case evidence and free the time of latent fingerprint examiners to be put towards more probative casework samples.

There are many areas within this body of research that can and should be examined further. Firstly, this study only analyzed two methods (MBD, GB) and two common ammunition types (nickel-plated 9mm Luger, brass 9mm Luger). With MBD demonstrating the higher potential for fingerprint development, it would be beneficial to analyze its functionality versus other dye staining techniques such as Rhodamine 6G or Basic Yellow 40. Additionally, there are many other types of ammunition that exist, of differing materials and calibers, which could potentially hold higher or lower ability to hold a latent fingerprint. Another field open for exploration involves the examination of different fingerprint donors and different loading techniques. While this research did need to utilize two donors, this was the result of timing challenges, and no rigorous analysis of the effect of fingerprint donor on the success of fingerprint development methods was performed. Importantly, the fingerprint donors in this study also used different methods of loading ammunition into magazines. Donor A pressed ammunition down primarily using the thumb while donor B used primarily the index finger. Based on this observation, the method used for loading ammunition into a magazine (use of thumb vs index finger to press in ammunition) is another factor that potentially contributes to the quality of latent fingerprint left behind. In addition to these, more data should be collected to account for factors that effect how many naturally-placed fingerprints appear, such as how long ago hands were washed, how many magazines are loaded, and amount of exercise performed prior to loading. Once a wide range of circumstances can be researched in-depth, with a focus on naturally-handled case-like sampling, it will become clear which circumstances are best suited for the successful development of latent fingerprints on cartridge cases and which circumstances might result in a laboratory instead focusing its time and efforts elsewhere.

7. REFERENCES

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8. CRITICAL DATA

Table 1. Number of cartridge cases assigned to control and test groups

	Brass 9mm Luger		Nickel-Plated 9mm Luger	
	MBD	GB	MBD	GB
Total Available	450		450	
Negative Control	8	8	8	8
Positive Control	8	8	8	8
Negative Control, Fired	8	8	8	8
Positive Control, Fired	8	8	8	8
Load/Unload	25	0*	25	25
Cycled	25	0*	25	25
Fired	125	125	125	125
Total Used	207	157	207	207

* Due to a control failure on unfired brass cartridge cases using the gun bluing method, load/unload and cycled samples of this type were not generated.

Table 2. Fingerprint Grading Scheme

Grade	Description
0	No print development. No ridge detail
1	Limited ridge detail, minutiae points not visible, pattern cannot be determined
2	Low quality. Visible minutiae points, but not of sufficient quantity for further examination
3	Moderate quality. Pattern is discernible, ridge detail is developed, limited quality by poor contrast or voids in the print
4	High quality. Ridge shape, direction, and detail is developed, spatial relationships are visible, minutiae points are clear. Potentially usable for identification

Figure 1. Positive and Negative Control Results. Br: brass, Ni: nickel-plated, GB: bun glue processed, MBD: MBD dye stain processed, Pos: positive control, Neg: negative control, UF: unfired, F: fired, #: sample number of cartridge case shown.

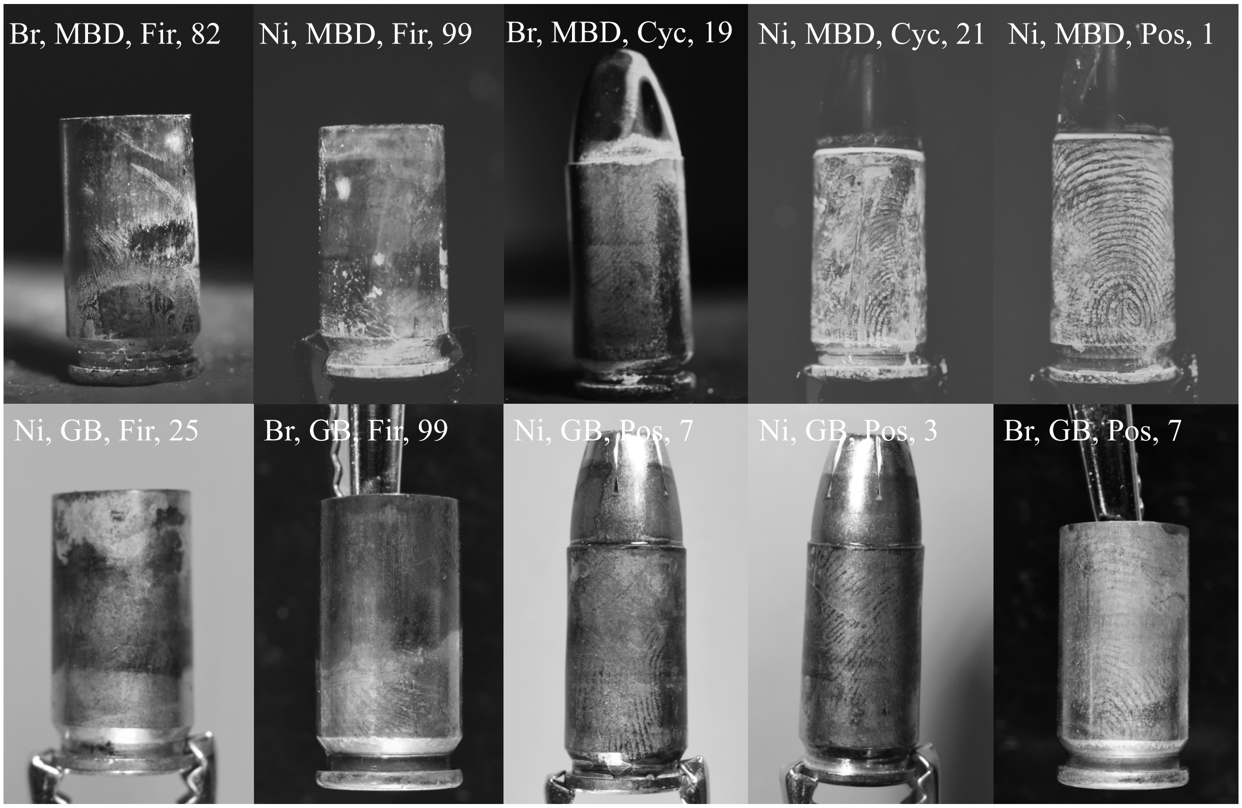

Figure 2. Grading Scale Examples. Top row is of MBD dye-stained samples and bottom row is gun blued samples, both organized 0 to 4 from left to right along the row. Br: brass, Ni: nickel-plated, GB: bun glue processed, MBD: MBD dye stain processed, Fir: fired sample, Cyc: cycled sample, Pos: positive control, #: sample number of cartridge case shown.

Table 3. Comparison of Mean Grades for MBD-processed vs GB-processed Brass Cartridge Cases

BR	MBD	GB	difference	U	p-value
Unfired NEG	0	0	—	—	—
Unfired POS	3.75	1	2.75	0	0.0005
LU	1	NA	—	—	—
CYC	1.08	NA	—	—	—
Fired NEG	0	0	—	—	—
Fired POS	2.125	1.75	0.375	22.5	0.32
FIR	0.192	0.248	-0.056	7328	0.24

Table 4. Comparison of Mean Grades for MBD-processed vs GB-processed Nickel-Plated Cartridge Cases

NI	MBD	GB	difference	U	p-value
Unfired NEG	0	0	—	—	—
Unfired POS	2.75	2.125	0.625	23	0.35
LU	1	1.04	-0.04	—*	—
CYC	1.16	1.04	0.12	287	0.30
Fired NEG	0	0	—	—	—
Fired POS	2.375	1.625	0.75	23	0.30
FIR	0.16	0.024	0.136	6750	0.0002

* Statistical comparison could not be performed due to no variance in one of the testing groups

Table 5. Likelihood of a Grade 3 or 4 for Brass Cartridge Cases

BR	MBD	GB
Unfired NEG	0	0
Unfired POS	8/8 (100%)	0
LU	0	NA
CYC	0	NA
Fired NEG	0	0
Fired POS	3/8 (37.5%)	1/8 (12.5%)
FIR	0	0

Table 6. Likelihood of a Grade 3 or 4 for Nickel-Plated Cartridge Cases

NI	MBD	GB
Unfired NEG	0	0
Unfired POS	4/8 (50%)	3/8 (37.5%)
LU	0	0
CYC	1/25 (4%)	0
Fired NEG	0	0
Fired POS	4/8 (50%)	2/8 (25%)
FIR	0	0

Figure 3. Photo of the of-value case-like sample fingerprint developed in this study. Ni: nickel-plated, MBD: MBD dye stain processed, Cyc: cycled sample, #: sample number of cartridge case shown.

Table 7. Comparison of Mean Grades for MBD-processed Brass Cartridge Cases vs MBD-processed Nickel-Plated Cartridge Cases

MBD	BR	NI	difference	test stat	p-value
Unfired NEG	0	0	—	—	—
Unfired POS	3.75	2.75	1	20	0.16
LU	1	1	—	—	—
CYC	1.08	1.16	-0.08	300	0.70
Fired NEG	0	0	—	—	—
Fired POS	2.125	2.375	-0.25	29.5	0.83
FIR	0.192	0.16	0.032	7615	0.60

Table 8. Comparison of Mean Grades for GB-processed Brass Cartridge Cases vs GB-processed Nickel-Plated Cartridge Cases

GB	BR	NI	difference	test stat	p-value
Unfired NEG	0	0	—	—	—
Unfired POS	1	2.125	-1.125	13	0.03
LU	NA	1.04	—	—	—
CYC	NA	1.04	—	—	—
Fired NEG	0	0	—	—	—
Fired POS	1.75	1.625	0.125	26.5	0.54
FIR	0.248	0.024	0.224	6062.5	2.55E-07

Figure 4. Failure of Gun Bluing Method on Unfired Brass Cartridge Cases. Br: brass, GB: bun glue processed, Pos: positive control, UF: unfired, #: sample number of cartridge case shown.

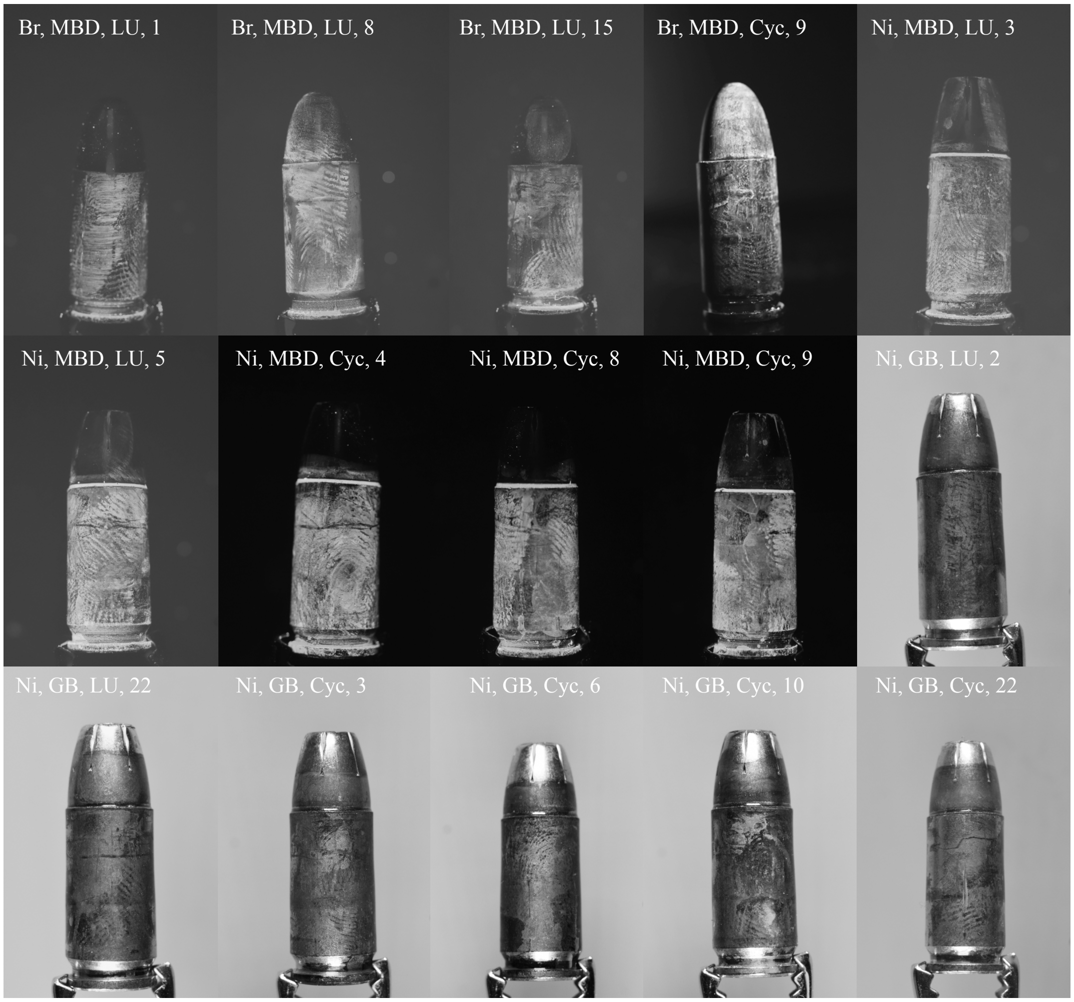

Figure 5. Examples of Overlap Preventing Higher Grades in Loaded/Unloaded and Cycled Samples. All samples shown received a grade of 1 or 2. Br: brass, Ni: nickel-plated, GB: bun glue processed, MBD: MBD dye stain processed, LU: Loaded/Unloaded sample, Cyc: cycled sample, #: sample number of cartridge case shown.

Table 9. Comparison of Mean Grades between Donors of Affected Sample Groups

BR		Donor A	Donor B	difference	U	p-value
MBD	Fired POS	1.83	3	1.17	—*	—
	FIR	0.21	0.14	-0.07	1482.5	0.45
GB	Fired POS	1.25	2.25	1	3.5	0.21
	FIR	0.35	0.15	-0.20	1567.5	0.01

* Statistical comparison could not be performed due to no variance in one of the testing groups

9. VITA

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Appendix A. Raw Data Tables

See Attached Tables on the following pages

Table A1. Results of Brass Cartridge Cases Processed by MBD Dye Staining

Sample Name	Sample #	Date Generated	Date Processed	Lot Number	Glue Used (g)	Time Fumed (min)	Photo ID	ISO	Shutter speed	F-stop	Score (0-4)
Br, Neg, 1	1	3/21/22	3/21/22	J26RA2A110	1.000	3:55	896-897	400	1/1.3	F8	0
Br, Neg, 2	2	3/21/22	3/21/22	J26RA2A110	1.000	3:55	898	400	1/1.3	F8	0
Br, Neg, 3	3	3/21/22	3/21/22	L10IBA200	1.000	3:55	899	400	1/1.3	F8	0
Br, Neg, 4	4	3/21/22	3/21/22	L10IBA200	1.000	3:55	900	400	1/1.3	F8	0
Br, Neg, 5	5	3/21/22	3/21/22	L10IBA200	1.000	3:55	901	400	1/1.3	F8	0
Br, Neg, 6	6	3/21/22	3/21/22	L10IBA200	1.000	3:55	902	400	1/1.3	F8	0
Br, Neg, 7	7	3/21/22	3/21/22	L10IBA200	1.000	3:55	903	400	1/1.3	F8	0
Br, Neg, 8	8	3/21/22	3/21/22	L10IBA200	1.000	3:55	904	400	1/1.3	F8	0
Br, Pos, 1	9	7/12/21	7/12/21	J19RA2A110	1.000	4:40	27	400	bulb	F8	4
Br, Pos, 2	10	7/12/21	7/12/21	J19RA2A110	1.000	4:40	34	400	bulb	F8	4
Br, Pos, 3	11	7/12/21	7/12/21	J19RA2A110	1.000	4:40	35	400	bulb	F8	4
Br, Pos, 4	12	7/12/21	7/12/21	J19RA2A110	1.000	4:40	36, 41	400	bulb	F8	3
Br, Pos, 5	13	7/12/21	7/12/21	J19RA2A110	1.000	4:40	37	400	bulb	F8	3
Br, Pos, 6	14	7/12/21	7/12/21	J19RA2A110	1.000	4:40	38	400	bulb	F8	4
Br, Pos, 7	15	7/12/21	7/12/21	J19RA2A110	1.000	4:40	39	400	bulb	F8	4
Br, Pos, 8	16	7/12/21	7/12/21	J19RA2A110	1.000	4:40	40	400	bulb	F8	4
Br, Neg, 1F	383	7/20/21	7/21/21	J19RA2A110	1.000	5:30	61	400	bulb	F8	0
Br, Neg, 2F	384	7/20/21	7/21/21	J19RA2A110	1.000	5:30	62	400	bulb	F8	0
Br, Neg, 3F	385	8/2/21	8/3/21	J19RA2A110	0.984	5:41	132	400	bulb	F8	0
Br, Neg, 4F	386	8/2/21	8/3/21	J19RA2A110	0.984	5:41	133	400	bulb	F8	0
Br, Neg, 5F	387	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	216	400	bulb	F8	0
Br, Neg, 6F	388	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	217	400	bulb	F8	0
Br, Neg, 7F	389	8/31/21	9/1/21	J19RA2A110	1.000	3:45	308	400	bulb	F8	0
Br, Neg, 8F	390	8/31/21	9/1/21	J19RA2A110	1.000	3:45	309	400	bulb	F8	0
Br, Pos, 1F	391	7/20/21	7/21/21	J19RA2A110	1.000	5:30	59	400	bulb	F8	3
Br, Pos, 2F	392	7/20/21	7/21/21	J19RA2A110	1.000	5:30	60	400	bulb	F8	2
Br, Pos, 3F	393	8/2/21	8/3/21	J19RA2A110	0.984	5:41	130	400	bulb	F8	1
Br, Pos, 4F	394	8/2/21	8/3/21	J19RA2A110	0.984	5:41	131	400	bulb	F8	2
Br, Pos, 5F	395	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	212-214	400	bulb	F8	1
Br, Pos, 6F	396	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	215	400	bulb	F8	2
Br, Pos, 7F	397	8/31/21	9/1/21	J19RA2A110	1.000	3:45	301-304	400	bulb	F8	3
Br, Pos, 8F	398	8/31/21	9/1/21	J19RA2A110	1.000	3:45	305- 307	400	bulb	F8	3
Br, L/U, 1	33	10/14/21	10/15/21	J19RA2A110	1.000	3:00	673	400	1/5	F8	1
Br, L/U, 2	34	10/14/21	10/15/21	J19RA2A110	1.000	3:00	674	400	1/5	F8	1
Br, L/U, 3	35	10/14/21	10/15/21	J19RA2A110	1.000	3:00	675	400	1/5	F8	1
Br, L/U, 4	36	10/14/21	10/15/21	J19RA2A110	1.000	3:00	676	400	1/5	F8	1
Br, L/U, 5	37	10/14/21	10/15/21	J19RA2A110	1.000	3:00	677	400	1/5	F8	1
Br, L/U, 6	38	10/14/21	10/15/21	J19RA2A110	1.000	3:00	678	400	1/5	F8	1
Br, L/U, 7	39	10/14/21	10/15/21	J19RA2A110	1.000	3:00	679	400	1/5	F8	1
Br, L/U, 8	40	10/14/21	10/15/21	J19RA2A110	1.000	3:00	680	400	1/5	F8	1
Br, L/U, 9	41	10/14/21	10/15/21	J19RA2A110	1.000	3:00	681	400	1/5	F8	1
Br, L/U, 10	42	10/14/21	10/15/21	J19RA2A110	1.000	3:00	682	400	1/5	F8	1
Br, L/U, 11	43	10/14/21	10/15/21	J19RA2A110	1.000	3:00	683	400	1/5	F8	1
Br, L/U, 12	44	10/14/21	10/15/21	J19RA2A110	1.000	3:00	684	400	1/5	F8	1
Br, L/U, 13	45	10/14/21	10/15/21	J19RA2A110	1.000	3:00	685	400	1/5	F8	1
Br, L/U, 14	46	10/14/21	10/15/21	J19RA2A110	1.000	3:00	686	400	1/5	F8	1
Br, L/U, 15	47	10/14/21	10/15/21	J19RA2A110	1.000	3:00	687	400	1/5	F8	1
Br, L/U, 16	48	10/14/21	10/15/21	J19RA2A110	1.000	3:00	688	400	1/5	F8	1
Br, L/U, 17	49	10/14/21	10/15/21	J19RA2A110	1.000	3:00	689	400	1/5	F8	1
Br, L/U, 18	50	10/14/21	10/15/21	J19RA2A110	1.000	3:00	690	400	1/5	F8	1
Br, L/U, 19	51	10/14/21	10/15/21	J19RA2A110	1.000	3:00	691	400	1/5	F8	1
Br, L/U, 20	52	10/14/21	10/15/21	J19RA2A110	1.000	3:00	692	400	1/5	F8	1
Br, L/U, 21	53	10/14/21	10/15/21	J19RA2A110	1.000	3:00	693	400	1/5	F8	1
Br, L/U, 22	54	10/14/21	10/15/21	J19RA2A110	1.000	3:00	694	400	1/5	F8	1
Br, L/U, 23	55	10/14/21	10/15/21	J19RA2A110	1.000	3:00	695	400	1/5	F8	1
Br, L/U, 24	56	10/14/21	10/15/21	J19RA2A110	1.000	3:00	696	400	1/5	F8	1
Br, L/U, 25	57	10/14/21	10/15/21	J19RA2A110	1.000	3:00	697	400	1/5	F8	1
Br, Cyc, 1	83	7/20/21	7/21/21	J19RA2A110	1.000	5:30	49	400	bulb	F8	2
Br, Cyc, 2	84	7/20/21	7/21/21	J19RA2A110	1.000	5:30	50	400	bulb	F8	1
Br, Cyc, 3	85	7/20/21	7/21/21	J19RA2A110	1.000	5:30	51	400	bulb	F8	1
Br, Cyc, 4	86	7/20/21	7/21/21	J19RA2A110	1.000	5:30	52	400	bulb	F8	1
Br, Cyc, 5	87	7/20/21	7/21/21	J19RA2A110	1.000	5:30	53	400	bulb	F8	1
Br, Cyc, 6	88	7/20/21	7/21/21	J19RA2A110	1.000	5:30	54	400	bulb	F8	1
Br, Cyc, 7	89	7/20/21	7/21/21	J19RA2A110	1.000	5:30	55	400	bulb	F8	1
Br, Cyc, 8	90	7/20/21	7/21/21	J19RA2A110	1.000	5:30	56	400	bulb	F8	0
Br, Cyc, 9	91	7/20/21	7/21/21	J19RA2A110	1.000	5:30	57	400	bulb	F8	2
Br, Cyc, 10	92	7/20/21	7/21/21	J19RA2A110	1.000	5:30	58	400	bulb	F8	1
Br, Cyc, 11	93	8/2/21	8/3/21	J19RA2A110	0.984	5:41	164	400	bulb	F8	1
Br, Cyc, 12	94	8/2/21	8/3/21	J19RA2A110	0.984	5:41	165	400	bulb	F8	1
Br, Cyc, 13	95	8/2/21	8/3/21	J19RA2A110	0.984	5:41	166, 167	400	bulb	F8	1

Br, Cyc, 14	96	8/2/21	8/3/21	J19RA2A110	0.984	5:41	168	400	bulb	F8	1
Br, Cyc, 15	97	8/2/21	8/3/21	J19RA2A110	0.984	5:41	169	400	bulb	F8	1
Br, Cyc, 16	98	8/2/21	8/3/21	J19RA2A110	0.984	5:41	170	400	bulb	F8	1
Br, Cyc, 17	99	8/2/21	8/3/21	J19RA2A110	0.984	5:41	171	400	bulb	F8	1
Br, Cyc, 18	100	8/2/21	8/3/21	J19RA2A110	0.984	5:41	172, 173	400	bulb	F8	1
Br, Cyc, 19	101	8/2/21	8/3/21	J19RA2A110	0.984	5:41	174	400	bulb	F8	2
Br, Cyc, 20	102	8/2/21	8/3/21	J19RA2A110	0.984	5:41	175, 176	400	bulb	F8	1
Br, Cyc, 21	103	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	218	400	bulb	F8	1
Br, Cyc, 22	104	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	219, 220	400	bulb	F8	1
Br, Cyc, 23	105	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	221	400	bulb	F8	1
Br, Cyc, 24	106	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	222	400	bulb	F8	1
Br, Cyc, 25	107	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	223	400	blb	F8	1
Br, Fir, 1	133	7/20/21	7/21/21	J19RA2A110	1.000	5:30	63	400	bulb	F8	0
Br, Fir, 2	134	7/20/21	7/21/21	J19RA2A110	1.000	5:30	64	400	bulb	F8	0
Br, Fir, 3	135	7/20/21	7/21/21	J19RA2A110	1.000	5:30	65	400	bulb	F8	0
Br, Fir, 4	136	7/20/21	7/21/21	J19RA2A110	1.000	5:30	66	400	bulb	F8	0
Br, Fir, 5	137	7/20/21	7/21/21	J19RA2A110	1.000	5:30	67	400	bulb	F8	0
Br, Fir, 6	138	7/20/21	7/21/21	J19RA2A110	1.000	5:30	68	400	bulb	F8	1
Br, Fir, 7	139	7/20/21	7/21/21	J19RA2A110	1.000	5:30	69	400	bulb	F8	0
Br, Fir, 8	140	7/20/21	7/21/21	J19RA2A110	1.000	5:30	70	400	bulb	F8	0
Br, Fir, 9	141	7/20/21	7/21/21	J19RA2A110	1.000	5:30	71	400	bulb	F8	1
Br, Fir, 10	142	7/20/21	7/21/21	J19RA2A110	1.000	5:30	72	400	bulb	F8	1
Br, Fir, 11	143	7/20/21	7/21/21	J19RA2A110	1.000	5:30	73	400	bulb	F8	0
Br, Fir, 12	144	7/20/21	7/21/21	J19RA2A110	1.000	5:30	74	400	bulb	F8	0
Br, Fir, 13	145	7/20/21	7/21/21	J19RA2A110	1.000	5:30	75	400	bulb	F8	0
Br, Fir, 14	146	7/20/21	7/21/21	J19RA2A110	1.000	5:30	76	400	bulb	F8	0
Br, Fir, 15	147	7/20/21	7/21/21	J19RA2A110	1.000	5:30	77	400	bulb	F8	0
Br, Fir, 16	148	7/20/21	7/21/21	J19RA2A110	1.000	5:30	78	400	bulb	F8	0
Br, Fir, 17	149	7/20/21	7/21/21	J19RA2A110	1.000	5:30	79	400	bulb	F8	0
Br, Fir, 18	150	7/20/21	7/21/21	J19RA2A110	1.000	5:30	80	400	bulb	F8	0
Br, Fir, 19	151	7/20/21	7/21/21	J19RA2A110	1.000	5:30	81	400	bulb	F8	0
Br, Fir, 20	152	7/20/21	7/21/21	J19RA2A110	1.000	5:30	82	400	bulb	F8	1
Br, Fir, 21	153	7/20/21	7/21/21	J19RA2A110	1.000	5:30	83	400	bulb	F8	0
Br, Fir, 22	154	7/20/21	7/21/21	J19RA2A110	1.000	5:30	84	400	bulb	F8	1
Br, Fir, 23	155	7/20/21	7/21/21	J19RA2A110	1.000	5:30	85	400	bulb	F8	0
Br, Fir, 24	156	7/20/21	7/21/21	J19RA2A110	1.000	5:30	86	400	bulb	F8	0
Br, Fir, 25	157	7/20/21	7/21/21	J19RA2A110	1.000	5:30	87	400	bulb	F8	1
Br, Fir, 26	158	7/20/21	7/21/21	J19RA2A110	1.000	5:30	88	400	bulb	F8	1
Br, Fir, 27	159	7/20/21	7/21/21	J19RA2A110	1.000	5:30	89	400	bulb	F8	0
Br, Fir, 28	160	7/20/21	7/21/21	J19RA2A110	1.000	5:30	90	400	bulb	F8	0
Br, Fir, 29	161	7/20/21	7/21/21	J19RA2A110	1.000	5:30	91	400	bulb	F8	0
Br, Fir, 30	162	7/20/21	7/21/21	J19RA2A110	1.000	5:30	92	400	bulb	F8	0
Br, Fir, 31	163	8/2/21	8/3/21	J19RA2A110	0.984	5:41	134	400	bulb	F8	0
Br, Fir, 32	164	8/2/21	8/3/21	J19RA2A110	0.984	5:41	135	400	bulb	F8	1
Br, Fir, 33	165	8/2/21	8/3/21	J19RA2A110	0.984	5:41	136	400	bulb	F8	0
Br, Fir, 34	166	8/2/21	8/3/21	J19RA2A110	0.984	5:41	137	400	bulb	F8	0
Br, Fir, 35	167	8/2/21	8/3/21	J19RA2A110	0.984	5:41	138	400	bulb	F8	0
Br, Fir, 36	168	8/2/21	8/3/21	J19RA2A110	0.984	5:41	139	400	bulb	F8	0
Br, Fir, 37	169	8/2/21	8/3/21	J19RA2A110	0.984	5:41	140	400	bulb	F8	0
Br, Fir, 38	170	8/2/21	8/3/21	J19RA2A110	0.984	5:41	141	400	bulb	F8	0
Br, Fir, 39	171	8/2/21	8/3/21	J19RA2A110	0.984	5:41	142	400	bulb	F8	0
Br, Fir, 40	172	8/2/21	8/3/21	J19RA2A110	0.984	5:41	143	400	bulb	F8	0
Br, Fir, 41	173	8/2/21	8/3/21	J19RA2A110	0.984	5:41	144	400	bulb	F8	2
Br, Fir, 42	174	8/2/21	8/3/21	J19RA2A110	0.984	5:41	145	400	bulb	F8	0
Br, Fir, 43	175	8/2/21	8/3/21	J19RA2A110	0.984	5:41	146	400	bulb	F8	0
Br, Fir, 44	176	8/2/21	8/3/21	J19RA2A110	0.984	5:41	147	400	bulb	F8	0
Br, Fir, 45	177	8/2/21	8/3/21	J19RA2A110	0.984	5:41	148	400	bulb	F8	0
Br, Fir, 46	178	8/2/21	8/3/21	J19RA2A110	0.984	5:41	149	400	bulb	F8	0
Br, Fir, 47	179	8/2/21	8/3/21	J19RA2A110	0.984	5:41	150	400	bulb	F8	0
Br, Fir, 48	180	8/2/21	8/3/21	J19RA2A110	0.984	5:41	151	400	bulb	F8	1
Br, Fir, 49	181	8/2/21	8/3/21	J19RA2A110	0.984	5:41	152	400	bulb	F8	0
Br, Fir, 50	182	8/2/21	8/3/21	J19RA2A110	0.984	5:41	153	400	bulb	F8	0
Br, Fir, 51	183	8/2/21	8/3/21	J19RA2A110	0.984	5:41	154	400	bulb	F8	0
Br, Fir, 52	184	8/2/21	8/3/21	J19RA2A110	0.984	5:41	155	400	bulb	F8	1
Br, Fir, 53	185	8/2/21	8/3/21	J19RA2A110	0.984	5:41	156	400	bulb	F8	0
Br, Fir, 54	186	8/2/21	8/3/21	J19RA2A110	0.984	5:41	157	400	bulb	F8	0
Br, Fir, 55	187	8/2/21	8/3/21	J19RA2A110	0.984	5:41	158	400	bulb	F8	0
Br, Fir, 56	188	8/2/21	8/3/21	J19RA2A110	0.984	5:41	159	400	bulb	F8	0
Br, Fir, 57	189	8/2/21	8/3/21	J19RA2A110	0.984	5:41	160	400	bulb	F8	0
Br, Fir, 58	190	8/2/21	8/3/21	J19RA2A110	0.984	5:41	161	400	bulb	F8	0
Br, Fir, 59	191	8/2/21	8/3/21	J19RA2A110	0.984	5:41	162	400	bulb	F8	0

Br, Fir, 60	192	8/2/21	8/3/21	J19RA2A110	0.984	5:41	163	400	bulb	F8	1
Br, Fir, 61	193	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	224	400	bulb	F8	0
Br, Fir, 62	194	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	225, 226	400	bulb	F8	0
Br, Fir, 63	195	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	227	400	bulb	F8	1
Br, Fir, 64	196	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	228	400	bulb	F8	1
Br, Fir, 65	197	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	229	400	bulb	F8	0
Br, Fir, 66	198	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	230	400	bulb	F8	0
Br, Fir, 67	199	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	231	400	bulb	F8	0
Br, Fir, 68	200	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	232	400	bulb	F8	0
Br, Fir, 69	201	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	233	400	bulb	F8	0
Br, Fir, 70	202	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	234, 235	400	bulb	F8	0
Br, Fir, 71	203	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	236	400	bulb	F8	0
Br, Fir, 72	204	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	237	400	bulb	F8	0
Br, Fir, 73	205	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	238	400	bulb	F8	0
Br, Fir, 74	206	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	239	400	bulb	F8	0
Br, Fir, 75	207	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	240	400	bulb	F8	0
Br, Fir, 76	208	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	241	400	bulb	F8	0
Br, Fir, 77	209	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	242	400	bulb	F8	1
Br, Fir, 78	210	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	243	400	bulb	F8	1
Br, Fir, 79	211	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	244	400	bulb	F8	0
Br, Fir, 80	212	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	245	400	bulb	F8	0
Br, Fir, 81	213	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	246	400	bulb	F8	0
Br, Fir, 82	214	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	247	400	bulb	F8	0
Br, Fir, 83	215	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	248	400	bulb	F8	0
Br, Fir, 84	216	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	249	400	bulb	F8	0
Br, Fir, 85	217	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	250	400	bulb	F8	0
Br, Fir, 86	218	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	251	400	bulb	F8	0
Br, Fir, 87	219	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	252	400	bulb	F8	0
Br, Fir, 88	220	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	253	400	bulb	F8	1
Br, Fir, 89	221	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	254	400	bulb	F8	0
Br, Fir, 90	222	8/17/21	8/20/21*	J19RA2A110	0.918	4:04	255	400	bulb	F8	1
Br, Fir, 91	223	8/31/21	9/1/21	J19RA2A110	1.000	3:45	310	400	bulb	F8	0
Br, Fir, 92	224	8/31/21	9/1/21	J19RA2A110	1.000	3:45	311	400	bulb	F8	0
Br, Fir, 93	225	8/31/21	9/1/21	J19RA2A110	1.000	3:45	312	400	bulb	F8	1
Br, Fir, 94	226	8/31/21	9/1/21	J19RA2A110	1.000	3:45	313	400	bulb	F8	0
Br, Fir, 95	227	8/31/21	9/1/21	J19RA2A110	1.000	3:45	314	400	bulb	F8	0
Br, Fir, 96	228	8/31/21	9/1/21	J19RA2A110	1.000	3:45	315	400	bulb	F8	1
Br, Fir, 97	229	8/31/21	9/1/21	J19RA2A110	1.000	3:45	316	400	bulb	F8	0
Br, Fir, 98	230	8/31/21	9/1/21	J19RA2A110	1.000	3:45	317	400	bulb	F8	0
Br, Fir, 99	231	8/31/21	9/1/21	J19RA2A110	1.000	3:45	318	400	bulb	F8	0
Br, Fir, 100	232	8/31/21	9/1/21	J19RA2A110	1.000	3:45	319	400	bulb	F8	1
Br, Fir, 101	233	8/31/21	9/1/21	J19RA2A110	1.000	3:45	320	400	bulb	F8	0
Br, Fir, 102	234	8/31/21	9/1/21	J19RA2A110	1.000	3:45	321	400	bulb	F8	0
Br, Fir, 103	235	8/31/21	9/1/21	J19RA2A110	1.000	3:45	322	400	bulb	F8	0
Br, Fir, 104	236	8/31/21	9/1/21	J19RA2A110	1.000	3:45	323	400	bulb	F8	0
Br, Fir, 105	237	8/31/21	9/1/21	J19RA2A110	1.000	3:45	324	400	bulb	F8	0
Br, Fir, 106	238	8/31/21	9/1/21	J19RA2A110	1.000	3:45	325	400	bulb	F8	0
Br, Fir, 107	239	8/31/21	9/1/21	J19RA2A110	1.000	3:45	326	400	bulb	F8	0
Br, Fir, 108	240	8/31/21	9/1/21	J19RA2A110	1.000	3:45	327	400	bulb	F8	0
Br, Fir, 109	241	8/31/21	9/1/21	J19RA2A110	1.000	3:45	328	400	bulb	F8	0
Br, Fir, 110	242	8/31/21	9/1/21	J19RA2A110	1.000	3:45	329	400	bulb	F8	1
Br, Fir, 111	243	8/31/21	9/1/21	J19RA2A110	1.000	3:45	330	400	bulb	F8	0
Br, Fir, 112	244	8/31/21	9/1/21	J19RA2A110	1.000	3:45	331	400	bulb	F8	0
Br, Fir, 113	245	8/31/21	9/1/21	J19RA2A110	1.000	3:45	332	400	bulb	F8	0
Br, Fir, 114	246	8/31/21	9/1/21	J19RA2A110	1.000	3:45	333	400	bulb	F8	0
Br, Fir, 115	247	8/31/21	9/1/21	J19RA2A110	1.000	3:45	334	400	bulb	F8	0
Br, Fir, 116	248	8/31/21	9/1/21	J19RA2A110	1.000	3:45	335	400	bulb	F8	0
Br, Fir, 117	249	8/31/21	9/1/21	J19RA2A110	1.000	3:45	336	400	bulb	F8	1
Br, Fir, 118	250	8/31/21	9/1/21	J19RA2A110	1.000	3:45	337	400	bulb	F8	0
Br, Fir, 119	251	8/31/21	9/1/21	J19RA2A110	1.000	3:45	338	400	bulb	F8	0
Br, Fir, 120	252	8/31/21	9/1/21	J19RA2A110	1.000	3:45	339	400	bulb	F8	0
Br, Fir, 121	253	8/31/21	9/1/21	J19RA2A110	1.000	3:45	340	400	bulb	F8	0
Br, Fir, 122	254	8/31/21	9/1/21	J19RA2A110	1.000	3:45	341	400	bulb	F8	0
Br, Fir, 123	255	8/31/21	9/1/21	J19RA2A110	1.000	3:45	342	400	bulb	F8	0
Br, Fir, 124	256	8/31/21	9/1/21	J19RA2A110	1.000	3:45	343	400	bulb	F8	0
Br, Fir, 125	257	8/31/21	9/1/21	J19RA2A110	1.000	3:45	344, 345	400	bulb	F8	0

* Note: samples processed on 8/20/21 were photographed on 8/22/21

Table A2. Results of Brass Cartridge Cases Processed by Gun Bluing

Sample Name	Sample #	Date Generated	Date Processed	Lot Number	Time GB (s)	Photo ID	ISO	Shutter speed	F-stop	Score (0-4)
Br, Neg, 1	17	3/21/22	3/21/22	J26RA2A110	42	877-879	400	1/1.6	F13	0
Br, Neg, 2	18	3/21/22	3/21/22	J26RA2A110	32	880-881	400	1/1.6	F13	0
Br, Neg, 3	19	3/21/22	3/21/22	J26RA2A110	37	882	400	1/1.6	F13	0
Br, Neg, 4	20	3/21/22	3/21/22	J26RA2A110	40	883	400	1/1.6	F13	0
Br, Neg, 5	21	3/21/22	3/21/22	J26RA2A110	41	884	400	1/1.6	F13	0
Br, Neg, 6	22	3/21/22	3/21/22	J26RA2A110	31	885	400	1/1.6	F13	0
Br, Neg, 7	23	3/21/22	3/21/22	J26RA2A110	31	886	400	1/1.6	F13	0
Br, Neg, 8	24	3/21/22	3/21/22	J26RA2A110	37	887	400	1/1.6	F13	0
Br, Pos, 1	25	7/12/21	7/12/21	J19RA2A110	1494	24	400	bulb	11	1
Br, Pos, 2	26	7/12/21	7/12/21	J19RA2A110	2126	25	400	bulb	11	1
Br, Pos, 3	27	7/12/21	7/16/21	J26RA2A110	1609	42	400	bulb	11	1
Br, Pos, 4	28	7/12/21	7/16/21	J26RA2A110	1633	43	400	bulb	11	0
Br, Pos, 5	29	7/12/21	7/16/21	J19RA2A110	1160	44	400	bulb	11	1
Br, Pos, 6	30	7/12/21	7/16/21	J19RA2A110	1292	45	400	bulb	11	1
Br, Pos, 7	31	7/12/21	7/16/21	J19RA2A110	1097	46	400	bulb	11	1
Br, Pos, 8	32	7/12/21	7/16/21	J19RA2A110	694	47, 48	400	bulb	11	2
Br, Neg, 1F	399	7/30/21	7/31/21	J19RA2A110	48	97	400	bulb	11	0
Br, Neg, 2F	400	7/30/21	7/31/21	J19RA2A110	45	98	400	bulb	11	0
Br, Neg, 3F	401	8/10/21	8/12/21	J26RA2A110	33	179	400	bulb	11	0
Br, Neg, 4F	402	8/10/21	8/12/21	J26RA2A110	34	180	400	bulb	11	0
Br, Neg, 5F	403	8/26/21	8/27/21	J19RA2A110	34	259	400	bulb	11	0
Br, Neg, 6F	404	8/26/21	8/27/21	J19RA2A110	35	260	400	bulb	11	0
Br, Neg, 7F	405	9/7/21	9/8/21	J19RA2A110	35	353	400	1/5	22	0
Br, Neg, 8F	406	9/7/21	9/8/21	J19RA2A110	35	354	400	1/5	22	0
Br, Pos, 1F	407	7/30/21	7/31/21	J19RA2A110	105	93, 94	400	bulb	11	1
Br, Pos, 2F	408	7/30/21	7/31/21	J19RA2A110	95	95, 96	400	bulb	11	1
Br, Pos, 3F	409	8/10/21	8/12/21	J26RA2A110	27	177	400	bulb	11	1
Br, Pos, 4F	410	8/10/21	8/12/21	J26RA2A110	49	178	400	bulb	11	2
Br, Pos, 5F	411	8/26/21	8/27/21	J19RA2A110	30	256-257, 291-292	400	bulb	11	2
Br, Pos, 6F	412	8/26/21	8/27/21	J19RA2A110	40	258, 293-294	400	bulb	11	1
Br, Pos, 7F	413	9/7/21	9/8/21	J19RA2A110	32	351	400	1/5	22	4
Br, Pos, 8F	414	9/7/21	9/8/21	J19RA2A110	29	352	400	1/5	22	2
Br, L/U, 1	58	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 2	59	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 3	60	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 4	61	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 5	62	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 6	63	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 7	64	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 8	65	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 9	66	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 10	67	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 11	68	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 12	69	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 13	70	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 14	71	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 15	72	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 16	73	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 17	74	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 18	75	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 19	76	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 20	77	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 21	78	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 22	79	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 23	80	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 24	81	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, L/U, 25	82	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 1	108	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 2	109	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 3	110	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 4	111	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 5	112	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 6	113	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 7	114	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 8	115	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 9	116	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 10	117	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 11	118	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 12	119	NA	NA	NA	NA	NA	NA	NA	NA	NA

Br, Cyc, 13	120	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 14	121	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 15	122	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 16	123	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 17	124	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 18	125	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 19	126	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 20	127	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 21	128	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 22	129	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 23	130	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 24	131	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Cyc, 25	132	NA	NA	NA	NA	NA	NA	NA	NA	NA
Br, Fir, 1	258	7/30/21	7/31/21	J19RA2A110	46	99	400	bulb	11	0
Br, Fir, 2	259	7/30/21	7/31/21	J19RA2A110	62	100	400	bulb	11	0
Br, Fir, 3	260	7/30/21	7/31/21	J19RA2A110	41	101	400	bulb	11	1
Br, Fir, 4	261	7/30/21	7/31/21	J19RA2A110	57	102	400	bulb	11	0
Br, Fir, 5	262	7/30/21	7/31/21	J19RA2A110	51	103	400	bulb	11	0
Br, Fir, 6	263	7/30/21	7/31/21	J19RA2A110	34	104	400	bulb	11	1
Br, Fir, 7	264	7/30/21	7/31/21	J19RA2A110	49	105	400	bulb	11	1
Br, Fir, 8	265	7/30/21	7/31/21	J19RA2A110	49	106	400	bulb	11	1
Br, Fir, 9	266	7/30/21	7/31/21	J19RA2A110	41	107	400	bulb	11	0
Br, Fir, 10	267	7/30/21	7/31/21	J19RA2A110	30	108	400	bulb	11	1
Br, Fir, 11	268	7/30/21	7/31/21	J19RA2A110	37	109	400	bulb	11	1
Br, Fir, 12	269	7/30/21	7/31/21	J19RA2A110	50	110	400	bulb	11	0
Br, Fir, 13	270	7/30/21	7/31/21	J19RA2A110	43	111	400	bulb	11	0
Br, Fir, 14	271	7/30/21	7/31/21	J19RA2A110	41	112	400	bulb	11	1
Br, Fir, 15	272	7/30/21	7/31/21	J19RA2A110	35	113	400	bulb	11	1
Br, Fir, 16	273	7/30/21	7/31/21	J19RA2A110	41	114	400	bulb	11	0
Br, Fir, 17	274	7/30/21	7/31/21	J19RA2A110	52	115	400	bulb	11	0
Br, Fir, 18	275	7/30/21	7/31/21	J19RA2A110	29	116	400	bulb	11	1
Br, Fir, 19	276	7/30/21	7/31/21	J19RA2A110	41	117	400	bulb	11	0
Br, Fir, 20	277	7/30/21	7/31/21	J19RA2A110	37	118	400	bulb	11	0
Br, Fir, 21	278	7/30/21	7/31/21	J19RA2A110	30	119	400	bulb	11	0
Br, Fir, 22	279	7/30/21	7/31/21	J19RA2A110	47	120	400	bulb	11	0
Br, Fir, 23	280	7/30/21	7/31/21	J19RA2A110	48	121	400	bulb	11	0
Br, Fir, 24	281	7/30/21	7/31/21	J19RA2A110	29	122	400	bulb	11	1
Br, Fir, 25	282	7/30/21	7/31/21	J19RA2A110	38	123	400	bulb	11	1
Br, Fir, 26	283	7/30/21	7/31/21	J19RA2A110	44	124	400	bulb	11	0
Br, Fir, 27	284	7/30/21	7/31/21	J19RA2A110	42	125	400	bulb	11	0
Br, Fir, 28	285	7/30/21	7/31/21	J19RA2A110	49	126, 127	400	bulb	11	1
Br, Fir, 29	286	7/30/21	7/31/21	J19RA2A110	42	128	400	bulb	11	0
Br, Fir, 30	287	7/30/21	7/31/21	J19RA2A110	30	129	400	bulb	11	1
Br, Fir, 31	288	8/10/21	8/12/21	J26RA2A110	33	181	400	bulb	11	1
Br, Fir, 32	289	8/10/21	8/12/21	J26RA2A110	35	182	400	bulb	11	0
Br, Fir, 33	290	8/10/21	8/12/21	J26RA2A110	39	183	400	bulb	11	0
Br, Fir, 34	291	8/10/21	8/12/21	J26RA2A110	36	184	400	bulb	11	0
Br, Fir, 35	292	8/10/21	8/12/21	J26RA2A110	27	185	400	bulb	11	0
Br, Fir, 36	293	8/10/21	8/12/21	J26RA2A110	35	186	400	bulb	11	0
Br, Fir, 37	294	8/10/21	8/12/21	J26RA2A110	39	187	400	bulb	11	0
Br, Fir, 38	295	8/10/21	8/12/21	J26RA2A110	26	188	400	bulb	11	0
Br, Fir, 39	296	8/10/21	8/12/21	J26RA2A110	39	189	400	bulb	11	0
Br, Fir, 40	297	8/10/21	8/12/21	J26RA2A110	44	190	400	bulb	11	0
Br, Fir, 41	298	8/10/21	8/12/21	J26RA2A110	40	191	400	bulb	11	0
Br, Fir, 42	299	8/10/21	8/12/21	J26RA2A110	40	192	400	bulb	11	0
Br, Fir, 43	300	8/10/21	8/12/21	J26RA2A110	33	193	400	bulb	11	0
Br, Fir, 44	301	8/10/21	8/12/21	J26RA2A110	35	194	400	bulb	11	1
Br, Fir, 45	302	8/10/21	8/12/21	J26RA2A110	32	195	400	bulb	11	0
Br, Fir, 46	303	8/10/21	8/12/21	J26RA2A110	31	196	400	bulb	11	0
Br, Fir, 47	304	8/10/21	8/12/21	J26RA2A110	34	197	400	bulb	11	0
Br, Fir, 48	305	8/10/21	8/12/21	J26RA2A110	33	198	400	bulb	11	1
Br, Fir, 49	306	8/10/21	8/12/21	J26RA2A110	38	199	400	bulb	11	0
Br, Fir, 50	307	8/10/21	8/12/21	J26RA2A110	34	200	400	bulb	11	1
Br, Fir, 51	308	8/10/21	8/12/21	J26RA2A110	34	201	400	bulb	11	0
Br, Fir, 52	309	8/10/21	8/12/21	J26RA2A110	32	202	400	bulb	11	0
Br, Fir, 53	310	8/10/21	8/12/21	J26RA2A110	35	203	400	bulb	11	0
Br, Fir, 54	311	8/10/21	8/12/21	J26RA2A110	43	204	400	bulb	11	0
Br, Fir, 55	312	8/10/21	8/12/21	J26RA2A110	32	205	400	bulb	11	1
Br, Fir, 56	313	8/10/21	8/12/21	J26RA2A110	31	206	400	bulb	11	0
Br, Fir, 57	314	8/10/21	8/12/21	J26RA2A110	37	207	400	bulb	11	0

Br, Fir, 58	315	8/10/21	8/12/21	J26RA2A110	34	208	400	bulb	11	1
Br, Fir, 59	316	8/10/21	8/12/21	J26RA2A110	36	209	400	bulb	11	1
Br, Fir, 60	317	8/10/21	8/12/21	J26RA2A110	26	210	400	bulb	11	1
Br, Fir, 61	318	8/26/21	8/27/21	J19RA2A110	38	261, 295	400	bulb	11	1
Br, Fir, 62	319	8/26/21	8/27/21	J19RA2A110	43	262, 296	400	bulb	11	1
Br, Fir, 63	320	8/26/21	8/27/21	J19RA2A110	30	263, 297	400	bulb	11	0
Br, Fir, 64	321	8/26/21	8/27/21	J19RA2A110	34	264	400	bulb	11	0
Br, Fir, 65	322	8/26/21	8/27/21	J19RA2A110	31	265	400	bulb	11	0
Br, Fir, 66	323	8/26/21	8/27/21	J19RA2A110	34	266	400	bulb	11	0
Br, Fir, 67	324	8/26/21	8/27/21	J19RA2A110	32	267	400	bulb	11	1
Br, Fir, 68	325	8/26/21	8/27/21	J19RA2A110	34	268	400	bulb	11	0
Br, Fir, 69	326	8/26/21	8/27/21	J19RA2A110	36	269	400	bulb	11	0
Br, Fir, 70	327	8/26/21	8/27/21	J19RA2A110	31	270	400	bulb	11	0
Br, Fir, 71	328	8/26/21	8/27/21	J19RA2A110	34	271	400	bulb	11	1
Br, Fir, 72	329	8/26/21	8/27/21	J19RA2A110	32	272	400	bulb	11	0
Br, Fir, 73	330	8/26/21	8/27/21	J19RA2A110	33	273, 298	400	bulb	11	0
Br, Fir, 74	331	8/26/21	8/27/21	J19RA2A110	33	274, 299	400	bulb	11	0
Br, Fir, 75	332	8/26/21	8/27/21	J19RA2A110	31	275, 300	400	bulb	11	0
Br, Fir, 76	333	8/26/21	8/27/21	J19RA2A110	30	276	400	bulb	11	0
Br, Fir, 77	334	8/26/21	8/27/21	J19RA2A110	35	277	400	bulb	11	0
Br, Fir, 78	335	8/26/21	8/27/21	J19RA2A110	31	278	400	bulb	11	0
Br, Fir, 79	336	8/26/21	8/27/21	J19RA2A110	33	279	400	bulb	11	0
Br, Fir, 80	337	8/26/21	8/27/21	J19RA2A110	32	280	400	bulb	11	0
Br, Fir, 81	338	8/26/21	8/27/21	J19RA2A110	33	281	400	bulb	11	0
Br, Fir, 82	339	8/26/21	8/27/21	J19RA2A110	35	282	400	bulb	11	0
Br, Fir, 83	340	8/26/21	8/27/21	J19RA2A110	38	283	400	bulb	11	0
Br, Fir, 84	341	8/26/21	8/27/21	J19RA2A110	32	284	400	bulb	11	0
Br, Fir, 85	342	8/26/21	8/27/21	J19RA2A110	33	285	400	bulb	11	0
Br, Fir, 86	343	8/26/21	8/27/21	J19RA2A110	26	286	400	bulb	11	0
Br, Fir, 87	344	8/26/21	8/27/21	J19RA2A110	34	287	400	bulb	11	0
Br, Fir, 88	345	8/26/21	8/27/21	J19RA2A110	40	288	400	bulb	11	0
Br, Fir, 89	346	8/26/21	8/27/21	J19RA2A110	34	289	400	bulb	11	0
Br, Fir, 90	347	8/26/21	8/27/21	J19RA2A110	32	290	400	bulb	11	0
Br, Fir, 91	348	9/7/21	9/8/21	J19RA2A110	34	355	400	1/5	22	0
Br, Fir, 92	349	9/7/21	9/8/21	J19RA2A110	38	356	400	1/5	22	1
Br, Fir, 93	350	9/7/21	9/8/21	J19RA2A110	34	357, 358	400	1/6	22	1
Br, Fir, 94	351	9/7/21	9/8/21	J19RA2A110	40	359, 360	400	1/2.5	22	0
Br, Fir, 95	352	9/7/21	9/8/21	J19RA2A110	39	361	400	1/2.5	22	0
Br, Fir, 96	353	9/7/21	9/8/21	J19RA2A110	32	362	400	1/2.5	22	0
Br, Fir, 97	354	9/7/21	9/8/21	J19RA2A110	31	363	400	1/2.5	22	0
Br, Fir, 98	355	9/7/21	9/8/21	J19RA2A110	31	364	400	1/2.5	22	1
Br, Fir, 99	356	9/7/21	9/8/21	J19RA2A110	38	365	400	1/2.5	22	1
Br, Fir, 100	357	9/7/21	9/8/21	J19RA2A110	38	366	400	1/2.5	22	0
Br, Fir, 101	358	9/7/21	9/8/21	J19RA2A110	36	367, 368	400	1/2.5	22	0
Br, Fir, 102	359	9/7/21	9/8/21	J19RA2A110	32	369	400	1/2.5	22	0
Br, Fir, 103	360	9/7/21	9/8/21	J19RA2A110	39	370	400	1/2.5	22	0
Br, Fir, 104	361	9/7/21	9/8/21	J19RA2A110	39	371-373	400	1/2.5	22	0
Br, Fir, 105	362	9/7/21	9/8/21	J19RA2A110	34	374	400	1/1.6	22	0
Br, Fir, 106	363	9/7/21	9/8/21	J19RA2A110	37	375	400	1/2	22	0
Br, Fir, 107	364	9/7/21	9/8/21	J19RA2A110	39	376	400	1/2	22	0
Br, Fir, 108	365	9/7/21	9/8/21	J19RA2A110	32	377	400	1/2	22	1
Br, Fir, 109	366	9/7/21	9/8/21	J19RA2A110	30	378	400	1/2	22	0
Br, Fir, 110	367	9/7/21	9/8/21	J19RA2A110	39	379	400	1/2	22	0
Br, Fir, 111	368	9/7/21	9/8/21	J19RA2A110	33	380	400	1/2	22	0
Br, Fir, 112	369	9/7/21	9/8/21	J19RA2A110	32	381	400	1/2	22	0
Br, Fir, 113	370	9/7/21	9/8/21	J19RA2A110	35	382, 383	400	1/2	22	0
Br, Fir, 114	371	9/7/21	9/8/21	J19RA2A110	37	384	400	1/2	22	0
Br, Fir, 115	372	9/7/21	9/8/21	J19RA2A110	41	385, 386	400	1/2	22	0
Br, Fir, 116	373	9/7/21	9/8/21	J19RA2A110	35	387, 388	400	1/2	22	0
Br, Fir, 117	374	9/7/21	9/8/21	J19RA2A110	37	389	400	1/3	22	0
Br, Fir, 118	375	9/7/21	9/8/21	J19RA2A110	42	390	400	1/3	22	0
Br, Fir, 119	376	9/7/21	9/8/21	J19RA2A110	38	391	400	1/3	22	0
Br, Fir, 120	377	9/7/21	9/8/21	J19RA2A110	37	392	400	1/3	22	0
Br, Fir, 121	378	9/7/21	9/8/21	J19RA2A110	49	393	400	1/3	22	0
Br, Fir, 122	379	9/7/21	9/8/21	J19RA2A110	41	394, 395	400	1/4	22	1
Br, Fir, 123	380	9/7/21	9/8/21	J19RA2A110	40	396	400	1/4	22	0
Br, Fir, 124	381	9/7/21	9/8/21	J19RA2A110	40	397	400	1/4	22	0
Br, Fir, 125	382	9/7/21	9/8/21	J19RA2A110	37	398	400	1/4	22	0

Table A3. Results of Nickel-Plated Cartridge Cases Processed by MBD Dye Staining

Sample Name	Sample #	Date Generated	Date Processed	Lot Number	Glue Used (g)	Time Fumed (min)	Photo ID	ISO	Shutter speed	F-stop	Score (0-4)
Ni, Neg, 1	1	3/21/22	3/21/22	F284V51	1.000	3:55	905	400	1/1.3	F8	0
Ni, Neg, 2	2	3/21/22	3/21/22	F284V51	1.000	3:55	906	400	1/1.3	F8	0
Ni, Neg, 3	3	3/21/22	3/21/22	F284V51	1.000	3:55	907	400	1/1.3	F8	0
Ni, Neg, 4	4	3/21/22	3/21/22	F284V51	1.000	3:55	908	400	1/1.3	F8	0
Ni, Neg, 5	5	3/21/22	3/21/22	F284V51	1.000	3:55	909	400	1/1.3	F8	0
Ni, Neg, 6	6	3/21/22	3/21/22	F284V51	1.000	3:55	910	400	1/1.3	F8	0
Ni, Neg, 7	7	3/21/22	3/21/22	F284V51	1.000	3:55	911	400	1/1.3	F8	0
Ni, Neg, 8	8	3/21/22	3/21/22	F284V51	1.000	3:55	912	400	1/1.3	F8	0
Ni, Pos, 1	9	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	630	400	1/5	F8	4
Ni, Pos, 2	10	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	631	400	1/5	F8	2
Ni, Pos, 3	11	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	632	400	1/5	F8	4
Ni, Pos, 4	12	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	633	400	1/5	F8	4
Ni, Pos, 5	13	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	764	400	1/5	F8	1
Ni, Pos, 6	14	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	765	400	1/5	F8	1
Ni, Pos, 7	15	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	766	400	1/5	F8	2
Ni, Pos, 8	16	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	767	400	1/5	F8	4
Ni, Neg, 1F	383	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	401	400	1/5	F8	0
Ni, Neg, 2F	384	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	402	400	1/5	F8	0
Ni, Neg, 3F	385	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	534	400	1/5	F8	0
Ni, Neg, 4F	386	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	535	400	1/5	F8	0
Ni, Neg, 5F	387	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	634	400	1/5	F8	0
Ni, Neg, 6F	388	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	635	400	1/5	F8	0
Ni, Neg, 7F	389	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	636	400	1/5	F8	0
Ni, Neg, 8F	390	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	637	400	1/5	F8	0
Ni, Pos, 1F	391	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	399	400	1/5	F8	4
Ni, Pos, 2F	392	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	400	400	1/5	F8	4
Ni, Pos, 3F	393	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	532	400	1/5	F8	4
Ni, Pos, 4F	394	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	533	400	1/5	F8	3
Ni, Pos, 5F	395	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	768	400	1/5	F8	1
Ni, Pos, 6F	396	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	769	400	1/5	F8	1
Ni, Pos, 7F	397	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	770	400	1/5	F8	1
Ni, Pos, 8F	398	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	771	400	1/5	F8	1
Ni, L/U, 1	33	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	808	400	1/5	F8	1
Ni, L/U, 2	34	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	809	400	1/5	F8	1
Ni, L/U, 3	35	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	810	400	1/5	F8	1
Ni, L/U, 4	36	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	811	400	1/5	F8	1
Ni, L/U, 5	37	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	812-813	400	1/5	F8	1
Ni, L/U, 6	38	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	814	400	1/5	F8	1
Ni, L/U, 7	39	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	815	400	1/5	F8	1
Ni, L/U, 8	40	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	816	400	1/5	F8	1
Ni, L/U, 9	41	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	817	400	1/5	F8	1
Ni, L/U, 10	42	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	818	400	1/5	F8	1
Ni, L/U, 11	43	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	819	400	1/5	F8	1
Ni, L/U, 12	44	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	820	400	1/5	F8	1
Ni, L/U, 13	45	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	821	400	1/5	F8	1
Ni, L/U, 14	46	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	822	400	1/5	F8	1
Ni, L/U, 15	47	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	823	400	1/5	F8	1
Ni, L/U, 16	48	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	824	400	1/5	F8	1
Ni, L/U, 17	49	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	825	400	1/5	F8	1
Ni, L/U, 18	50	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	826	400	1/5	F8	1
Ni, L/U, 19	51	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	827	400	1/5	F8	1
Ni, L/U, 20	52	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	828	400	1/5	F8	1
Ni, L/U, 21	53	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	829	400	1/5	F8	1
Ni, L/U, 22	54	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	830	400	1/5	F8	1
Ni, L/U, 23	55	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	831	400	1/5	F8	1
Ni, L/U, 24	56	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	832	400	1/5	F8	1
Ni, L/U, 25	57	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	833	400	1/5	F8	1
Ni, Cyc, 1	83	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	443-446	400	1/5	F8	1
Ni, Cyc, 2	84	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	447-450	400	1/5	F8	1
Ni, Cyc, 3	85	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	451-454	400	1/5	F8	2
Ni, Cyc, 4	86	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	455-458	400	1/5	F8	1
Ni, Cyc, 5	87	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	459-462	400	1/5	F8	1
Ni, Cyc, 6	88	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	463-466	400	1/5	F8	1
Ni, Cyc, 7	89	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	467-470	400	1/5	F8	1
Ni, Cyc, 8	90	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	471-474	400	1/5	F8	1
Ni, Cyc, 9	91	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	475-478	400	1/5	F8	1
Ni, Cyc, 10	92	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	479-482	400	1/5	F8	1
Ni, Cyc, 11	93	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	566-567	400	1/5	F8	1
Ni, Cyc, 12	94	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	568	400	1/5	F8	1
Ni, Cyc, 13	95	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	569	400	1/5	F8	1
Ni, Cyc, 14	96	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	570	400	1/5	F8	1

Ni, Cyc, 15	97	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	571	400	1/5	F8	1
Ni, Cyc, 16	98	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	572	400	1/5	F8	1
Ni, Cyc, 17	99	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	573	400	1/5	F8	1
Ni, Cyc, 18	100	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	574	400	1/5	F8	1
Ni, Cyc, 19	101	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	575	400	1/5	F8	1
Ni, Cyc, 20	102	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	576	400	1/5	F8	2
Ni, Cyc, 21	103	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	668	400	1/5	F8	3
Ni, Cyc, 22	104	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	669	400	1/5	F8	1
Ni, Cyc, 23	105	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	670	400	1/5	F8	1
Ni, Cyc, 24	106	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	671	400	1/5	F8	1
Ni, Cyc, 25	107	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	672	400	1/5	F8	1
Ni, Fir, 1	133	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	403	400	1/5	F8	1
Ni, Fir, 2	134	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	404	400	1/5	F8	0
Ni, Fir, 3	135	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	405	400	1/5	F8	0
Ni, Fir, 4	136	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	406	400	1/5	F8	0
Ni, Fir, 5	137	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	407	400	1/5	F8	0
Ni, Fir, 6	138	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	408	400	1/5	F8	0
Ni, Fir, 7	139	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	409	400	1/5	F8	1
Ni, Fir, 8	140	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	410	400	1/5	F8	1
Ni, Fir, 9	141	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	411	400	1/5	F8	0
Ni, Fir, 10	142	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	412	400	1/5	F8	0
Ni, Fir, 11	143	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	413	400	1/5	F8	1
Ni, Fir, 12	144	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	414	400	1/5	F8	0
Ni, Fir, 13	145	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	415	400	1/5	F8	0
Ni, Fir, 14	146	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	416	400	1/5	F8	0
Ni, Fir, 15	147	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	417	400	1/5	F8	0
Ni, Fir, 16	148	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	418	400	1/5	F8	0
Ni, Fir, 17	149	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	419	400	1/5	F8	1
Ni, Fir, 18	150	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	420	400	1/5	F8	0
Ni, Fir, 19	151	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	421	400	1/5	F8	0
Ni, Fir, 20	152	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	422	400	1/5	F8	0
Ni, Fir, 21	153	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	423	400	1/5	F8	0
Ni, Fir, 22	154	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	424, 425	400	1/5	F8	1
Ni, Fir, 23	155	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	426	400	1/5	F8	0
Ni, Fir, 24	156	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	427	400	1/5	F8	0
Ni, Fir, 25	157	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	428, 429	400	1/5	F8	1
Ni, Fir, 26	158	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	430	400	1/5	F8	0
Ni, Fir, 27	159	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	431	400	1/5	F8	0
Ni, Fir, 28	160	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	432, 433	400	1/5	F8	1
Ni, Fir, 29	161	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	434	400	1/5	F8	1
Ni, Fir, 30	162	9/9/21	9/10/21	F078QP2-F077U06	1.000	2:24	435	400	1/5	F8	0
Ni, Fir, 31	163	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	536	400	1/5	F8	1
Ni, Fir, 32	164	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	537	400	1/5	F8	0
Ni, Fir, 33	165	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	538	400	1/5	F8	0
Ni, Fir, 34	166	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	539	400	1/5	F8	1
Ni, Fir, 35	167	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	540	400	1/5	F8	0
Ni, Fir, 36	168	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	541	400	1/5	F8	0
Ni, Fir, 37	169	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	542	400	1/5	F8	0
Ni, Fir, 38	170	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	543	400	1/5	F8	0
Ni, Fir, 39	171	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	544	400	1/5	F8	1
Ni, Fir, 40	172	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	545	400	1/5	F8	1
Ni, Fir, 41	173	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	546	400	1/5	F8	1
Ni, Fir, 42	174	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	547	400	1/5	F8	0
Ni, Fir, 43	175	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	548	400	1/5	F8	0
Ni, Fir, 44	176	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	549	400	1/5	F8	1
Ni, Fir, 45	177	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	550	400	1/5	F8	1
Ni, Fir, 46	178	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	551	400	1/5	F8	0
Ni, Fir, 47	179	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	552	400	1/5	F8	0
Ni, Fir, 48	180	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	553	400	1/5	F8	0
Ni, Fir, 49	181	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	554	400	1/5	F8	0
Ni, Fir, 50	182	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	555	400	1/5	F8	0
Ni, Fir, 51	183	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	556	400	1/5	F8	1
Ni, Fir, 52	184	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	557	400	1/5	F8	0
Ni, Fir, 53	185	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	558	400	1/5	F8	0
Ni, Fir, 54	186	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	559	400	1/5	F8	0
Ni, Fir, 55	187	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	560	400	1/5	F8	0
Ni, Fir, 56	188	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	561	400	1/5	F8	0
Ni, Fir, 57	189	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	562	400	1/5	F8	0
Ni, Fir, 58	190	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	563	400	1/5	F8	0
Ni, Fir, 59	191	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	564	400	1/5	F8	0
Ni, Fir, 60	192	9/16/21	9/17/21	F078QP2-F077U06	1.000	2:15	565	400	1/5	F8	0
Ni, Fir, 61	193	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	638	400	1/5	F8	0

Ni, Fir, 62	194	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	639	400	1/5	F8	1
Ni, Fir, 63	195	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	640	400	1/5	F8	0
Ni, Fir, 64	196	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	641	400	1/5	F8	0
Ni, Fir, 65	197	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	642	400	1/5	F8	0
Ni, Fir, 66	198	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	643	400	1/5	F8	0
Ni, Fir, 67	199	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	644	400	1/5	F8	0
Ni, Fir, 68	200	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	645	400	1/5	F8	1
Ni, Fir, 69	201	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	646	400	1/5	F8	0
Ni, Fir, 70	202	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	647	400	1/5	F8	0
Ni, Fir, 71	203	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	648	400	1/5	F8	0
Ni, Fir, 72	204	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	649	400	1/5	F8	0
Ni, Fir, 73	205	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	650	400	1/5	F8	0
Ni, Fir, 74	206	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	651	400	1/5	F8	0
Ni, Fir, 75	207	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	652	400	1/5	F8	0
Ni, Fir, 76	208	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	653	400	1/5	F8	0
Ni, Fir, 77	209	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	654	400	1/5	F8	0
Ni, Fir, 78	210	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	655	400	1/5	F8	0
Ni, Fir, 79	211	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	656	400	1/5	F8	0
Ni, Fir, 80	212	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	657	400	1/5	F8	0
Ni, Fir, 81	213	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	658	400	1/5	F8	0
Ni, Fir, 82	214	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	659	400	1/5	F8	0
Ni, Fir, 83	215	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	660	400	1/5	F8	0
Ni, Fir, 84	216	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	661	400	1/5	F8	0
Ni, Fir, 85	217	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	662	400	1/5	F8	0
Ni, Fir, 86	218	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	663	400	1/5	F8	0
Ni, Fir, 87	219	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	664	400	1/5	F8	0
Ni, Fir, 88	220	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	665	400	1/5	F8	0
Ni, Fir, 89	221	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	666	400	1/5	F8	0
Ni, Fir, 90	222	10/14/21	10/15/21	F078QP2-F077U06	1.000	3:00	667	400	1/5	F8	0
Ni, Fir, 91	223	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	772	400	1/5	F8	0
Ni, Fir, 92	224	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	773	400	1/5	F8	0
Ni, Fir, 93	225	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	774	400	1/5	F8	0
Ni, Fir, 94	226	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	775	400	1/5	F8	0
Ni, Fir, 95	227	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	776	400	1/5	F8	0
Ni, Fir, 96	228	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	777	400	1/5	F8	0
Ni, Fir, 97	229	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	778	400	1/5	F8	0
Ni, Fir, 98	230	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	779	400	1/5	F8	0
Ni, Fir, 99	231	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	780	400	1/5	F8	1
Ni, Fir, 100	232	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	781-782	400	1/5 1/2.5	F8	0
Ni, Fir, 101	233	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	783	400	1/5	F8	0
Ni, Fir, 102	234	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	784	400	1/5	F8	0
Ni, Fir, 103	235	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	785	400	1/5	F8	0
Ni, Fir, 104	236	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	786	400	1/5	F8	0
Ni, Fir, 105	237	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	787	400	1/5	F8	0
Ni, Fir, 106	238	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	788	400	1/5	F8	0
Ni, Fir, 107	239	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	789	400	1/5	F8	0
Ni, Fir, 108	240	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	790	400	1/5	F8	0
Ni, Fir, 109	241	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	791	400	1/5	F8	0
Ni, Fir, 110	242	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	792	400	1/5	F8	0
Ni, Fir, 111	243	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	793	400	1/5	F8	0
Ni, Fir, 112	244	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	794	400	1/5	F8	0
Ni, Fir, 113	245	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	795	400	1/5	F8	0
Ni, Fir, 114	246	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	796	400	1/5	F8	0
Ni, Fir, 115	247	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	797	400	1/5	F8	0
Ni, Fir, 116	248	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	798	400	1/5	F8	0
Ni, Fir, 117	249	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	799	400	1/5	F8	0
Ni, Fir, 118	250	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	800	400	1/5	F8	0
Ni, Fir, 119	251	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	801	400	1/5	F8	0
Ni, Fir, 120	252	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	802	400	1/5	F8	0
Ni, Fir, 121	253	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	803	400	1/5	F8	0
Ni, Fir, 122	254	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	804	400	1/5	F8	0
Ni, Fir, 123	255	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	805	400	1/5	F8	0
Ni, Fir, 124	256	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	806	400	1/5	F8	0
Ni, Fir, 125	257	10/28/21	10/29/21	F078QP2-F077U06	1.000	3:20	807	400	1/5	F8	0

Table A4. Results of Nickel-Plated Cartridge Cases Processed by Gun Bluing

Sample Name	Sample #	Date Generated	Date Processed	Lot Number	Time GB (s)	Photo ID	ISO	Shutter speed	F-stop	Score (0-4)
Ni, Neg, 1	17	3/21/22	3/21/22	F078QP2-F077U06	49	888	400	1/1.6	F13	0
Ni, Neg, 2	18	3/21/22	3/21/22	F284V51	46	889	400	1/1.6	F13	0
Ni, Neg, 3	19	3/21/22	3/21/22	F284V51	59	890	400	1/1.6	F13	0
Ni, Neg, 4	20	3/21/22	3/21/22	F284V51	57	891	400	1/1.6	F13	0
Ni, Neg, 5	21	3/21/22	3/21/22	F284V51	65	892	400	1/1.6	F13	0
Ni, Neg, 6	22	3/21/22	3/21/22	F284V51	61	893	400	1/1.6	F13	0
Ni, Neg, 7	23	3/21/22	3/21/22	F284V51	53	894	400	1/1.6	F13	0
Ni, Neg, 8	24	3/21/22	3/21/22	F284V51	73	895	400	1/1.6	F13	0
Ni, Pos, 1	25	10/12/21	10/13/21*	F078QP2-F077U06	49	577-582	400	1/30	F11	4
Ni, Pos, 2	26	10/12/21	10/13/21*	F078QP2-F077U06	56	583	400	1/30	F11	1
Ni, Pos, 3	27	10/12/21	10/13/21*	F078QP2-F077U06	51	584	400	1/30	F11	3
Ni, Pos, 4	28	10/12/21	10/13/21*	F078QP2-F077U06	46	585	400	1/30	F11	2
Ni, Pos, 5	29	11/9/21	11/10/21	F078QP2-F077U06	80	834	400	1/40	F11	1
Ni, Pos, 6	30	11/9/21	11/10/21	F078QP2-F077U06	82	835	400	1/40	F11	3
Ni, Pos, 7	31	11/9/21	11/10/21	F078QP2-F077U06	66	836	400	1/40	F11	2
Ni, Pos, 8	32	11/9/21	11/10/21	F078QP2-F077U06	83	837	400	1/40	F11	1
Ni, Neg, 1F	399	9/14/21	9/15/21	F078QP2-F077U06	65	489	400	1/80	F11	0
Ni, Neg, 2F	400	9/14/21	9/15/21	F078QP2-F077U06	52	490	400	1/80	F11	0
Ni, Neg, 3F	401	10/12/21	10/13/21*	F078QP2-F077U06	54	588	400	1/30	F11	0
Ni, Neg, 4F	402	10/12/21	10/13/21*	F078QP2-F077U06	45	589	400	1/30	F11	0
Ni, Neg, 5F	403	10/26/21	10/27/21	F078QP2-F077U06	59	707	400	1/40	F11	0
Ni, Neg, 6F	404	10/26/21	10/27/21	F078QP2-F077U06	49	708	400	1/40	F11	0
Ni, Neg, 7F	405	11/9/21	11/10/21	F078QP2-F077U06	58	840	400	1/40	F11	0
Ni, Neg, 8F	406	11/9/21	11/10/21	F078QP2-F077U06	61	841	400	1/40	F11	0
Ni, Pos, 1F	407	9/14/21	9/15/21	F078QP2-F077U06	82	483-487	400	1/80	F11	3
Ni, Pos, 2F	408	9/14/21	9/15/21	F078QP2-F077U06	87	488	400	1/80	F11	4
Ni, Pos, 3F	409	10/12/21	10/13/21*	F078QP2-F077U06	42	586	400	1/30	F11	1
Ni, Pos, 4F	410	10/12/21	10/13/21*	F078QP2-F077U06	47	587	400	1/30	F11	1
Ni, Pos, 5F	411	10/26/21	10/27/21	F078QP2-F077U06	51	705	400	1/40	F11	1
Ni, Pos, 6F	412	10/26/21	10/27/21	F078QP2-F077U06	48	706	400	1/40	F11	1
Ni, Pos, 7F	413	11/9/21	11/10/21	F078QP2-F077U06	61	838	400	1/40	F11	1
Ni, Pos, 8F	414	11/9/21	11/10/21	F078QP2-F077U06	76	839	400	1/40	F11	1
Ni, L/U, 1	58	9/26/21	9/27/21	F078QP2-F077U06	68	739	400	1/40	F11	1
Ni, L/U, 2	59	9/26/21	9/27/21	F078QP2-F077U06	65	740	400	1/40	F11	2
Ni, L/U, 3	60	9/26/21	9/27/21	F078QP2-F077U06	63	741	400	1/40	F11	1
Ni, L/U, 4	61	9/26/21	9/27/21	F078QP2-F077U06	60	742	400	1/40	F11	1
Ni, L/U, 5	62	9/26/21	9/27/21	F078QP2-F077U06	67	743	400	1/40	F11	1
Ni, L/U, 6	63	9/26/21	9/27/21	F078QP2-F077U06	63	744	400	1/40	F11	1
Ni, L/U, 7	64	9/26/21	9/27/21	F078QP2-F077U06	54	745	400	1/40	F11	1
Ni, L/U, 8	65	9/26/21	9/27/21	F078QP2-F077U06	58	746	400	1/40	F11	1
Ni, L/U, 9	66	9/26/21	9/27/21	F078QP2-F077U06	58	747	400	1/40	F11	1
Ni, L/U, 10	67	9/26/21	9/27/21	F078QP2-F077U06	76	748	400	1/40	F11	1
Ni, L/U, 11	68	9/26/21	9/27/21	F078QP2-F077U06	58	749	400	1/40	F11	1
Ni, L/U, 12	69	9/26/21	9/27/21	F078QP2-F077U06	61	750	400	1/40	F11	1
Ni, L/U, 13	70	9/26/21	9/27/21	F078QP2-F077U06	52	751	400	1/40	F11	1
Ni, L/U, 14	71	9/26/21	9/27/21	F078QP2-F077U06	57	752	400	1/40	F11	1
Ni, L/U, 15	72	9/26/21	9/27/21	F078QP2-F077U06	57	753	400	1/40	F11	1
Ni, L/U, 16	73	9/26/21	9/27/21	F078QP2-F077U06	63	754	400	1/40	F11	1
Ni, L/U, 17	74	9/26/21	9/27/21	F078QP2-F077U06	50	755	400	1/40	F11	1
Ni, L/U, 18	75	9/26/21	9/27/21	F078QP2-F077U06	61	756	400	1/40	F11	1
Ni, L/U, 19	76	9/26/21	9/27/21	F078QP2-F077U06	54	757	400	1/40	F11	1
Ni, L/U, 20	77	9/26/21	9/27/21	F078QP2-F077U06	63	758	400	1/40	F11	1
Ni, L/U, 21	78	9/26/21	9/27/21	F078QP2-F077U06	60	759	400	1/40	F11	1
Ni, L/U, 22	79	9/26/21	9/27/21	F078QP2-F077U06	65	760	400	1/40	F11	1
Ni, L/U, 23	80	9/26/21	9/27/21	F078QP2-F077U06	53	761	400	1/40	F11	1
Ni, L/U, 24	81	9/26/21	9/27/21	F078QP2-F077U06	63	762	400	1/40	F11	1
Ni, L/U, 25	82	9/26/21	9/27/21	F078QP2-F077U06	67	763	400	1/40	F11	1
Ni, Cyc, 1	108	9/14/21	9/15/21	F078QP2-F077U06	87	521	400	1/60	F11	1
Ni, Cyc, 2	109	9/14/21	9/15/21	F078QP2-F077U06	83	522	400	1/60	F11	1
Ni, Cyc, 3	110	9/14/21	9/15/21	F078QP2-F077U06	89	523, 524	400	1/60	F11	1
Ni, Cyc, 4	111	9/14/21	9/15/21	F078QP2-F077U06	69	525	400	1/60	F11	1
Ni, Cyc, 5	112	9/14/21	9/15/21	F078QP2-F077U06	61	526	400	1/60	F11	1
Ni, Cyc, 6	113	9/14/21	9/15/21	F078QP2-F077U06	53	527	400	1/60	F11	2
Ni, Cyc, 7	114	9/14/21	9/15/21	F078QP2-F077U06	72	528	400	1/60	F11	1
Ni, Cyc, 8	115	9/14/21	9/15/21	F078QP2-F077U06	73	529	400	1/60	F11	1
Ni, Cyc, 9	116	9/14/21	9/15/21	F078QP2-F077U06	55	530	400	1/60	F11	1
Ni, Cyc, 10	117	9/14/21	9/15/21	F078QP2-F077U06	65	531	400	1/60	F11	1
Ni, Cyc, 11	118	10/12/21	10/13/21*	F078QP2-F077U06	56	620	400	1/30	F11	1
Ni, Cyc, 12	119	10/12/21	10/13/21*	F078QP2-F077U06	65	621	400	1/30	F11	1

Ni, Cyc, 13	120	10/12/21	10/13/21*	F078QP2-F077U06	53	622	400	1/30	F11	1
Ni, Cyc, 14	121	10/12/21	10/13/21*	F078QP2-F077U06	65	623	400	1/30	F11	1
Ni, Cyc, 15	122	10/12/21	10/13/21*	F078QP2-F077U06	59	624	400	1/30	F11	1
Ni, Cyc, 16	123	10/12/21	10/13/21*	F078QP2-F077U06	55	625	400	1/30	F11	1
Ni, Cyc, 17	124	10/12/21	10/13/21*	F078QP2-F077U06	61	626	400	1/30	F11	1
Ni, Cyc, 18	125	10/12/21	10/13/21*	F078QP2-F077U06	55	627	400	1/30	F11	1
Ni, Cyc, 19	126	10/12/21	10/13/21*	F078QP2-F077U06	62	628	400	1/30	F11	1
Ni, Cyc, 20	127	10/12/21	10/13/21*	F078QP2-F077U06	55	629	400	1/30	F11	1
Ni, Cyc, 21	128	10/26/21	10/27/21	F078QP2-F077U06	57	698-700	400	1/40	F11	1
Ni, Cyc, 22	129	10/26/21	10/27/21	F078QP2-F077U06	62	701	400	1/40	F11	1
Ni, Cyc, 23	130	10/26/21	10/27/21	F078QP2-F077U06	52	702	400	1/40	F11	1
Ni, Cyc, 24	131	10/26/21	10/27/21	F078QP2-F077U06	51	703	400	1/40	F11	1
Ni, Cyc, 25	132	10/26/21	10/27/21	F078QP2-F077U06	65	704	400	1/40	F11	1
Ni, Fir, 1	258	9/14/21	9/15/21	F078QP2-F077U06	60	491	400	1/80	F11	0
Ni, Fir, 2	259	9/14/21	9/15/21	F078QP2-F077U06	54	492	400	1/80	F11	0
Ni, Fir, 3	260	9/14/21	9/15/21	F078QP2-F077U06	59	493	400	1/80	F11	0
Ni, Fir, 4	261	9/14/21	9/15/21	F078QP2-F077U06	56	494	400	1/80	F11	0
Ni, Fir, 5	262	9/14/21	9/15/21	F078QP2-F077U06	55	495	400	1/80	F11	0
Ni, Fir, 6	263	9/14/21	9/15/21	F078QP2-F077U06	59	496	400	1/80	F11	0
Ni, Fir, 7	264	9/14/21	9/15/21	F078QP2-F077U06	60	497	400	1/60	F11	0
Ni, Fir, 8	265	9/14/21	9/15/21	F078QP2-F077U06	59	498	400	1/60	F11	0
Ni, Fir, 9	266	9/14/21	9/15/21	F078QP2-F077U06	67	499	400	1/60	F11	0
Ni, Fir, 10	267	9/14/21	9/15/21	F078QP2-F077U06	63	500	400	1/60	F11	0
Ni, Fir, 11	268	9/14/21	9/15/21	F078QP2-F077U06	59	501	400	1/60	F11	0
Ni, Fir, 12	269	9/14/21	9/15/21	F078QP2-F077U06	55	502	400	1/60	F11	0
Ni, Fir, 13	270	9/14/21	9/15/21	F078QP2-F077U06	63	503	400	1/60	F11	0
Ni, Fir, 14	271	9/14/21	9/15/21	F078QP2-F077U06	68	504	400	1/60	F11	0
Ni, Fir, 15	272	9/14/21	9/15/21	F078QP2-F077U06	42	505	400	1/60	F11	0
Ni, Fir, 16	273	9/14/21	9/15/21	F078QP2-F077U06	49	506	400	1/60	F11	0
Ni, Fir, 17	274	9/14/21	9/15/21	F078QP2-F077U06	41	507	400	1/60	F11	0
Ni, Fir, 18	275	9/14/21	9/15/21	F078QP2-F077U06	47	508	400	1/60	F11	0
Ni, Fir, 19	276	9/14/21	9/15/21	F078QP2-F077U06	39	509	400	1/60	F11	0
Ni, Fir, 20	277	9/14/21	9/15/21	F078QP2-F077U06	46	510	400	1/60	F11	0
Ni, Fir, 21	278	9/14/21	9/15/21	F078QP2-F077U06	38	511	400	1/60	F11	0
Ni, Fir, 22	279	9/14/21	9/15/21	F078QP2-F077U06	43	512	400	1/60	F11	0
Ni, Fir, 23	280	9/14/21	9/15/21	F078QP2-F077U06	50	513	400	1/60	F11	0
Ni, Fir, 24	281	9/14/21	9/15/21	F078QP2-F077U06	52	514	400	1/60	F11	0
Ni, Fir, 25	282	9/14/21	9/15/21	F078QP2-F077U06	43	515	400	1/60	F11	0
Ni, Fir, 26	283	9/14/21	9/15/21	F078QP2-F077U06	57	516	400	1/60	F11	0
Ni, Fir, 27	284	9/14/21	9/15/21	F078QP2-F077U06	50	517	400	1/60	F11	0
Ni, Fir, 28	285	9/14/21	9/15/21	F078QP2-F077U06	57	518	400	1/60	F11	0
Ni, Fir, 29	286	9/14/21	9/15/21	F078QP2-F077U06	61	519	400	1/60	F11	0
Ni, Fir, 30	287	9/14/21	9/15/21	F078QP2-F077U06	53	520	400	1/60	F11	0
Ni, Fir, 31	288	10/12/21	10/13/21*	F078QP2-F077U06	44	590	400	1/30	F11	0
Ni, Fir, 32	289	10/12/21	10/13/21*	F078QP2-F077U06	47	591	400	1/30	F11	0
Ni, Fir, 33	290	10/12/21	10/13/21*	F078QP2-F077U06	52	592	400	1/30	F11	1
Ni, Fir, 34	291	10/12/21	10/13/21*	F078QP2-F077U06	48	593	400	1/30	F11	0
Ni, Fir, 35	292	10/12/21	10/13/21*	F078QP2-F077U06	44	594	400	1/30	F11	0
Ni, Fir, 36	293	10/12/21	10/13/21*	F078QP2-F077U06	43	595	400	1/30	F11	0
Ni, Fir, 37	294	10/12/21	10/13/21*	F078QP2-F077U06	47	596	400	1/30	F11	0
Ni, Fir, 38	295	10/12/21	10/13/21*	F078QP2-F077U06	54	597	400	1/30	F11	1
Ni, Fir, 39	296	10/12/21	10/13/21*	F078QP2-F077U06	59	598	400	1/30	F11	0
Ni, Fir, 40	297	10/12/21	10/13/21*	F078QP2-F077U06	53	599	400	1/30	F11	0
Ni, Fir, 41	298	10/12/21	10/13/21*	F078QP2-F077U06	31	600	400	1/30	F11	0
Ni, Fir, 42	299	10/12/21	10/13/21*	F078QP2-F077U06	38	601	400	1/30	F11	0
Ni, Fir, 43	300	10/12/21	10/13/21*	F078QP2-F077U06	44	602	400	1/30	F11	0
Ni, Fir, 44	301	10/12/21	10/13/21*	F078QP2-F077U06	45	603	400	1/30	F11	0
Ni, Fir, 45	302	10/12/21	10/13/21*	F078QP2-F077U06	36	604	400	1/30	F11	0
Ni, Fir, 46	303	10/12/21	10/13/21*	F078QP2-F077U06	36	605	400	1/30	F11	0
Ni, Fir, 47	304	10/12/21	10/13/21*	F078QP2-F077U06	41	606	400	1/30	F11	0
Ni, Fir, 48	305	10/12/21	10/13/21*	F078QP2-F077U06	37	607	400	1/30	F11	0
Ni, Fir, 49	306	10/12/21	10/13/21*	F078QP2-F077U06	40	608	400	1/30	F11	0
Ni, Fir, 50	307	10/12/21	10/13/21*	F078QP2-F077U06	47	609	400	1/30	F11	0
Ni, Fir, 51	308	10/12/21	10/13/21*	F078QP2-F077U06	45	610	400	1/30	F11	0
Ni, Fir, 52	309	10/12/21	10/13/21*	F078QP2-F077U06	48	611	400	1/30	F11	0
Ni, Fir, 53	310	10/12/21	10/13/21*	F078QP2-F077U06	49	612	400	1/30	F11	0
Ni, Fir, 54	311	10/12/21	10/13/21*	F078QP2-F077U06	37	613	400	1/30	F11	0
Ni, Fir, 55	312	10/12/21	10/13/21*	F078QP2-F077U06	39	614	400	1/30	F11	0
Ni, Fir, 56	313	10/12/21	10/13/21*	F078QP2-F077U06	37	615	400	1/30	F11	0
Ni, Fir, 57	314	10/12/21	10/13/21*	F078QP2-F077U06	38	616	400	1/30	F11	0

Ni, Fir, 58	315	10/12/21	10/13/21*	F078QP2-F077U06	43	617	400	1/30	F11	0
Ni, Fir, 59	316	10/12/21	10/13/21*	F078QP2-F077U06	42	618	400	1/30	F11	0
Ni, Fir, 60	317	10/12/21	10/13/21*	F078QP2-F077U06	42	619	400	1/30	F11	0
Ni, Fir, 61	318	10/26/21	10/27/21	F078QP2-F077U06	42	709	400	1/40	F11	0
Ni, Fir, 62	319	10/26/21	10/27/21	F078QP2-F077U06	53	710	400	1/40	F11	0
Ni, Fir, 63	320	10/26/21	10/27/21	F078QP2-F077U06	44	711	400	1/40	F11	0
Ni, Fir, 64	321	10/26/21	10/27/21	F078QP2-F077U06	53	712	400	1/40	F11	0
Ni, Fir, 65	322	10/26/21	10/27/21	F078QP2-F077U06	47	713	400	1/40	F11	0
Ni, Fir, 66	323	10/26/21	10/27/21	F078QP2-F077U06	54	714	400	1/40	F11	0
Ni, Fir, 67	324	10/26/21	10/27/21	F078QP2-F077U06	44	715	400	1/40	F11	0
Ni, Fir, 68	325	10/26/21	10/27/21	F078QP2-F077U06	44	716	400	1/40	F11	0
Ni, Fir, 69	326	10/26/21	10/27/21	F078QP2-F077U06	58	717	400	1/40	F11	0
Ni, Fir, 70	327	10/26/21	10/27/21	F078QP2-F077U06	59	718	400	1/40	F11	0
Ni, Fir, 71	328	10/26/21	10/27/21	F078QP2-F077U06	46	719	400	1/40	F11	0
Ni, Fir, 72	329	10/26/21	10/27/21	F078QP2-F077U06	52	720	400	1/40	F11	0
Ni, Fir, 73	330	10/26/21	10/27/21	F078QP2-F077U06	45	721	400	1/40	F11	0
Ni, Fir, 74	331	10/26/21	10/27/21	F078QP2-F077U06	46	722	400	1/40	F11	0
Ni, Fir, 75	332	10/26/21	10/27/21	F078QP2-F077U06	39	723	400	1/40	F11	0
Ni, Fir, 76	333	10/26/21	10/27/21	F078QP2-F077U06	51	724	400	1/40	F11	0
Ni, Fir, 77	334	10/26/21	10/27/21	F078QP2-F077U06	35	725	400	1/40	F11	0
Ni, Fir, 78	335	10/26/21	10/27/21	F078QP2-F077U06	48	726	400	1/40	F11	0
Ni, Fir, 79	336	10/26/21	10/27/21	F078QP2-F077U06	43	727	400	1/40	F11	0
Ni, Fir, 80	337	10/26/21	10/27/21	F078QP2-F077U06	51	728	400	1/40	F11	0
Ni, Fir, 81	338	10/26/21	10/27/21	F078QP2-F077U06	39	729	400	1/40	F11	0
Ni, Fir, 82	339	10/26/21	10/27/21	F078QP2-F077U06	42	730	400	1/40	F11	0
Ni, Fir, 83	340	10/26/21	10/27/21	F078QP2-F077U06	47	731	400	1/40	F11	0
Ni, Fir, 84	341	10/26/21	10/27/21	F078QP2-F077U06	47	732	400	1/40	F11	0
Ni, Fir, 85	342	10/26/21	10/27/21	F078QP2-F077U06	49	733	400	1/40	F11	0
Ni, Fir, 86	343	10/26/21	10/27/21	F078QP2-F077U06	55	734	400	1/40	F11	0
Ni, Fir, 87	344	10/26/21	10/27/21	F078QP2-F077U06	64	735	400	1/40	F11	0
Ni, Fir, 88	345	10/26/21	10/27/21	F078QP2-F077U06	58	736	400	1/40	F11	0
Ni, Fir, 89	346	10/26/21	10/27/21	F078QP2-F077U06	58	737	400	1/40	F11	0
Ni, Fir, 90	347	10/26/21	10/27/21	F078QP2-F077U06	50	738	400	1/40	F11	0
Ni, Fir, 91	348	11/9/21	11/10/21	F078QP2-F077U06	53	842	400	1/40	F11	0
Ni, Fir, 92	349	11/9/21	11/10/21	F078QP2-F077U06	61	843	400	1/40	F11	1
Ni, Fir, 93	350	11/9/21	11/10/21	F078QP2-F077U06	58	844	400	1/40	F11	0
Ni, Fir, 94	351	11/9/21	11/10/21	F078QP2-F077U06	50	845	400	1/40	F11	0
Ni, Fir, 95	352	11/9/21	11/10/21	F078QP2-F077U06	51	846	400	1/40	F11	0
Ni, Fir, 96	353	11/9/21	11/10/21	F078QP2-F077U06	57	847	400	1/40	F11	0
Ni, Fir, 97	354	11/9/21	11/10/21	F078QP2-F077U06	56	848	400	1/40	F11	0
Ni, Fir, 98	355	11/9/21	11/10/21	F078QP2-F077U06	73	849	400	1/40	F11	0
Ni, Fir, 99	356	11/9/21	11/10/21	F078QP2-F077U06	56	850	400	1/40	F11	0
Ni, Fir, 100	357	11/9/21	11/10/21	F078QP2-F077U06	57	851	400	1/40	F11	0
Ni, Fir, 101	358	11/9/21	11/10/21	F078QP2-F077U06	40	852	400	1/40	F11	0
Ni, Fir, 102	359	11/9/21	11/10/21	F078QP2-F077U06	39	853	400	1/40	F11	0
Ni, Fir, 103	360	11/9/21	11/10/21	F078QP2-F077U06	46	854	400	1/40	F11	0
Ni, Fir, 104	361	11/9/21	11/10/21	F078QP2-F077U06	52	855	400	1/40	F11	0
Ni, Fir, 105	362	11/9/21	11/10/21	F078QP2-F077U06	34	856	400	1/40	F11	0
Ni, Fir, 106	363	11/9/21	11/10/21	F078QP2-F077U06	50	857	400	1/40	F11	0
Ni, Fir, 107	364	11/9/21	11/10/21	F078QP2-F077U06	59	858	400	1/40	F11	0
Ni, Fir, 108	365	11/9/21	11/10/21	F078QP2-F077U06	54	859	400	1/40	F11	0
Ni, Fir, 109	366	11/9/21	11/10/21	F078QP2-F077U06	51	860	400	1/40	F11	0
Ni, Fir, 110	367	11/9/21	11/10/21	F078QP2-F077U06	48	861	400	1/40	F11	0
Ni, Fir, 111	368	11/9/21	11/10/21	F078QP2-F077U06	47	862	400	1/40	F11	0
Ni, Fir, 112	369	11/9/21	11/10/21	F078QP2-F077U06	49	863	400	1/40	F11	0
Ni, Fir, 113	370	11/9/21	11/10/21	F078QP2-F077U06	55	864	400	1/40	F11	0
Ni, Fir, 114	371	11/9/21	11/10/21	F078QP2-F077U06	42	865	400	1/40	F11	0
Ni, Fir, 115	372	11/9/21	11/10/21	F078QP2-F077U06	46	866	400	1/40	F11	0
Ni, Fir, 116	373	11/9/21	11/10/21	F078QP2-F077U06	36	867	400	1/40	F11	0
Ni, Fir, 117	374	11/9/21	11/10/21	F078QP2-F077U06	51	868	400	1/40	F11	0
Ni, Fir, 118	375	11/9/21	11/10/21	F078QP2-F077U06	42	869	400	1/40	F11	0
Ni, Fir, 119	376	11/9/21	11/10/21	F078QP2-F077U06	49	870	400	1/40	F11	0
Ni, Fir, 120	377	11/9/21	11/10/21	F078QP2-F077U06	46	871	400	1/40	F11	0
Ni, Fir, 121	378	11/9/21	11/10/21	F078QP2-F077U06	52	872	400	1/40	F11	0
Ni, Fir, 122	379	11/9/21	11/10/21	F078QP2-F077U06	43	873	400	1/40	F11	0
Ni, Fir, 123	380	11/9/21	11/10/21	F078QP2-F077U06	51	874	400	1/40	F11	0
Ni, Fir, 124	381	11/9/21	11/10/21	F078QP2-F077U06	52	875	400	1/40	F11	0
Ni, Fir, 125	382	11/9/21	11/10/21	F078QP2-F077U06	47	876	400	1/40	F11	0

* Note: samples processed on 10/13/21 were photographed on 10/15/21