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Hand Grenades and Primer Discharge Residues

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ABSTRACT: The feasibility of detecting primer discharge residue (PDR), using the scanning electron microscopy/energy-dispersive X-ray (SEM/EDX) method, on suspects in hand grenade throwing incidents was studied. Two types of hand grenades were examined. It was found that unique primer particles are discharged in close proximity to the thrower and may subsequently be found on his person. In addition, it was found that, with these types of grenades, characteristic particles containing elements such as bismuth and tin may also be found. These particles, when found, may serve as an indication of a suspect's connection to a hand grenade throwing.

KEYWORDS: criminalistics, explosives, primer discharge residues, hand grenades, chemical analysis

Primer particle identification is a well-founded and widespread method used for screening and identifying suspects in shooting incidents [*1–4*]. It may be expanded and used in other cases as well. An example of this is the examination of primer particle residues from rivet guns [*5*]. Another type of case is that of hand grenade throwing, which occurs in both terrorist attacks and crime-related reprisals. These other types of cases inherently require a more general term than gunshot residue (GSR) or cartridge discharge residue (CDR), and we have used the term "primer discharge residue" (PDR). The Division of Identification and Forensic Science (DIFS) of the Israel Police, along with the Bomb Disposal Division, decided to examine the possibility of expanding examinations of primer discharge residues to the screening and identifying of suspects in such incidents.

This decision was encouraged by an actual case in which a hand grenade wrapped in a strip of cloth was thrown by a terrorist into a school yard. The cloth had apparently fallen from the hand grenade after it was thrown but before it exploded. This theory was substantiated by soot marks on the cloth (Fig. 1), which left an outline of the grenade's safety lever. To use the cloth to connect the suspect to the scene of the crime, a primer particle examination was carried out, which resulted in the finding of a vast amount of primer residue particles that matched, in morphology and composition, particles from exploded primers of the same type of grenade.

Finding primer residue particles in grenade throwing incidents is not trivial, as there is a basic difference between the act of shooting and that of throwing a grenade. In the case of shooting, the person holds the gun at the time of firing; in the usual method of

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FIG. 1—*Soot outline of a hand grenade's safety lever found on a strip of cloth.*

grenade throwing, the primer is detonated after the grenade leaves the hand of the thrower.

The following is a concise description of a common hand grenade's mechanism and throwing process, designed to illucidate the subject for those unfamiliar with it (see Fig. 2). The safety pin (A) is removed, and when the grenade is thrown, the safety lever (B) is released and springs away, loosening the firing pin spring (D). The firing pin (C) then springs, striking and igniting the percussion primer (E), which in turn burns the time fuse (F) and explodes the grenade after a set time determined by the manufacturer.

In the Israel Military Industries (IMI) No. 26 grenade, a special hole (H in Fig. 2) sealed with a thin metal foil is located on the side of the mechanism (Fig. 3). This opening, known as a vent-hole, was developed as a safety measure to amplify the sound of the primer's percussion.

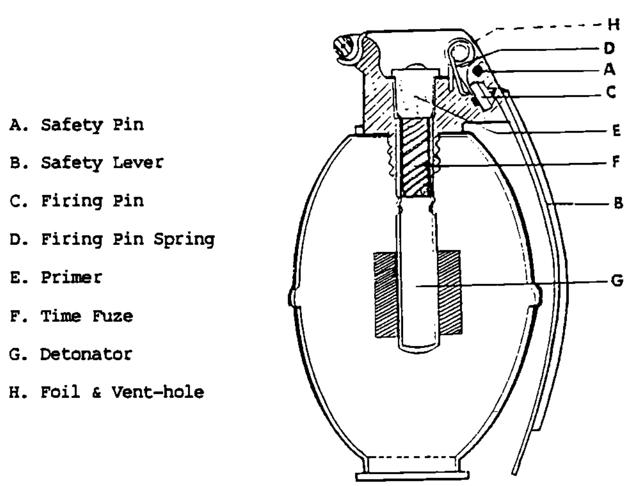

FIG. 2—*Schematic drawing of a hand grenade's mechanism.*

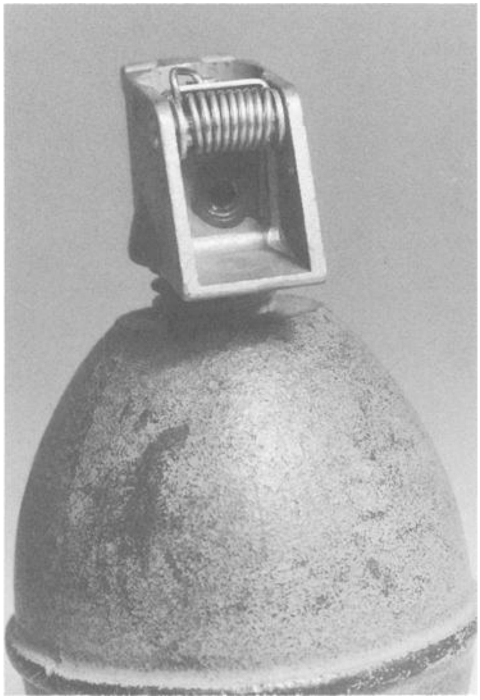

FIG. 3—*The upper part of an IMI No. 26 hand grenade: the vent-hole appears just below the spring at the top.*

Experimental Procedure

IMI No. 26 and Soviet-made F-1 hand grenades were studied and used in this work. The detonator mechanisms in these hand grenades were unscrewed and removed from the fragmentation body containing the explosive, and in some instances, the time fuse also was removed.

These mechanisms were detonated and primer particles were collected for scanning electron microscopy/energy-dispersive X-ray (SEM/EDX) analysis. Two methods were used. In the first, discharged primer particles were sampled directly from within the primer cup after its detonation. In the second, an adhesive-backed stub was positioned 5 cm away from the vent-hole of the mechanism. A divider was placed to make a separation between particles expelled from the opening between the primer and the detonator (which one would not expect to find on the hands of the thrower since this opening leads into the body of the grenade) and those particles expelled from the grenade through the vent-hole (which may reach the thrower).

The sampled particles were then analyzed using a CamScan IV scanning electron microscope equipped with a Seforad (Israel) lithium/silicon detector and a Tracor-Northern TN-5500 energy-dispersive X-ray (EDX) analysis system.

In the next stage, the act of throwing a hand grenade was videotaped using a JVC S-1000 Super-VHS camera. Training grenades fitted with only the detonator mechanism were used in this stage (Fig. 4).

Eleven test throwings were carried out using training grenades fitted with a detonation mechanism. Since the training grenades were reused each time, they were washed in an ultrasonic bath and wrapped in a plastic covering to avoid possible contamination. These test throwings were done both outdoors, with a wind present (nine throwings), and in a

FIG. 4—*Training grenades: (1) Russian F-1, (2) IMI No. 26.*

closed range (two throwings). In all the test throwings, blanks were sampled from the participants' persons before the grenade was thrown.

Each subject was sampled twice immediately after the throwing, using adhesive-backed (3M Scotch Brand tape No. 465) 1-in. (2.54-cm) aluminum stubs. One stub was used to sample the subject's arms and hands. The other stub was used to sample the subject's upper torso, facial area, and hair.

The stubs were then examined in the above-mentioned SEM/EDX system, coupled with the CamScan/Metropolitan Police automatic particle analysis system [*6*].

Results and Discussion

Figure 5 is a typical frame taken from a videotaping of one hand-grenade throwing test. In close proximity to the thrower's hand, the plastic-wrapped grenade can be seen and, evolving from it, a smoke cloud. The same finding was observed in all the other tests.

The initial velocity of the thrown grenade will have an effect on the distance between the cloud of particles and the thrower's hand. In our experiments the throwing distances were between 10 and 20 m. Since the conditions of throwing hand grenades are not predictable, distances of this magnitude are fairly reasonable.

In the past, members of the bomb-disposal unit had thrown training grenades and their hands had been sampled with adhesive stubs [*7*]. SEM/EDX analysis was carried out and the samples were found to contain a vast number of particles containing tin whose origin was unknown. In order to discover where the tin originated from, the mechanism from an IMI No. 26 hand grenade was taken apart and all its materials and components were analyzed.

When the primer cup of this grenade was sampled and analyzed after detonation, the primer particle composition was found to consist of lead (Pb), barium (Ba), and antimony (Sb), with some zinc (Zn) and silicon (Si) (Fig. 6). No copper was found, as opposed to what was reported in the Aerospace Report [*8*]. There, it was noted that a particle containing zinc without copper usually indicates a non-PDR origin. This case is an exception to the rule. In addition, the morphology of the particles was typical of PDR,

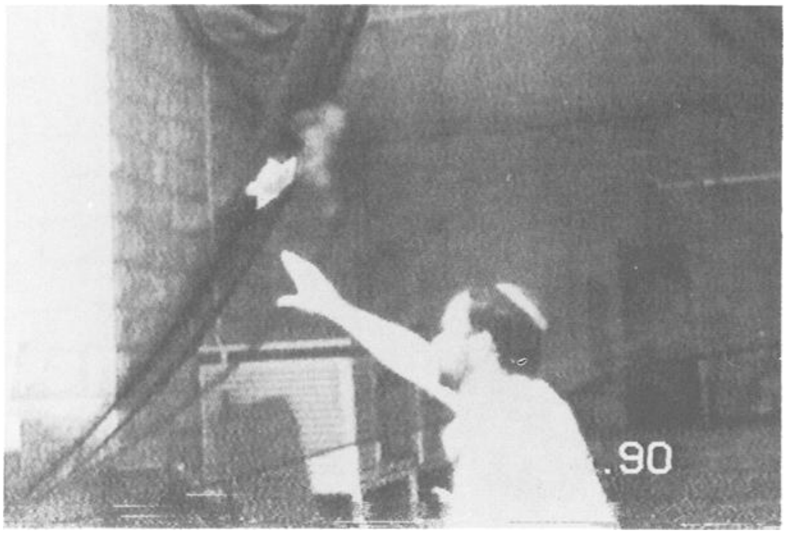

FIG. 5—*Cloud of particles near the grenade thrower's hand.*

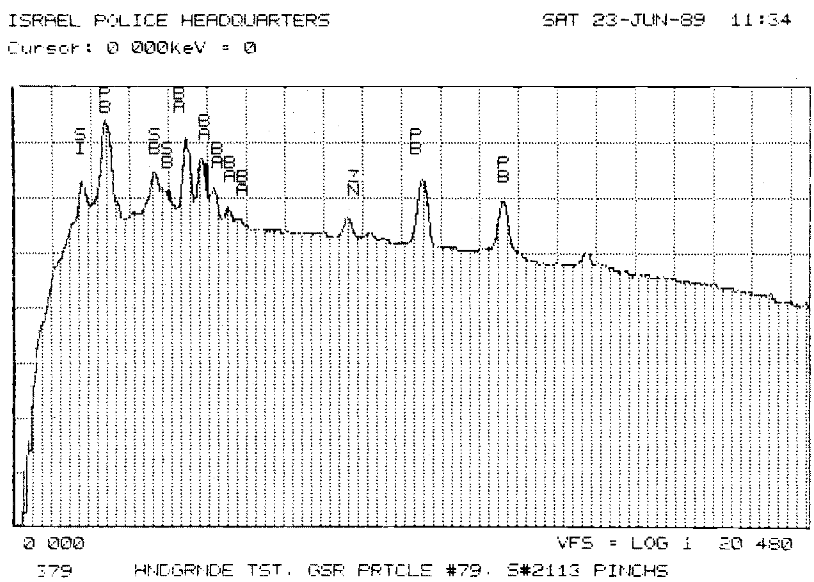

FIG. 6—*EDX spectrum of primer discharge residue from an IMI No. 26 hand grenade, sampled from the primer cup.*

being spherical with nodules. However, when the adhesive stub facing the vent-hole of the grenade was examined after detonation, some PDR particles were found containing tin (Fig. 7). In addition, there were many tin particles with lead. From these findings it was apparent that the source of the tin particles was not the primer but some other source close to the primer. This source of tin (with small amounts of lead) was found to be the foil which sealed the vent-hole. This foil melts at the time of detonation and tin droplets are spread over a wide area (Fig. 8). Since the bomb-disposal unit had made the test throwings using the same training grenade repeatedly, while only changing the detonation

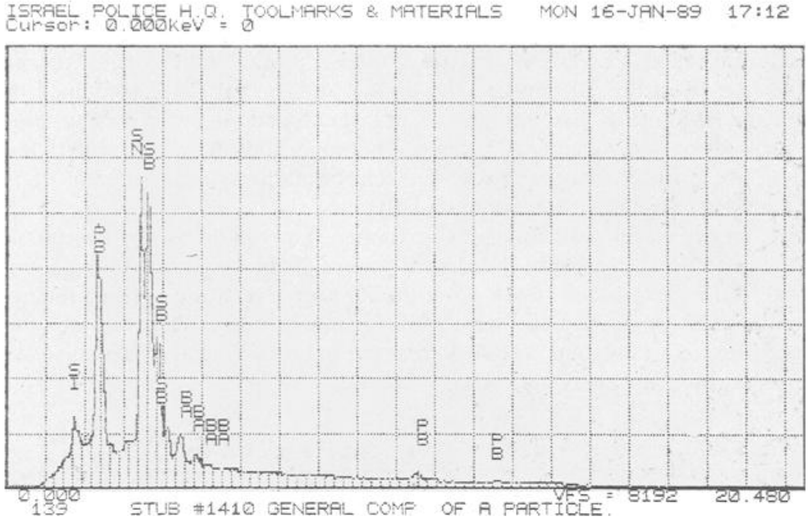

FIG. 7—*EDX spectrum of a primer discharge residue particle, sampled from the thrower, which also contains tin from the vent-hole.*

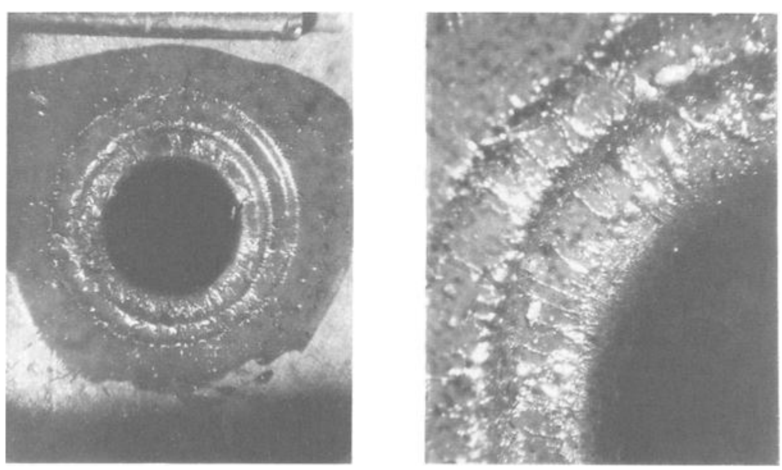

FIG. 8—*Melted tin droplets around the vent-hole:* (left) *overall view,* (right) *enlarged portion of the same figure.*

mechanism, the training grenade had become highly contaminated with tin particles, which in turn were transferred to the throwers.

The particles containing tin in addition to the "unique" elements are similar to the composition found in PDR from Sellier Bellot, Prague (SBP) ammunition. In both the hand grenades and SBP ammunition, tin from a foil synthesizes with the primer to form characteristic residue compositions containing tin. This phenomenon, in which the PDR composition may be affected by surrounding materials, could have important consequences on the concept of its uniqueness.

The second type of hand grenade examined was the Russian-made F-1. From examination of the mechanism, videotaping, and a PDR trap that was set up, it was apparent that a vast number of particles in a cloud leave the mechanism through various openings. Analysis of the particles sampled after detonation revealed a PDR particle composition containing Pb, Ba, and Sb, with small amounts of aluminum (Al) and Si (Fig. 9). In addition, irregular particles containing bismuth (Bi) and chrome (Cr) or bismuth, chrome, and lead were found. SEM/EDX analysis of the F-1 primer and detonator revealed that the time fuse (F in Fig. 2) between the primer and the explosive contained bismuth, chrome, and silicon (Fig. 10). Compounds of bismuth and various chromates are known [*9*] to be used for delay elements of fuses. This connection between bismuth and PDR should be noted since it has been reported that bismuth particles found in PDR SEM/EDX analysis are usually from cosmetics [*10*].

Data from the eleven test throwings performed, nine outdoors and two indoors, are tabulated in Table 1. In eight of the eleven, primer discharge particles were found on at least one of the sample stubs taken from the thrower. Six of the positive findings were from outdoor throwings and two were from the indoor ones. While outdoor throwings are more prevalent in regular casework, cases of indoor throwings, such as in stairwells or apartment buildings, may also be encountered.

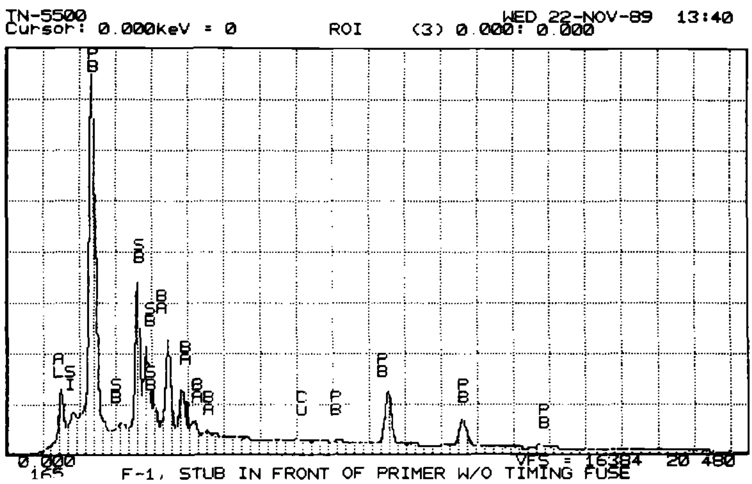

FIG. 9—*EDX spectrum of primer discharge residue from an F-1 hand grenade.*

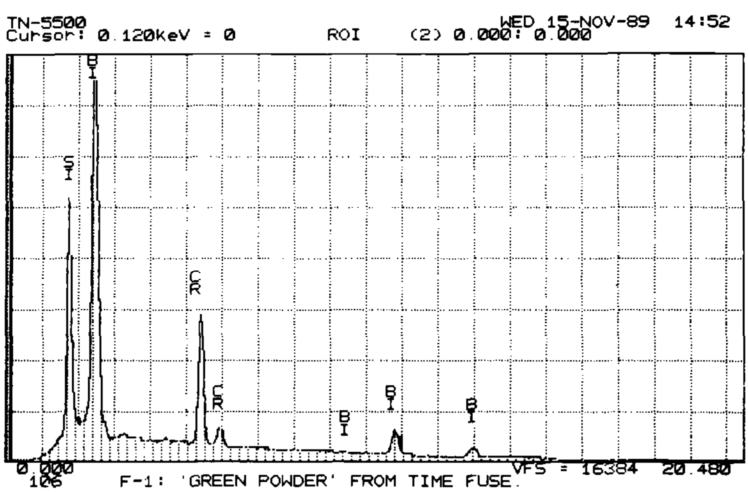

FIG. 10—*EDX spectrum of an F-1 grenade time fuse component.*

TABLE 1—*Results from test throwings of hand granades.*

Test No.	Hand Grenade	Indoor (i)/ Outdoor (o)	Sample from Hands/Arms[a]	Samples from Head/Torso[a]	Remarks
1	IMI No. 26	o	5	...	
2	IMI No. 26	o	...	1	
3	IMI No. 26	o	...	3	many Sn particles on hands
4	IMI No. 26	o	...	...	many Sn particles on hands
5	IMI No. 26	o	...	...	
6	IMI No. 26	i	3	2	many Sn particles on hands
7	IMI No. 26	i	...	2	
8	IMI No. 26	o	...	...	
9	IMI No. 26	o	17	2	9 "Pure," 8 + Sn
10	F-1	o	30	...	Bi + Cr particles
11	F-1	o	1	1	

[a]Number of PDR particles found in 1 cm^2 on the sampling stub.

In the eight instances of positive results, between 1 and 30 PDR particles were found in each. It must be remembered, however, that samples were taken immediately after the throwings. One would expect the particles from hand grenades to behave similarly to those from firearms with respect to their duration of adherence [*11*].[2]

In the test throwings of the IMI No. 26 hand grenade with the positive results, significant numbers of spherical particles containing tin or tin with other PDR-related elements (Pb, Ba, and Sb) were also found. Even in the test throwings in which no unique particles were found, significant numbers of these spherical tin particles were found. These particles, though not unique, may be indicative of a connection to an IMI No. 26 hand grenade throwing (or other grenades with a similar vent-hole foil) if found on a suspect.

Conclusions

Test throwings of Israel Military Industries No. 26 and Russian F-1 training hand grenades were made and videotaped. It was apparent that, in a manner similarly to the act of shooting, a cloud of particles is discharged in close proximity to the thrower, SEM/EDX analysis of the primer discharge residue (PDR) showed that these particles have the characteristic unique lead, barium, and antimony composition found also in gunshot and cartridge discharge residues. These particles were found on samples taken from subjects after the throwing of a hand grenade.

Acknowledgments

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