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Improved Method for Shooting Distance Estimation. Part 1. Bullet Holes in Clothing Items

REFERENCE: Glattstein B, Vinokurov A, Levin N, Zeichner A. Improved method for shooting distance estimation. Part 1. Bullet holes in clothing items. J Forensic Sci 2000;45(4):801–806.

ABSTRACT: An improved method for firing distance estimation on clothing is described. The novel part of the method includes transfer of total nitrite (nitrite ions and smokeless powder residues) from the target to an adhesive lifter. After the transfer, lead and copper deposits around the bullet entrance hole are visualized by rhodizonate and rubeanic acid, respectively. The Modified Greiss Test is carried out after alkaline hydrolysis of the smokeless powder residues on the adhesive lifter.

KEYWORDS: forensic science, shooting distance, adhesive lifter, Griess reagent, sodium rhodizonate, rubeanic acid

The range from which a weapon has been fired is an important component in the reconstruction of firearm-related offenses (murder, suicide, accident). The firing distance estimation is based on the examination of the visual patterns of gunshot residues (GSR) around the bullet entrance hole and on the examination of these patterns after their visualization by specific color reactions. There are many variables with gunshot residue that will affect the GSR pattern, such as: distance, caliber, weapon type, target material, muzzle-target angle, and propellant type. For this purpose quantitative determination of metallic components of GSR, by methods such as atomic absorption spectroscopy (AAS) (1,2) or neutron activation (3), are applied also. The reported visualization methods include examination of only lead and nitrite patterns.

Lead distribution pattern is obtained by one of two methods:

1. The sheet printing method (SPM) combined with the sodium rhodizonate test (SRT) using white filter paper (4), or
2. By compression and diffusion onto an acetic acid—soaked cellophane foil in which the lead is precipitated as a brownish lead sulfide (5).

Nitrite distribution pattern, originating from the burned smokeless powder, is obtained by the SPM using fixed photographic paper soaked with reagents prior to use, for the Modified Griess Test (MGT) (6).

These tests are usually carried out in sequence. The sequence proposed by the FBI laboratory (7) is MGT first, followed by SRT. They claim also that particulate lead is a random nonreproducible phenomenon and the presence of vaporous lead is quite significant in that it is found principally at closer ranges. Our experience, as described later, supports these observations.

Before starting the estimation of the shooting distance it is desirable to determine that the hole is a bullet entrance hole. This can be done by applying methods for chemical visualization of lead (rhodizonate) and copper (rubeanic acid) at the perimeter of the hole (8). However, we could not visualize lead in the perimeter of the bullet entrance hole in all shooting cases, although it was known that a lead bullet was used. A similar phenomenon was observed for copper.

The widely used MGT detects only free nitrite ions formed from the combustion of the smokeless powder. The unburned smokeless powder particles cannot be detected by this method. Alkaline hydrolysis prior to the MGT has been proposed to increase the sensitivity of the test (9). The purpose of the alkaline hydrolysis is to cause disproportionating of the unburned nitrocellulose and nitroglycerine (the main components of the smokeless powder) to carbonyl compounds and free nitrite ion, thus increasing the available amount of nitrite ions for MGT. We have introduced this modification in the procedures used for the firing distance estimation in our laboratory.

Modification of the reagents in the MGT method which increases the color intensity was reported by us previously (10).

Some problems reported when the MGT is employed directly on the clothes are (11):

(a) Some types of clothing were damaged when treated by the hot press.
(b) On some woolen surfaces, the fixed photographic paper obtained a uniform orange color which interfered with the color obtained with the Griess reaction.

Some other problems were encountered when the hydrolysis procedure was carried out before the MGT. These are:

(a) Certain types of blue jeans and shoe polish (shoes) (9) were found to cause serious background problems.
(b) Since the hydrolysis step is conducted in a drying oven at 100°C for an 1 h, bloody exhibits may develop an unpleasant odor.

In recent years, several ammunition firms have introduced lead-free ammunition. This technology uses lead-free primers and totally metal-jacketed (TMJ) bullets. The lead bullet core is encased in a copper alloy jacket, thus no lead is exposed at the base where hot gases can vaporize lead (as in conventional full-jacketed bul-

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Received 18 June 1999; and in revised form 21 Sept. 1999; accepted 21 Sept. 1999.

lets). In such cases, because lead is not a component of the gunshot residues, lead patterns cannot be detected for firing distance determination. The zincon reagent which gives a color reaction with zinc and titanium was proposed for firing distance determination in the case of lead-free ammunitions having zinc and titanium in the primer (12).

Visualization of copper deposit distribution may be useful whenever lead-free, copper-jacketed ammunition is used.

In this study we propose an improved method for firing distance estimation on clothes. The method is based on the examination of the visualized patterns of lead, copper, and total nitrite residues around the bullet entrance hole. First, an adhesive lifter is applied on the target to remove gunpowder residues. Then the reagents of the rhodizonate and rubeanic acid are applied on the target itself by the SPM for the visualization of lead and copper deposits, respectively. In the next step an alkaline hydrolysis is carried out on the gunpowder residues removed by the adhesive lifter. This is then followed by the MGT. The use of an adhesive lifter prevents the problems, mentioned above, when carrying out hydrolysis directly on the clothing.

Experimental

The Sheet Printing Method

SPM was applied using a specially designed and built press. This press is operated by compressed air with adjustable pressure and temperature and the compressed area is 30×30 cm^2 (Fig. 1). The press is used in the procedures for lead, copper, and total nitrite visualization.

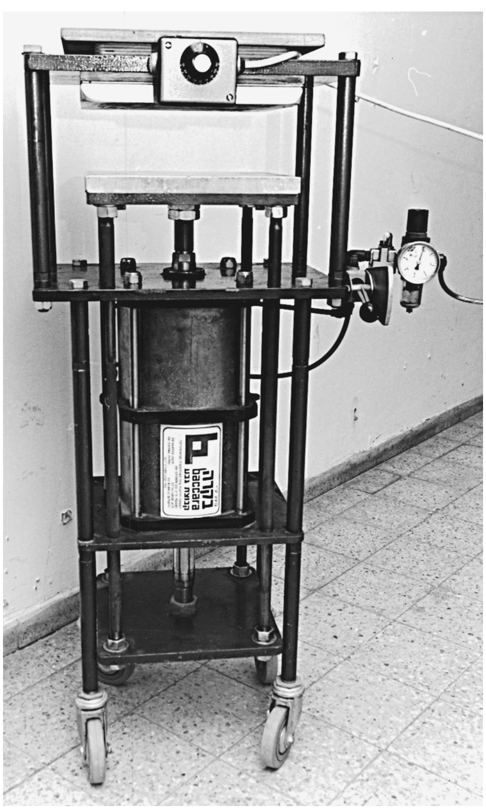

FIG. 1—*Photograph of the press.*

Total Nitrite Pattern Visualization

Materials

1. A "peelable" (low adhesion) transparent adhesive lifter (25×25 cm) with a protective cover (supplied by ISA Ltd., Crasly Street, Bulwell, Nottingham, England).
2. 2% KOH in ethanol.
3. Modified Griess Test (MGT) reagent: 3% sulfanilamide and 0.3% N-(1-naphthyl)ethylenediamine dihydrochloride dissolved in 5% phosphoric acid (AR).
4. Fixed photographic paper.

Procedure

1. The adhesive lifter is placed over the exhibit and subjected to a pressure of about 1.3 atm in the press for 5 s.
2. The adhesive lifter is then removed from the exhibit, attached to a cardboard, and sprayed *lightly* with the KOH solution and placed in an oven at about 100°C for 1 h.
3. The photographic paper is sensitized by dipping in the MGT reagent solution for a few seconds.
4. The excess solution on the photographic paper is removed by wiping with a paper towel. It is important that the excess solution is completely removed. The sensitized paper is placed on the adhesive lifter and subjected to pressure of 1.3 atm in the press at about 70°C for about 1 min.

Lead Pattern Visualization

Materials

1. 10% acetic acid (AR) in distilled water.
2. Freshly prepared 0.2% (w/v) of sodium rhodizonate solution in distilled water.
3. Buffer solution of pH 2.8 (1.9 g sodium bitartarate and 1.5 g of tartaric acid in 100 mL of distilled water.
4. Benchkote (Whatman) filter paper (10×10 cm) stapled to a cardboard.

Procedure

1. The Benchkote filter paper is sprayed with the acetic acid solution.
2. The paper is laid gently on the exhibit, and then both of them are placed in the press subjected to a pressure of 1.3 atm in the press for 2 min.
3. The paper is then removed and sprayed by the sodium rhodizonate solution. Then it is sprayed with the buffer solution.

Copper Pattern Visualization

Materials

1. 10% ammonium hydroxide (AR) in distilled water.
2. Saturated rubeanic acid in ethanol.
3. Benchkote filter paper (10×10 cm) stapled to a cardboard.

Procedure

1. The Benchkote filter paper is sprayed with the ammonia solution.
2. The paper is laid gently on the exhibit, and then both of them are placed in a press subjected to a pressure of 1.3 atm for 2 min.
3. The paper is then removed and sprayed with the rubeanic acid solution.

Ammunition Used and Shooting Experiments

The ammunition used in the experiments were 9 mm parabellum FMJ Winchester Super X and 0.22" LR Winchester copper washed. Shots were fired at a white cotton cloth from a range of contact; 25 and 75 cm for the 9 mm caliber, and contact range, 25 and 65 cm for the 0.22" caliber.

Transfer Efficiency of the GSR from the Target to the Adhesive Lifter

The transfer efficiency of gunpowder residues around the bullet entrance holes to the adhesive lifter was examined as follows: The adhesive lifter was applied on half of the target and the total nitrite was visualized on the adhesive lifter. This was compared to the visualized pattern obtained on the second half of the target.

Experiments were also carried out in a similar manner to examine transfer of lead and copper deposits from the targets to the adhesive lifter. The purpose of the latter experiments was to determine whether the application of the lifter will interfere with the examination of the lead and copper patterns on the target.

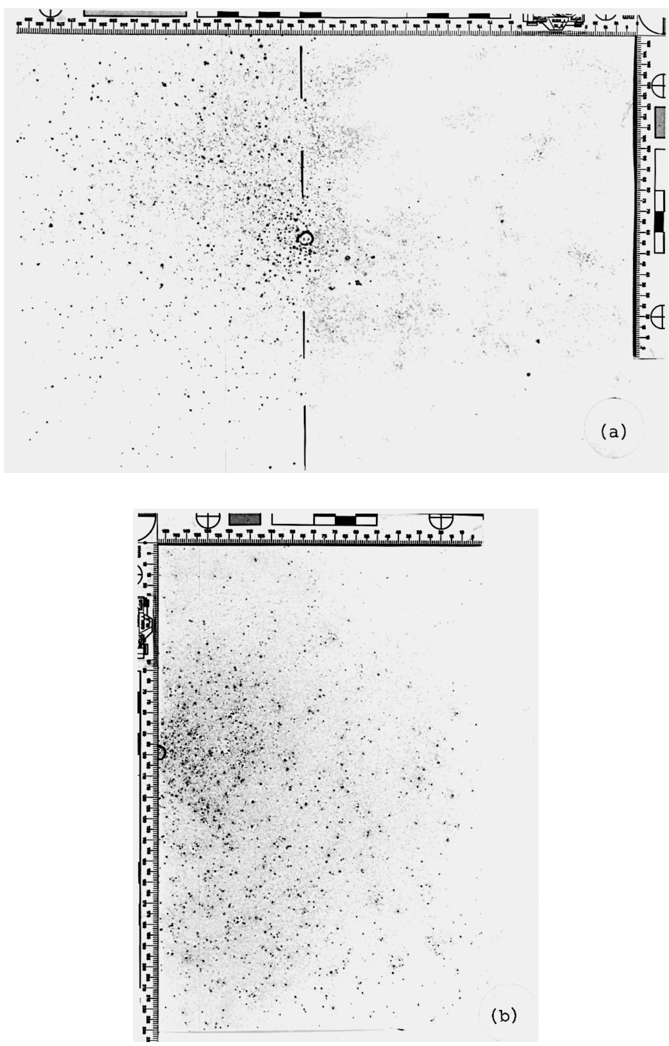

FIG. 2—*Total nitrite pattern in a test shot (ammunition Winchester Super - X 9 mm parabellum FMJ, distance 25 cm) (see also text).* (a) *MGT applied on a white cotton target (after application of the lifter on half of the target). The location of the bullet hole and half of the target are marked in the photographs.* (b) *MGT is applied on the adhesive lifter. The location of the bullet hole is marked as a half circle on the photograph.*

The 9 mm Winchester Super-X ammunition was chosen to demonstrate the importance of the hydrolysis prior to applying MGT for visualization of the nitrite pattern.

Results

The following results were observed regarding the transfer efficiency of gunpowder residues of lead and copper to an adhesive lifter from the cotton targets.

(a) Almost a complete transfer of gunpowder residues to the adhesive lifter was obtained (Figs. 2–5).
(b) Almost no transfer of lead and copper deposits as vapor (continuous deposit) was observed in the contact and near-contact shooting ranges.
(c) Most of the lead and copper in the form of particles was transferred to the adhesive lifter.

Discussion

Based on the obtained results, we can conclude that the distribution of lead, copper, and gunpowder residues around the entrance

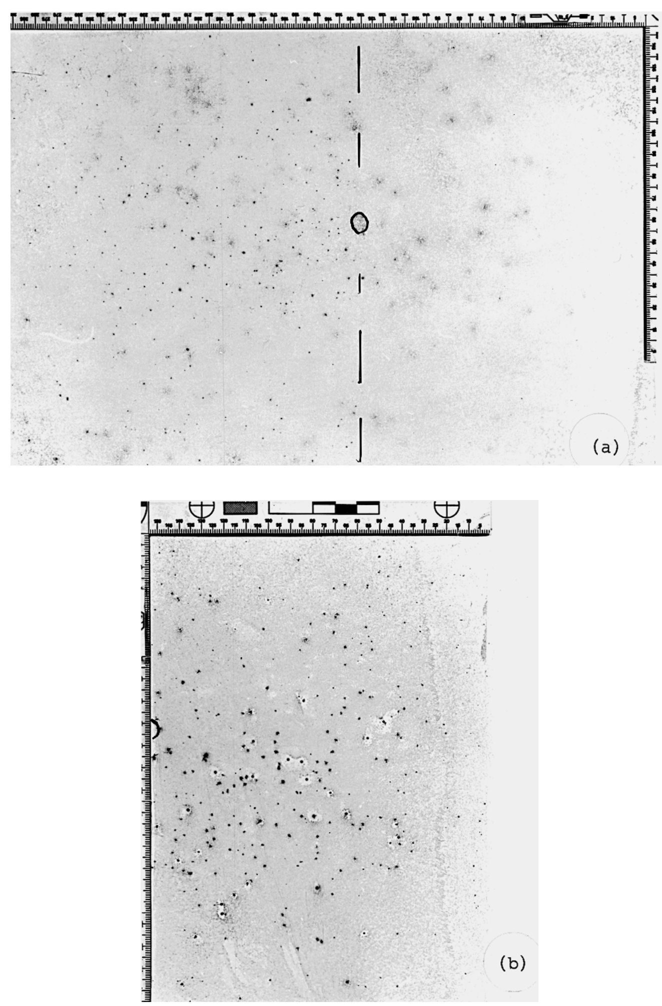

FIG. 3—*Total nitrite pattern (as in Fig. 2) in a test shot (ammunition Winchester Super - X 9 mm parabellum FMJ, distance 75 cm).* (a) *MGT applied on a white cotton target.* (b) *MGT applied on the adhesive lifter.*

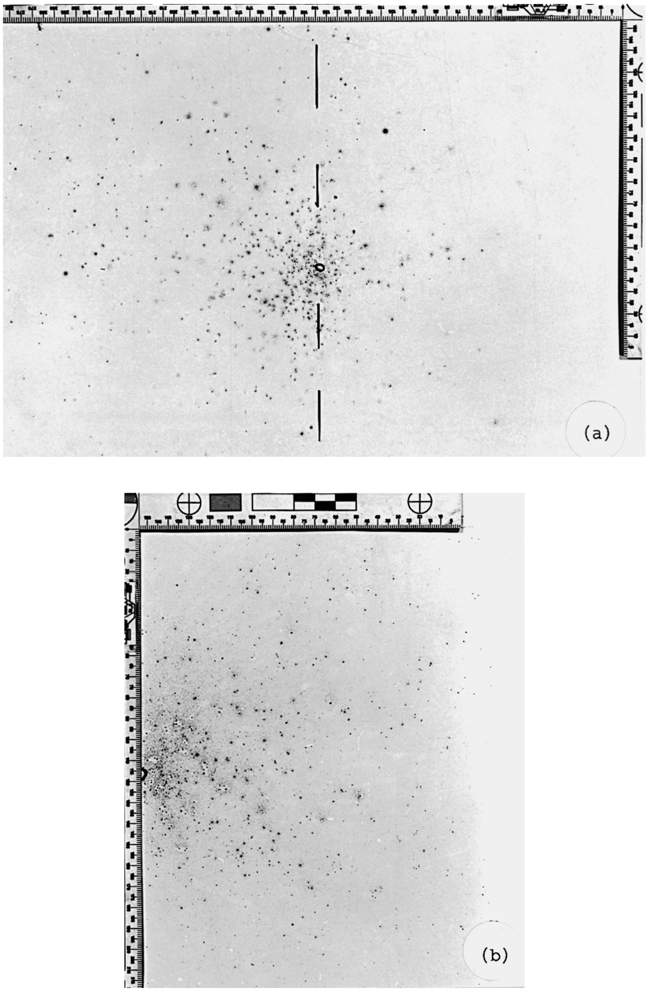

FIG. 4—*Total nitrite pattern (as in Fig. 2) in a test shot (ammunition Winchester 0.22″ LR, copper washed, distance 25 cm).* (a) *MGT applied on a white cotton target.* (b) *MGT is applied on the adhesive lifter.*

bullet hole may serve for shooting distance estimation in the following manner:

(a) First, gunpowder residues are lifted from the target by an adhesive lifter. It was shown that practically all such residues are lifted. They may be visualized on the lifter without facing the problems encountered with the direct total nitrite visualization on the clothing targets. The “peelable” adhesive lifter hardly lifts fibers that may interfere as a background from clothing.

(b) After the removal of the gunpowder residues, lead and copper deposits may be visualized on the target using rhodizonate and rubeanic acid reagents, respectively. This step should be carried out after the lifting of gunpowder residues with an adhesive lifter, because applying the Benchkote filter paper on a target lifts part of the gunpowder residues. Only lead and copper patterns found in the form of vapor will serve for shooting distance estimation. Such a pattern occurs only at close ranges and is not removed by the lifter. On the other hand, as we observed, particulate lead and copper are mostly transferred to the lifter. In addition, as was reported (7), particulate lead is a random nonreproducible phenomenon and therefore is not reliable for shooting distance estimation. Our experience confirms this observation not only for lead, but also for copper as well. Thus the transfer of the particulate lead and copper to the adhesive lifter is not relevant to shooting distance estimation.

The different behavior of vaporous, in contrast to particulate lead and copper, may be explained in the following way.

When a firearm is discharged, the gunpowder ignites with an increase in temperature to about 3600°C. The temperature in the cartridge rises to 1500 to 2000°C (13). Bullets, typically made of lead or jacketed with copper alloys, are exposed to this high temperature of the discharge environment. These metals, when vaporized, may be deposited as a cloud on the target at short ranges, and as discrete particles or as a fine coating on smokeless powder particles in the longer range (7). When the metal is in the form of vapor, it probably condenses and solidifies on the textile. Thus it is incorporated in the target and it is impossible to remove it with the adhesive lifter. Figure 6 shows that at close ranges, copper deposits on a target as vapor, similarly to lead. On the other hand, in the longer ranges a considerable part of the metal residues is probably in the form of cooled solid particles. Therefore, the adherence to the textile may be expected to be much less as is demonstrated by their ef-

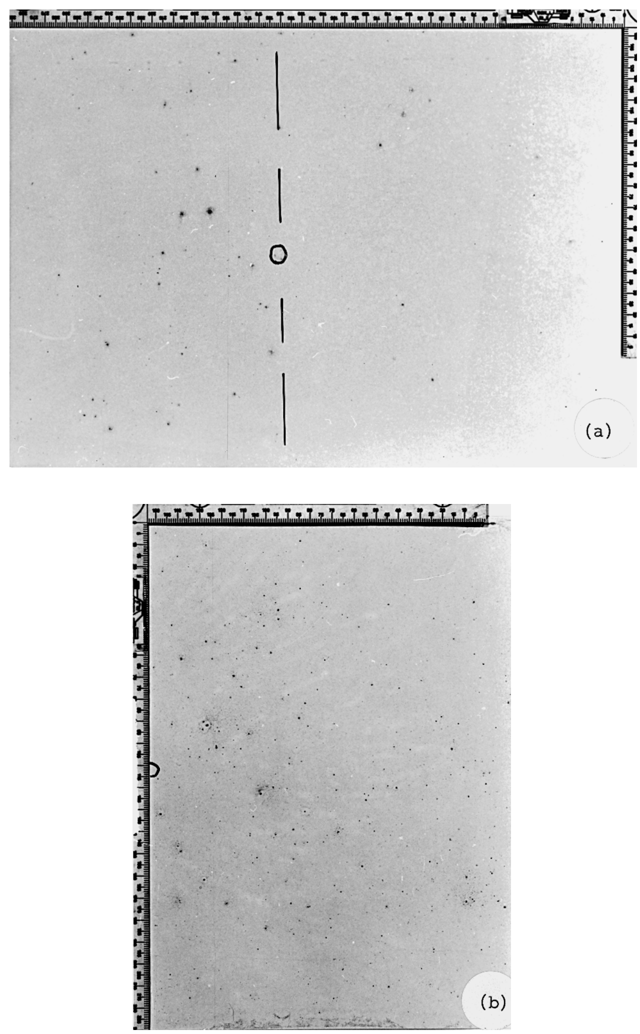

FIG. 5—*Total nitrite pattern (as in Fig. 2) in a test shot, ammunition 0.22″ Winchester LR, copper washed, distance 65 cm.* (a) *MGT applied on a white cotton target.* (b) *MGT applied on the adhesive lifter.*

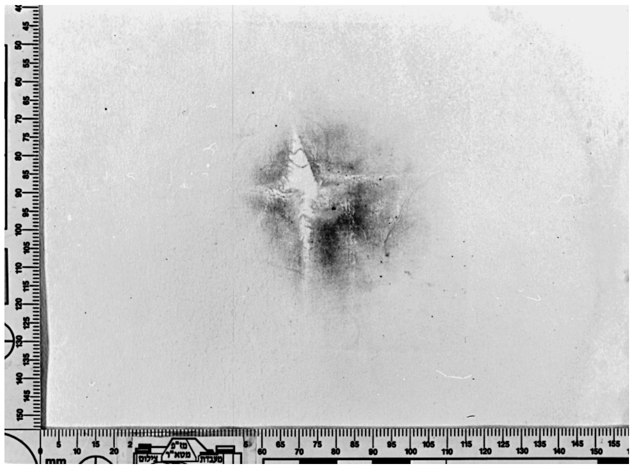

FIG. 6—*Visualization of a copper deposit in contact range on the a cotton target, ammunition Winchester 0.22′ LR.*

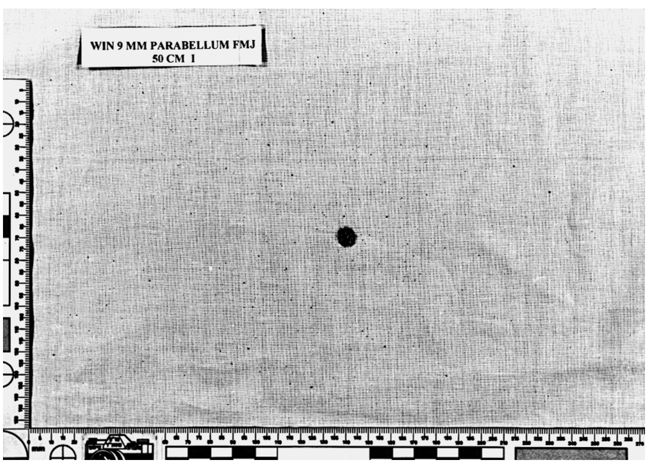

FIG. 7—*Visual gunpowder residue pattern in the test shot on a white cotton target, ammunition 9 mm Winchester Super-X FMJ, distance 50 cm.*

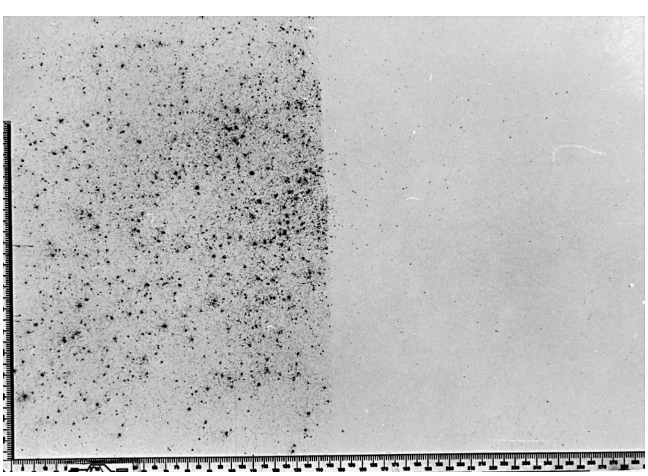

FIG. 8—*The target in Fig. 7 after applying MGT: Right half of the target without hydrolysis prior to MGT. Left half of the target with hydrolysis prior to MGT.*

ficient removal using the adhesive lifter. Probably gunpowder residues impinge on the target mostly as solid particles. Their adherence to the textile is not strong enough to prevent their complete removal by the adhesive lifter.

The importance of the hydrolysis step in the gunpowder residue visualization is demonstrated in Figs. 7 and 8. As may be seen in this type of ammunition (Winchester Super-X), the difference in patterns obtained with and without hydrolysis is very large. Thus, in such cases, it is very important to carry out hydrolysis prior to the MGT. Based on the authors' experience, not all ammunition types demonstrate such a hydrolysis step difference.

It should be noted that the procedure for visualization of the gunpowder residues on the adhesive lifter (hydrolysis followed by MGT) may be repeated without any loss of information. A possible explanation for this phenomenon is that there is a local stoichiometric excess of hydrolyzable nitrite compounds in a particle compared to the available quantity of the base. This possibility may be very important in the legal process, since the defense experts may use it for the reexamination of the evidence. This procedure cannot be carried out again directly on the cloth target (without using the lifter), since the photographic paper picks up part of the particles from the target. This does not happen with the adhesive lifter. The procedure for the visualization of vaporous lead and copper deposits on the shot target may be repeated as well. It should also be pointed out that it is important to spray the alkaline solution lightly on the lifter for the hydrolysis step. Also, the fixed photographic paper sensitized with the MGT reagent has to be wiped with a tissue paper before the application of the lifter. These steps prevent smear of the colored reaction products on the photographic paper, because the adhesive lifter is not an absorbing medium as is textile.

As mentioned previously, when total metal jacket ammunition is used (e.g., lead-free ammunition) no lead pattern will be visualized and only copper visualization can serve for bullet entrance hole detection and for close firing range estimation. In our experience, in cases when full-metal jacket or copper-washed ammunition is used, the copper pattern around the bullet entrance hole after visualization by the rubeanic acid is always much more pronounced than the lead pattern after visualization by the rhodizonate.

Acknowledgments

The authors would like to express their thanks to Mr. Leizer Sin-David from the photography lab for his photography assistance and to Mr. Azriel Gorski for his assistance in editing the manuscript.

References

1. Sellier K. Shot range determination. Forensic Sci Prog 6, Berlin, Heidelberg: Springer-Verlag 1991.
2. Krishnan SS. Firing distance determination by atomic absorption spectrophotometry. J Forensic Sci 1974;19:351–6.
3. Krishnan SS. Firing distance determination by neutron activation analysis. J Forensic Sci 1967;12:471–83.
4. Bashinsky JS, Davis JE, Young C. Detection of lead in gunshot residues on targets using the sodium rhodizonate test. AFTE 1974;6(4):5–6.
5. Leszczynski Ch. Die Bestimmung der Schubentferung, Kriminalistik 13, 1959;377–82.
6. Dillon JH. The modified Griess test: A chemically specific chromophoric test for nitrite compounds in gunshot residues. AFTE 1990; 22(3):243–50.
7. Dillon JH. A protocol for gunshot examination in muzzle to target distance determination. AFTE 1990;22(3):257–74.
8. Steinberg M, Leist Y, Tassa M. A new field kit for bullet hole identification. J Forensic Sci 1984;29(1):169–76.
9. Raverby M. Determination of firing distance by total nitrite. Interna-

tional Congress on Techniques for Criminal Identification and Counter Terrorism 1985, Identa-85, Jerusalem, Israel.
10. Zeichner A, Glattstein B. Improved reagents for firing distance determination. J Energetic Mat 1986;4:187–97.
11. Bonfanti M, Gallusser A. Problems encountered in the detection of gunshot residues. AFTE 1995;27(2):105–22.
12. Beijer R. Experience with zincon, a useful reagent for the determination of firing range with respect to leadfree ammunition. J Forensic Sci 1994;July;39(4):981–7.
13. Thornton JI. The chemistry of death by gunshot. Anal Chim Acta 1994;288:71–81.

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