SANDIA REPORT

SAND2001-3942
Unlimited Release
Printed January 2002

Field Test Kit for Gunshot Residue Detection

Pamela K. Walker and Philip J. Rodacy

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation,
a Lockheed Martin Company, for the United States Department of
Energy under Contract DE-AC04-94AL85000.

Approved for public release; further dissemination unlimited.

Sandia National Laboratories

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Telephone: (865)576-8401
Facsimile: (865)576-5728
E-Mail: reports@adonis.osti.gov
Online ordering: http://www.doe.gov/bridge

Available to the public from
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Rd
Springfield, VA 22161

Telephone: (800)553-6847
Facsimile: (703)605-6900
E-Mail: orders@ntis.fedworld.gov
Online order: http://www.ntis.gov/ordering.htm

SAND2001-3942
Unlimited Release
Printed January 2002

Field Test Kit for Gunshot Residue Detection

Pamela K. Walker and Philip J. Rodacy
Explosive Systems and Materials
Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185-1452

Abstract

One of the major needs of the law enforcement field is a product that quickly, accurately, and inexpensively identifies whether a person has recently fired a gun—even if the suspect has attempted to wash the traces of gunpowder off. The Field Test Kit for Gunshot Residue Identification based on Sandia National Laboratories technology works with a wide variety of handguns and other weaponry using gunpowder.

There are several organic chemicals in small arms propellants such as nitrocellulose, nitroglycerine, dinitrotoluene, and nitrites left behind after the firing of a gun that result from the incomplete combustion of the gunpowder. Sandia has developed a colorimetric shooter identification kit for *in situ* detection of gunshot residue (GSR) from a suspect.

The test kit is the first of its kind and is small, inexpensive, and easily transported by individual law enforcement personnel requiring minimal training for effective use. It will provide immediate information identifying gunshot residue.

Acknowledgements

The authors would like to thank David Paul, Roy Dickey, and Mike Bernard for their assistance in staging and performing the live-fire testing. We would also like to extend our thanks to Kevin McMahon for his assistance in licensing this technology and to Susan Bender for her invaluable help in preparing this manuscript.

Table of Contents

Table of Tables

Table of Figures

Introduction

A crucial aspect of crime investigation is the ability to rapidly identify the key suspects. Statistics show that the first seventy-two hours is the most critical time for investigation of a crime scene. When called to the scene of a shooting, officers need to rapidly isolate suspects from witnesses. The lack of a stable field technique to detect the recent firing of a handgun by an individual means that a decision to further investigate a suspect may be delayed until analytical results are returned from a remote forensics laboratory. In many cases, this inability to rapidly determine who had recently fired a weapon significantly hampers the officer's ability to solve a shooting. No field test kit currently exists that will allow an officer to identify a person who has recently fired a gun.

Sandia National Laboratories (SNL) have developed a field-portable test kit that will provide the law enforcement community with immediate confirmation of recent gun use and assist in rapidly focussing on key suspects. This field kit will allow an officer to collect a non-invasive swab sample from a suspect and obtain field results that will determine whether or not the person who had been swiped had recently fired a gun. The swab/test kit is self-contained and provides results in less than 3 minutes.

Background on Gunshot Residue Testing

Initial literature searches found that laboratory solutions to this problem have been around for decades, with forensic tests for gunshot residue (GSR) published as early as 1933[1]. These published tests divide the chemical tests into two categories: organic and inorganic chemistry. However, none of these methods has ever been deployed as a field kit.

The "melted paraffin test" was the first test to be used. Melted wax was poured onto a suspect's hands and allowed to harden. The wax cast was removed and sprayed with a chemical solution to detect gun shot residue[1]. The gunpowder used in bullets is primarily single-based smokeless powder made of nitrocellulose (NC). A double-based gunpowder will contain nitroglycerine (NG), as well as NC. This organic chemical test turns any nitrates from unburned NC or NG on the casting blue.

Other chemical tests were developed in the 1960's to detect the presence of antimony, barium, and lead from the bullet primer[1]. These tests were more conclusive because these specific inorganic elements are rarely found naturally in the environment. Again, these tests show color changes as the developing solution was added to the GSR. When all three elements were found on a person's hands, recent exposure to GSR was probable.

Since the late 1970's, the scanning electron microscope (SEM) has been used to identify GSR. This technique is the most reliable laboratory method for GSR identification and analysis. This procedure starts with swiping the suspect's hands, clothes, belt, or shoes with a swab wetted with dilute nitric acid. Any particles or chemicals are transferred to the swab, which is then taken to the crime lab for SEM analysis. The SEM provides high magnification to view GSR particles, the characteristic spherical shape of the residual lead and elemental identification of barium, and antimony. The SEM energy dispersive x-ray capability is used to confirm these elements. These laboratory tests typically require several hours to complete. SEM instruments are very expensive, require a vibration-free environment, and a specially trained operator. As a result, very few law enforcement agencies own a SEM and samples are shipped to other laboratories.

The lack of a real-time field technique to detect the recent firing of a handgun means that a decision by a law enforcement officer to further investigate a suspect may be delayed for hours or days until the analytical results are returned from the laboratory. The following technology described in this paper is a chemical test kit that is small, portable, and can be used the field. This report describes the development, evaluation and testing of a chemical test kit that is small, portable, and can be used in any environment for the rapid screening of suspects.

SNL Field Portable Gunshot Residue Kit

Colorimetric tests have been admitted as corroborating evidence in the Pennsylvania Supreme Court[1] that a defendant had recently fired a gun[1]. Chemical color tests were investigated because they are very inexpensive and require only small amounts of chemicals. They are very effective, can be administered by personnel with very minimal training, and can be packaged for field use. Laboratory tests were done to verify that these colorimetric tests worked on known quantities of GSR. Once the performance characteristics of the colorimetric tests were completed, additional tests were performed at shooting ranges to gather data on actual GSR from various gun types and shooters.

Diphenylamine (DPA) Test

Preliminary laboratory tests were completed to determine a lower limit of detection for the melted paraffin test described above. The test was modified to make it simpler to eventually take to the field. A dry glass-fiber swab was substituted for wax and used to collect the GSR from the hands. These circular swabs, (Barringer Technologies, Inc.[2]) 1.25-inch diameter, are composed of a fiberglass felt. A teflon swab was also tested but did not absorb the color-developing solution, and therefore, was eliminated from further testing. The color-developing solution (Appendix A) was made from concentrated sulfuric acid and diphenylamine, DPA. The diphenylamine solution, clear initially, changes to a blue color when oxidized by the nitrates from residual nitroglycerine (NG) and nitrocellulose (NC).

To verify the sensitivity of the DPA test, the lower limits of detection were determined by doping swabs with laboratory solution that mimicked GSR. The solution was made from NC (12.55 % nitration) dissolved in acetone at a concentration of 8 ppm. This solution was deposited on the glass-fiber swab with a microliter syringe and the acetone was allowed to evaporate. Drops of the DPA/acid solution were added until the swab was completely wet (approximately 0.75 milliliters). Deposits of NC as small as

700 nanograms (700 x 10^{-9} grams) turned blue when developed with the DPA/acid solution described above.

Similar tests were done with 10 ppm solutions of NG dissolved in acetonitrile and acetone. Deposits of NG as small as 1000 nanograms produced a blue coloration.

The sulfuric acid used for theses tests can be hazardous if not handled correctly. It can cause skin burns on contact and can dissolve various organic materials such as clothing. The DPA tests were repeated using the weaker acetic acid (vinegar, pH ~ 5), instead of the stronger sulfuric acid (pH 1) to determine if a less caustic acid could be used. The result of this substitution were not successful. The color changing chemistry depends on low pH. The final packaging and use of the field test kit must take into account the hazardous nature of the sulfuric acid. A integral neutralization system may be included in the package.

Sodium Rhodizonate Test

A second colorimetric test was examined as a comparison to the above DPA/acid test. This colorimetric test analyzes for the presence of barium and/or lead, which are constituents of the bullet primer[1] and yields a red-brown color when either lead or barium is present.

A laboratory test solution was made of sodium rhodizonate dissolved in water (Appendix A). This solution was added dropwise to swabs which had been used to collect residue from shooters' hands. The orange color of this solution turned the swabs orange, and turned any lead or barium residue on them to red-brown. The color change was extremely hard to see, as the GSR particles from the primer are extremely small.

Field Tests

After preliminary colorimetric tests were completed in the laboratory, testing was done in the field to determine which of the two tests described above was better for visually determining GSR. Three field tests were performed; two at Sandia, and one at a commercial shooting-range (Caliber's Indoor Shooting Range, Albuquerque, New Mexico).

The first tests were done to characterize the DPA/acid solution. Nine guns were tested using different types of ammunition, shooters, and numbers of shots. These tests were done at Sandia's remote Terminal Ballistics Facility using our staff as subjects. The tests were conducted during the month of June and the warm weather enhanced the reaction time. Cold weather would cause the reaction to be a bit slower and tests done near freezing (39°F) showed the reaction to be complete within two minutes. All guns had been cleaned using a typical cleaning kit prior to testing. The shooter's hands were wiped using a dry swab both before and after shooting a gun. The web between the thumb and forefinger, along with the palm and back of the hand up to the wrist were swiped. Both hands were swiped, as some shooters held the gun with two hands. Note that moistening the swab with a small amount of water will enhance the GSR collection from the suspect and will not greatly interfere with the color developing. The tests described here, however, were performed using dry swabs to simulate “worst-case” conditions.

The pre-test verified that no pre-existing contamination was present on the shooter’s hands before he arrived at the test site. The post-test revealed which guns left GSR on the shooter’s hands. After swiping, the DPA/sulfuric acid solution was added dropwise to each swab until the swab was wet. The blue color developed fully during a two minute wait. During that time, small, dark blue specks appeared indicating nitrates. Photographs of the pre and post-tests are found in Appendix B.

Sandia Test A was done in one day with only one shooter firing one shot from each of nine guns. His hands were swiped before he fired each gun, then he fired just one shot. The shooter’s hands were washed with soap and water after each shot, then this same individual picked up the next gun and repeated the process.

Sandia Test B was done on a different day and used the same weapons and ammunition used for test A. This time, 12 different people fired from one to six shots from a weapon. This allowed us to collect samples from people who may have different body oils and contamination on their hands. It also allowed us to determine the effect of firing multiple shots. Again, hands were swiped before and after the gun was fired.

Caliber’s, Inc. Test was conducted at a commercial shooting range because it was very probable that positive results would be seen. The goal was to see which of two tests was better at registering positive. Both the DPA and sodium rhodizonate test kits were tested to determine which was better at developing a color discernable to the naked eye. These tests were randomly applied to numerous patrons of the shooting range when they entered the building to determine any pre-existing contamination, and again upon exiting to detect GSR after having shot their guns. The types of guns, caliber, and number of shots were not recorded.

Results

Results from Sandia's field tests are shown in Table 1.

Table 1: GSR Results from Field Tests

Gun (ammo)	Sandia Test A	Sandia Test B
22 revolver (short)	1 shot -***negative***	6 shots – ***negative***
22 revolver (long)	1 shot - positive	6 shots – positive
22 automatic (short)	1 shot - positive	6 shots – positive
22 automatic (long)	1 shot - positive	6 shots – positive
38 revolver	1 shot - positive	6 shots – positive
9 mm semi	1 shot - positive	6 shots – positive
45 automatic	1 shot - positive	6 shots – positive
12 ga. shotgun	1 shot - positive	3 shots – positive
20 ga. shotgun	1 shot - ***negative***	1 shot – positive 3 shots – positive
22 rifle (short)	1 shot - positive	6 shots – positive
22 rifle (long)	1 shot - ***negative***	6 shots – positive
308 rifle	1 shot - positive	6 shots - positive

The three guns which tested "*negative*" in Test A were new guns, bought recently for this project, and had never been fired before. This may be coincidental, or new guns may not have as many "leaks" as guns which have been fired many times. This would have to be investigated more to be conclusive.

Only one gun from Test B proved "negative". This 22 revolver was tested a third time to collect more evidence as to its tendency to leave behind GSR and again it failed to leak GSR. The swabs from Test B were photographed when the color intensity was at its maximum. These photos in Appendix B show the pre-swipe (top photo) and post-swipe (bottom photo).

The DPA test consistently gave obvious results showing blue specks. The sodium rhodizonate test showed a red/brown color on particles which were almost too small to be seen. The particle size of the metallic lead remaining from firing the primer is so small in diameter that the sodium rhodizonate test, which was very vivid in the lab, provided no clear indication of any GSR when tested in the field.

Conclusion

Sandia has evaluated two colorimetric tests for their applicability to field testing suspects to determine whether or not that suspect had recently fired a gun. The two tests, a sodium rhodizonate test for the determination of lead and barium and a diphenylamine/acid test for the determination of residual nitroglycerine and nitrocellulose, were tested under both laboratory and field conditions. After slight modification from published procedures, the DPA/acid test was chosen as the better of the two as the color change is more dramatic and more easily seen in the field under low-light conditions.

The DPA/acid test was shown to be able to detect as little as 700 nanograms (700×10^{-9} grams) of nitrocellulose. Field testing of 12 weapons at Sandia indicated that this detection limit is sufficient to produce a positive indication that a person has fired one shot from a new gun in 75% of the tests. When firing multiple shots (3 to 6) or when firing a weapon that is contaminated with GSR, the test provides a positive reaction over 90% of the time.

The test provides results within two minutes at room temperature, while at lower temperatures (39° F) the test requires about slightly longer for the color to develop. The development of the color is pH-dependent. The color fades after approximately one half hour after the color has developed. Taking a photo of the swipe with the blue specks on it is necessary if a permanent record of the colorimetric test is needed. If additional corroborating evidence were needed, any antimony, barium, or lead that was collected from the suspect will still be on the swab and can be confirmed in a laboratory using any of several analytical tests.

References

1. Jungreis, Ervin, Spot Test Analysis: Clinical, Environmental, Forensic, and Geochemical Applications, second edition. 1997.

2. Barringer Technologies, 30 Technology Drive, Warren, New Jersey.

3 Wolzen, G.M.; Nesbitt, R.S.; Calloway, A.R.; Loper, G.L.; Jones, P.F., Equipment Systems Improvement Program: Final Report on Particle Analysis for Gunshot Residue Detection. Law Enforcement Development Group, Aerospace Corporation, El Segundo, CA, Ivan Getting Labs. Corporation Source Codes: 000512043.

Appendix A: Formulations for Colorimetric Test Kit

This appendix contains the formulations for colorimetric test kits used in Sandia's testing. They were all found in the textbook from Reference 1. A few drops of these solutions should be added to a swab from a suspect's hand and the color developed for two minutes to determine a positive result.

1) page 85, diphenylamine test for nitrates from unburned gun powder:
   Add 10 milliliters concentrated sulfuric acid to 2 milliliters distilled water under constant stirring. Add to this solution 0.05 grams diphenylamine and stir until the solid is completely dissolved. Store in a glass bottle.

2) page 81, sodium rhodizonate solution tests for lead and barium:
   Add 0.2 grams sodium rhodizonate to 100 milliliters of distilled water and stir. Solution will be orange. Store in glass bottle.

Appendix B: Gunshot Residue Photographs

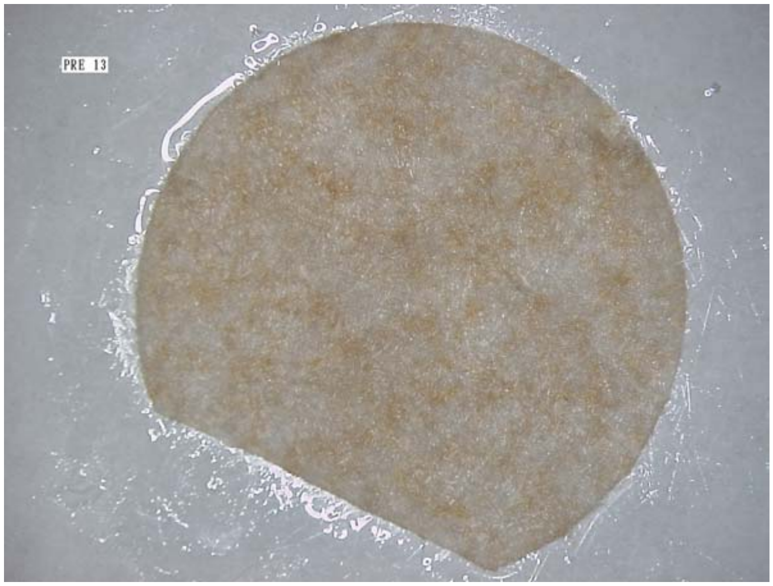

Figure 1: 22 revolver (short ammo) clean pre-swipe.

Figure 2: 22 revolver (short ammo) no GSR on post-swipe after 6 shots.

Figure 3: 22 revolver (long ammo) clean pre-swipe.

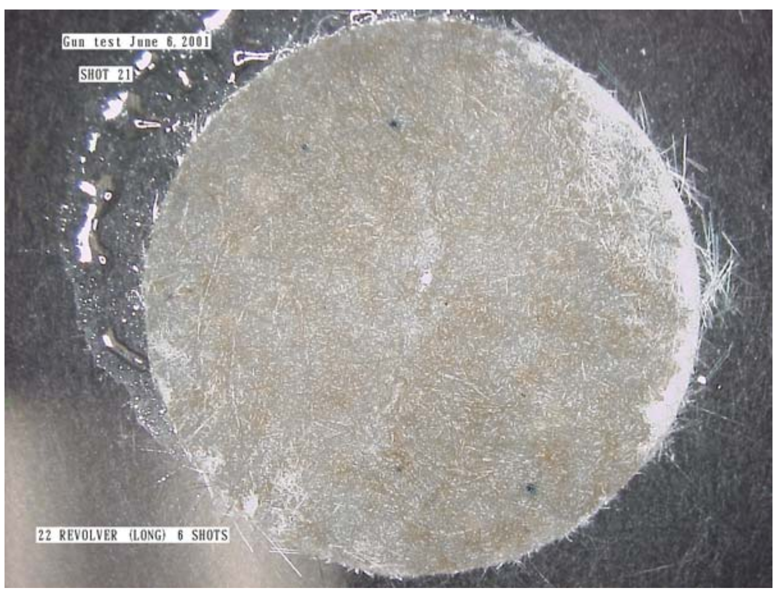

Figure 4: 22 revolver (long ammo) positive results on post-swipe.

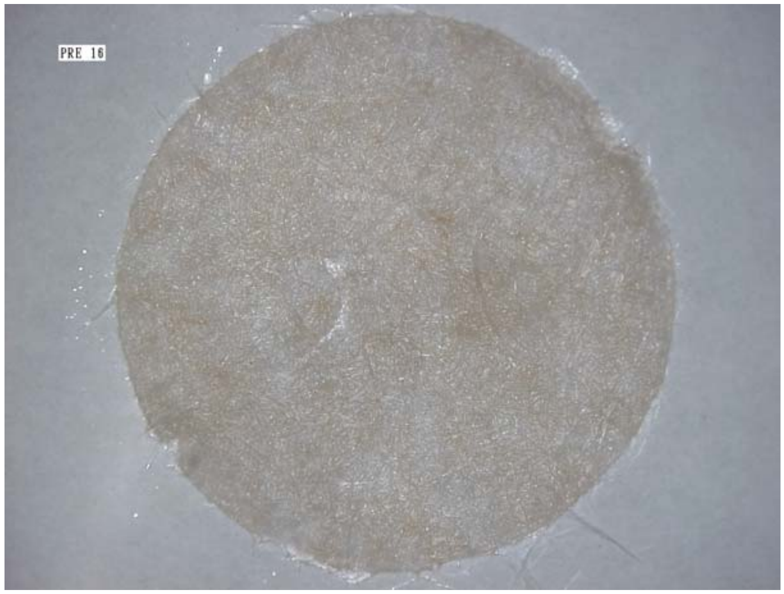

Figure 5: 22 automatic (short ammo) clean pre-swipe.

Figure 6: 22 automatic (short ammo) positive results on post-swipe after 6 shots.

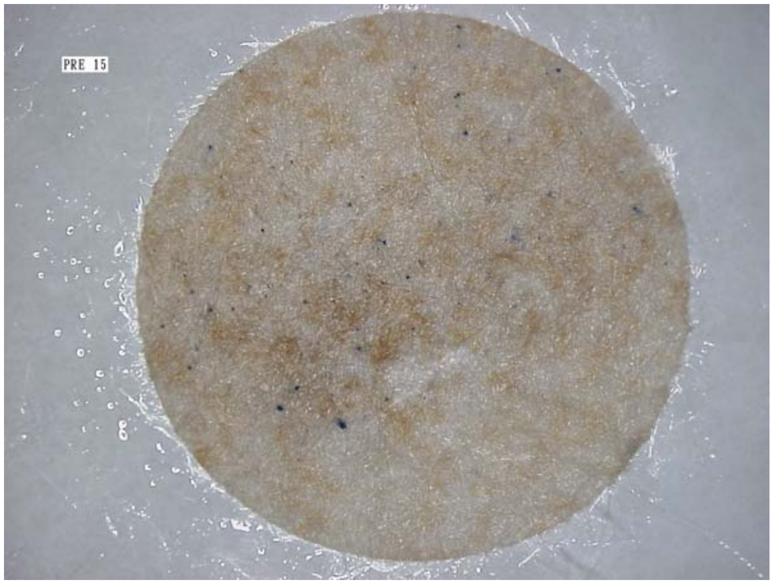

Figure 7: 22 automatic (long ammo) positive results on pre-swipe.

Shooter handled all nine guns before firing.

Figure 8: 22 automatic (long ammo) positive results on post-swipe after 6 shots.

Figure 9: 38 revolver clean pre-swipe.

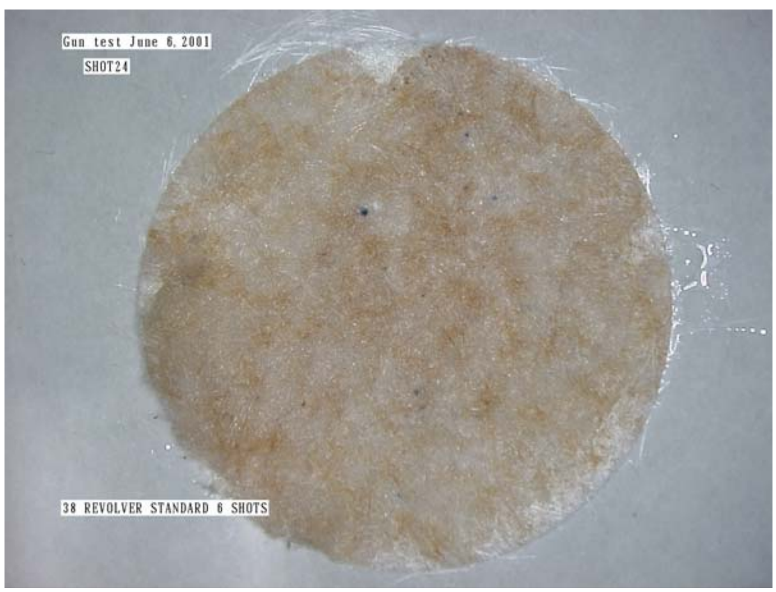

Figure 10: 38 revolver positive results on post-swipe after 6 shots.

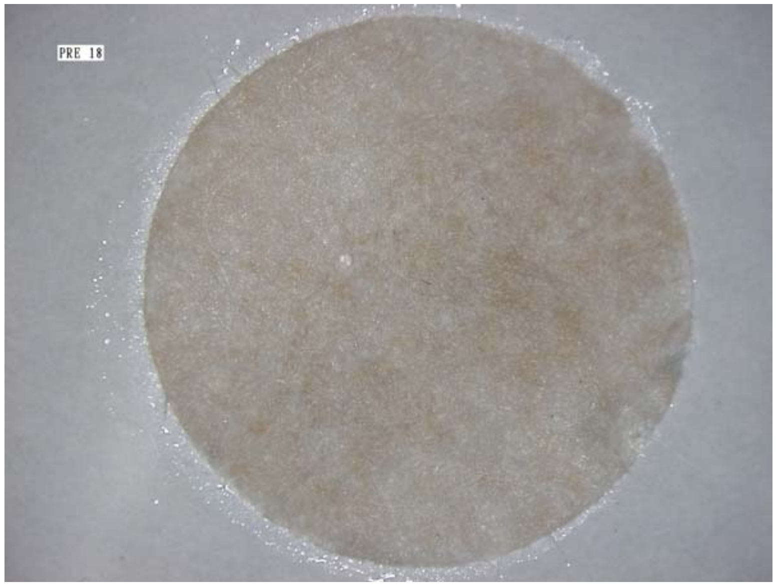

Figure 11: 9 mm semi-automatic clean pre-swipe.

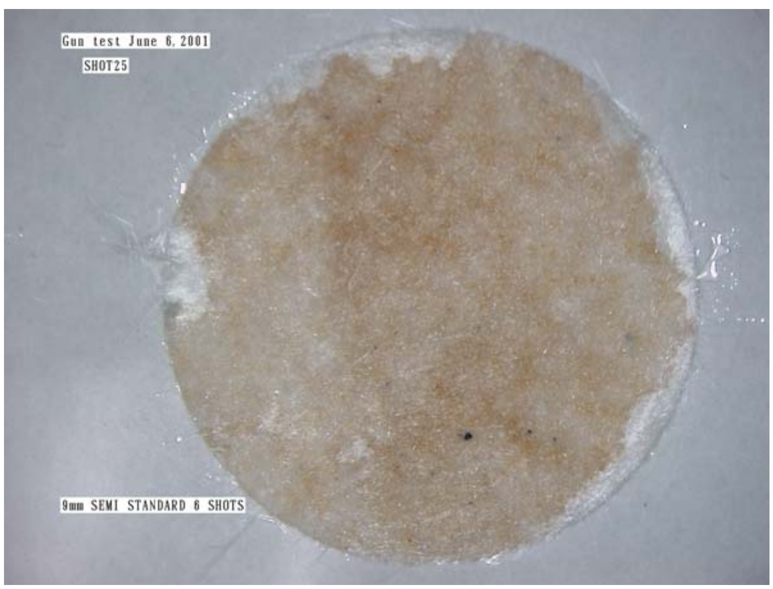

Figure 12: 9 mm semi-automatic positive results on post-swipe after 6 shots.

Figure 13: 45 automatic clean pre-wipe.

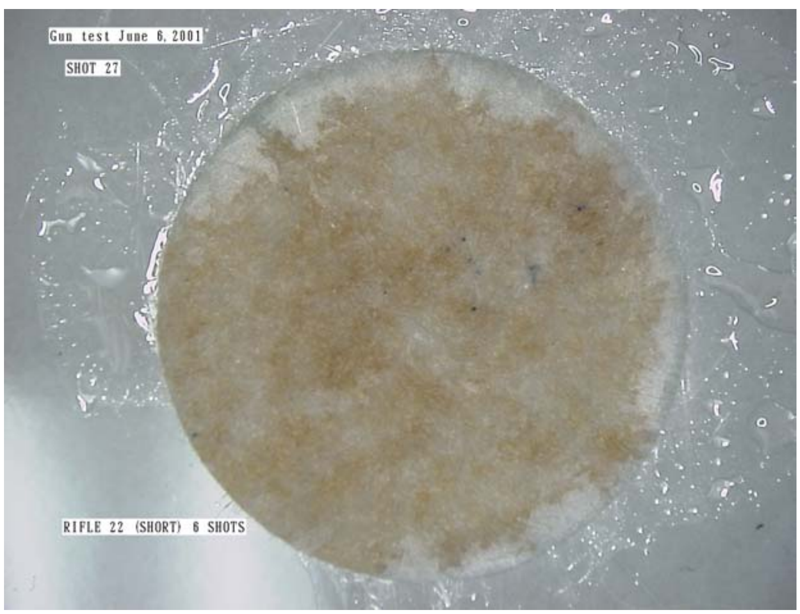

Figure 14: 45 automatic positive results on post-swipe after 6 shots.

Figure 15: 12 ga. shotgun clean pre-swipe.

Figure 16: 12 ga. shotgun positive results after 3 shots.

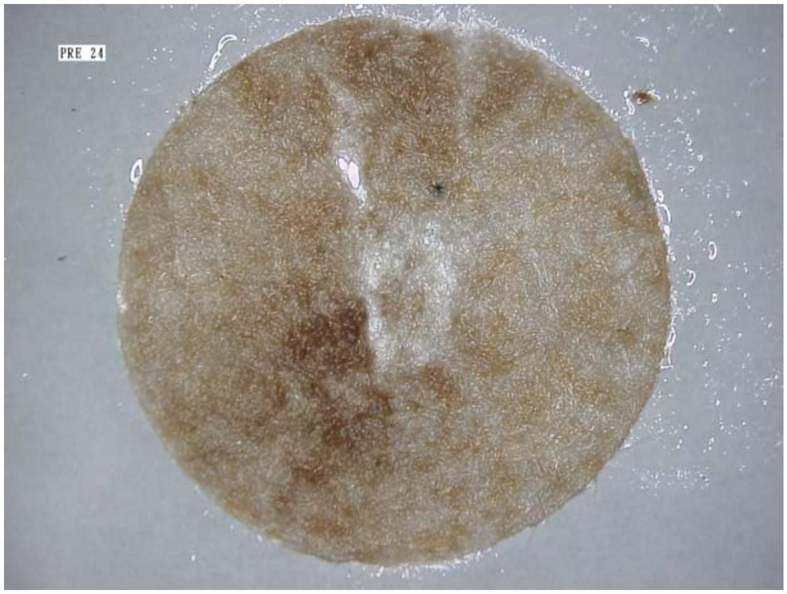

Figure 17: 20 ga. shotgun positive results on pre-swipe.

Shooter was part of the set-up team.

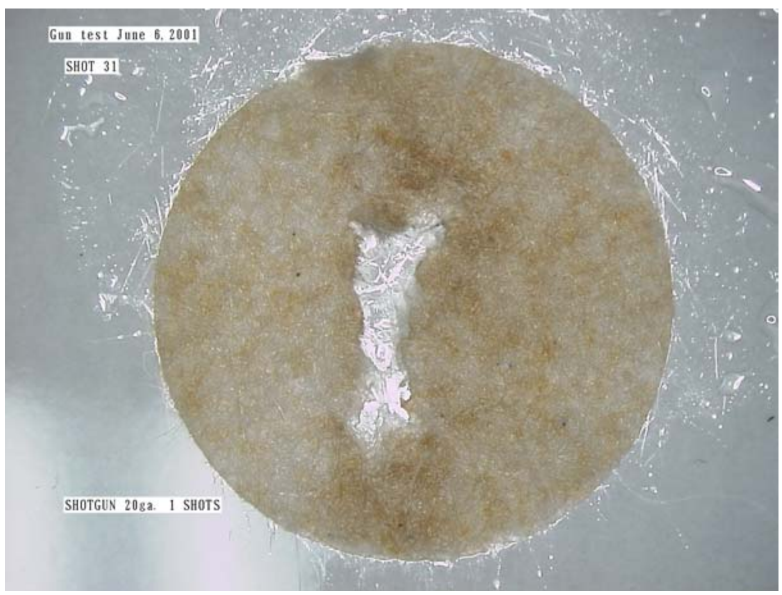

Figure 18: 20 ga. shotgun positvie results on post-swipe after 1 shot.

(This swipe was rubbed sufficiently hard on the hand and a hole was made.)

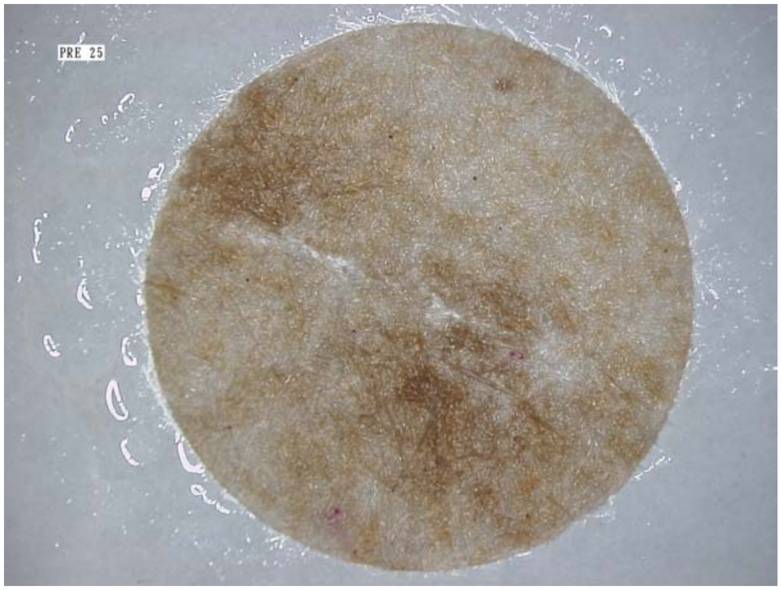

Figure 19: 20 ga. shotgun positive results on pre-swipe.

Shooter was part of the set-up team.

Figure 20: 20 ga. shotgun positive results on post-swipe after 3 shots.

Figure 21: 22 rifle (short ammo) clean pre-swipe.

Figure 22: 22 rifle (short ammo) positive results on post-swipe after 6 shots.

Figure 23: 308 rifle clean pre-swipe.

Figure 24: 308 rifle positive results on post-swipe after 6 shots.

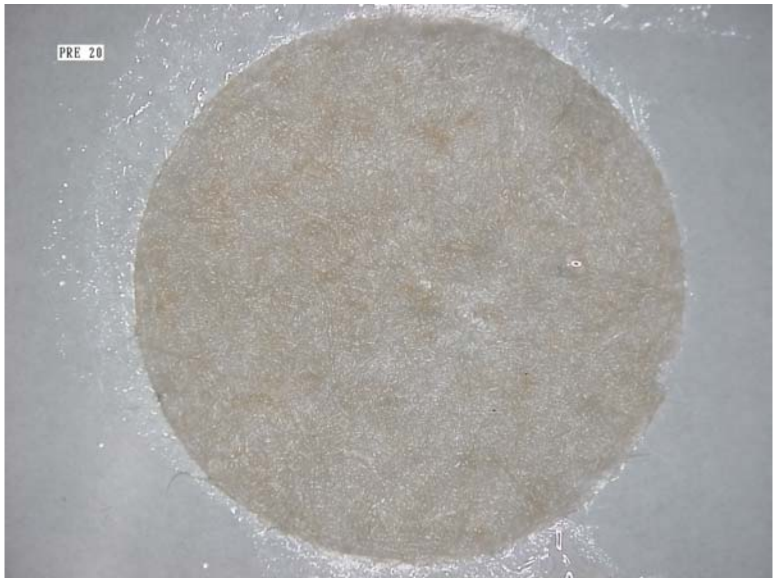

Figure 25: 22 rifle (long ammo) clean pre-swipe.

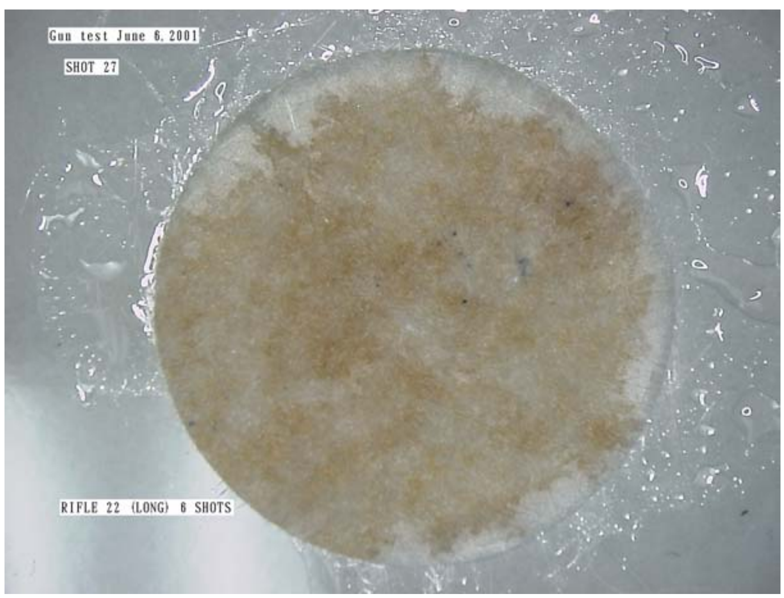

Figure 26: 22 rifle (long ammo) positive results on post-swipe after 6 shots.

Distribution

1	MS 0953	Jim Rice
1	MS 0521	Tom Cutchen
1	MS 0457	John Stichman
1	MS 1452	Bill Marshall, 2552
1	MS 1453	Greg Scharrer, 2553
1	MS 1454	Lloyd Bonzon, 2554
1	MS 0763	Gordon Smith, 5861
1	MS 1380	Kevin McMahon, 1321
5	MS 1452	Pam Walker, 2552
5	MS 1452	Phil Rodacy, 2552
3	MS 1452	Susan Bender, 2552
1	MS 1454	Dave Paul, 2554
1	MS 1454	Mike Bernard, 2554
1	MS 1454	Roy Dickey, 2554
1	MS 9018	Central Technical Files, 8945-1
2	MS 0899	Technical Library, 9616
1	MS 0612	Review and Approval Desk, 9612 for DOE/OSTI