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A Study of .22 Caliber Rimfire Exploding Bullets: Effects in Ordnance Gelatin

REFERENCE: Josselson, A. R., Johnson, A. C., Washington, W. D., Wagner, G. N., Garner, D. D. Johnson, F. B., and Lundy, D. R., **"A Study of .22 Caliber Rimfire Exploding Bullets: Effects in Ordnance Gelatin,"** *Journal of Forensic Sciences*, JFSCA, Vol. 30, No. 3, July 1985, pp. 760–772.

ABSTRACT: This is a study of commercially available .22 caliber rimfire ammunition manufactured to explode on bullet impact. Factors considered were bullet velocity, angle of impact, missile deformation, and depth of penetration and cavitation in ordnance gelatin. Microscopic, radiographic, and high speed motion picture photographic techniques were employed. This study found that the angle of impact was critical for detonation of the bullet.

KEYWORDS: criminalistics, ballistics, wound ballistics, exploding bullets

Exploder bullets of this particular type were developed for use against animate targets [*1–3*]. The purpose of the exploding projectile is to transfer to the target the combined energy of the bullet and the explosive charge contained therein. It is designed to detonate on impact, creating a larger wound cavity than the standard bullet. In addition, the projectile fragments into many small particles during the explosion. In theory this would preclude the bullet from penetrating the target completely and perhaps striking a second unintentional target. Menzies and Anderson [*1*] and Hammond et al [*4*] discuss and summarize a bullet's effectiveness in relationship to safety in law enforcement use. Exploding bullets are commercially available in calibers ranging from .22 to .45 caliber. This study involves .22 caliber bullets, their impact with 20% ordnance gelating and wounding potential.

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Air Force, the Department of the Navy, or the Department of Defense. Received for publication 25 June 1984; revised manuscript received 23 Nov. 1984; accepted for publication 24 Nov. 1984.

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Materials and Methods

The explosive bullets studied were .22 long rifle (LR) caliber rimfire ammunition marketed under the name "Devastator" and manufactured by Bingham, Ltd., Atlanta, GA. This ammunition was obtained commercially in boxes of twelve cartridges insulated by polyurethane foam (Fig. 1).

The Devastator bullets were fired from the following .22 LR caliber firearms:

(1) RG Industries revolver, Model RG 14, 44.5-mm (1-3/4-in.) barrel;
(2) Smith and Wesson revolver, Model 34, 101.6-mm (4-in.) barrel;
(3) Colt semi-automatic pistol, Hunstman Model, 152.4-mm (6-in.) barrel;
(4) Colt single-action revolver, Buntline Scout Model, 241.3-mm (9-1/2-in.) barrel;
(5) Colt single-action revolver, Frontier Scout Model, 304.8-mm (12-in.) barrel;
(6) Armalite semi-automatic rifle, Model AR-7 Explorer, 4.06.4-mm (16-in.) barrel; and
(7) Anschutz bolt-action rifle, Junior Varminter Model, 552.5-mm (21-3/4-in.) barrel.

For control purposes, .22 caliber LR Remington standard velocity lead cartridges, .22 caliber LR Winchester copper-coated lead cartridges (Super-Speed®), and .22 caliber LR Omark-CCI copper-coated hollow-point lead cartridges (Mini-Mag) were also evaluated.

One Devastator and three Super-Speed rounds were fired from each firearm through photoelectric screens connected to a computing chronograph (Model 4001, Electronic Counters, Inc.). At least one Devastator round from each firearm was fired at a 90° angle from a distance of 0.6 m (2 ft) into 20% gelatin blocks (Pharmagel A, Ordnance Type 250 A, Kind and Knox Gelatin Co.) which measured 12.7 by 12.7 by 36 cm (5 by 5 by 14 in.). The impact was recorded on film (Kodak® 4-X Reversal Film 7277) using a Hycam high-speed motion-picture camera at 8000 frames per second. For comparison, similar data was collected using the control ammunition. Firing perpendicularly from 0.6 m (2 ft), the depth of penetration into each block and the size of the temporary cavity formed by the explosion of the Devastator bullets were measured. Similar measurements were obtained on the control bullets. Each block was radiographed with a Faxitron® Model 805, Radiographic Inspection System, (Field Emmission Corp., McMinnville, OR) using Kodak XTL-2 film and photographed. Devastator bullets were then fired from the RG-14 revolver into gelatin blocks at angles of

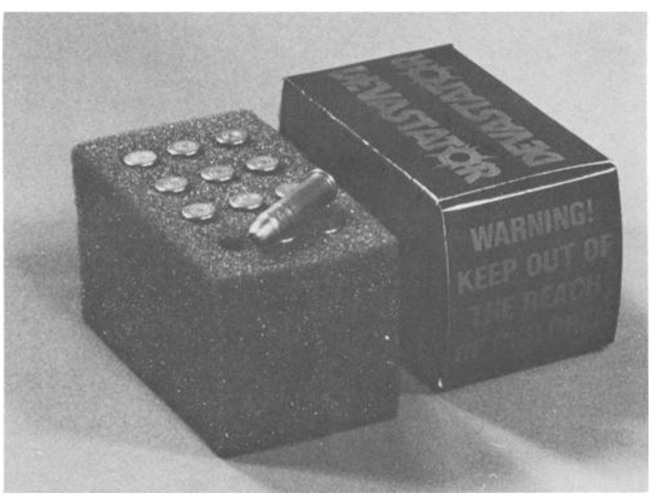

FIG. 1—*Exploding bullets obtained commercially in boxes of twelve cartridges insulated by polyurethane foam.*

approximately 80, 70, 60, 45, and 30°. Additionally, at 90° Devastator bullets were fired from this revolver at distances up to 9 m (30 ft) into gelatin blocks.

One Devastator bullet was mounted in Castolite Resin, 20-8120-009 (Buehler, Ltd., Evanston, IL) and cut with an Isomet low speed diamond saw (Buehler). Two Devastator bullets were disassembled, photographed, and analyzed. Portions of gelatin blocks containing particulate materials of exploded bullets were dissolved in water at 60°C. The particles were collected on a Whatman No. 1 filter paper, washed with water at 60°C and transferred to carbon discs. These were coated with carbon and examined in a Philips 501B scanning electron microscope (SEM) with an EDAX 711 energy dispersive X-ray analysis system (EDX).

The relative incapacitation indices (RII) for the Devastator bullets fired from the RG-14 revolver, Colt (241.3- and 304.8-mm [9-1/2 and 12-in.]) revolvers, and the AR-7 rifle as well as the Winchester (Super-Speed) bullet fired from the RG-14 revolver were calculated.

The RII was developed in 1979 by the U.S. Army Ballistic Research Laboratory (BRL) to study the terminal effects of police handgun ammunition. A three-dimensional computer code of the human body, the "Computer Man," was constructed and each of many tiny volume units (5 by 5 by 25 mm) of the model was given a relative value ("Vulnerability In-

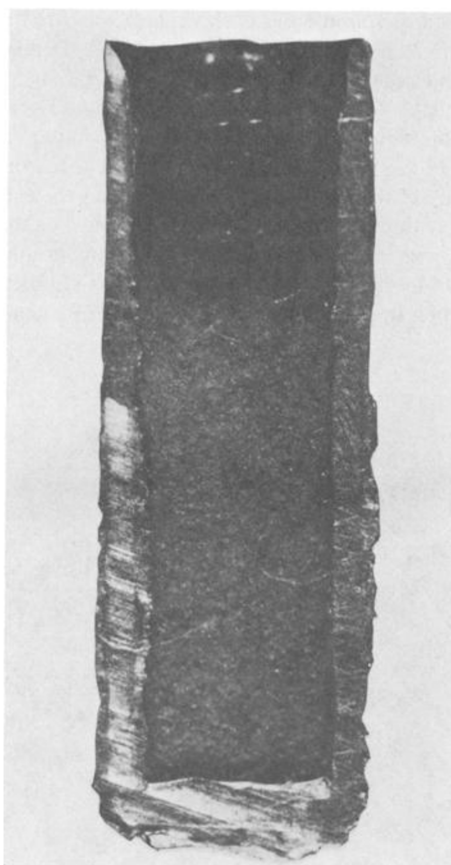

FIG. 2—*Cross section of cylinder with explosive charge.* ×18.

dex") in regard to its overall importance with regards to instant incapacitation of that unit by a handgun bullet. This Vulnerability Index (VI) is thus a measure of the relative importance of body tissue to stopping power along the path the bullet travels through the body. The test bullets were shot into gelatin blocks and, using high-speed motion-pictures, the radius of the temporary cavity at 1-cm increments measured. A formula was then developed to indicate relative bullet effectiveness (RII) [5]:

$$RII = \int_{x=0}^{x=\text{maximum penetration depth}} V_1 \cdot R^2 c \, dx$$

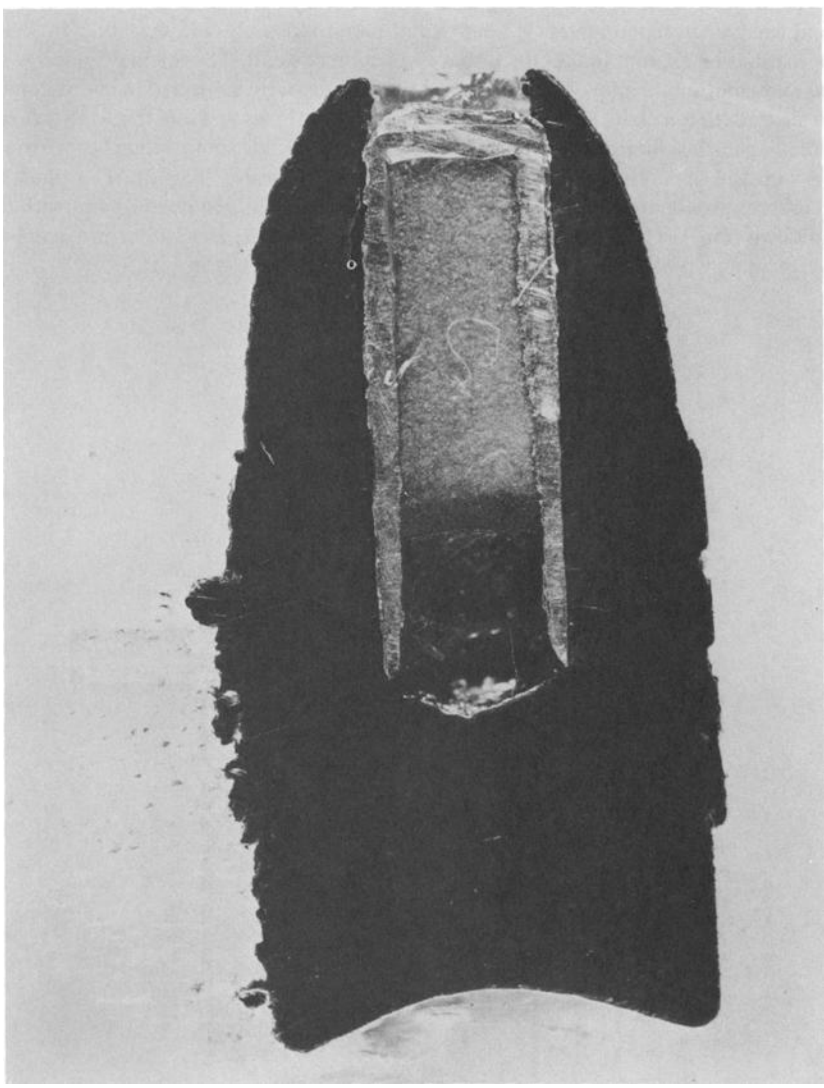

FIG.3—*Cross section of .22 cal. Devastator.* ×18.

where

R_c = radius of temporary cavity, cm;

V_1 = vulnerability index at x, cm; and

x = depth of penetration into gelatin, cm.

Results

Ammunition Design

Two Devastator cartridges were disassembled and subjected to chemical and physical examinations. The .22 caliber LR Devastator cartridge is a modified .22 caliber LR, hollow-point, copper-coated lead cartridge (CCI Mini-Mag®) manufactured by Omark-CCI, Inc., Lewiston, ID. The CCI Mini-Mag bullet is modified by deep drilling of the existing hollow-point cavity to accept a metal cylinder (length: approximately 6.35 mm [0.25 in.], diameter approximatley 2.1 mm [0.083. in.]) that is open on one end. The metal cylinder was identified as an aluminum alloy. The contents of the cylinder were subjected to microscopic, infrared spectrophotometric, and X-ray spectrometric techniques and identified. Before insertion in the bullet, the aluminum canister is filled with a lead azide composition (approximately 24 mg) and the open end sealed with a nitrocellulose adhesive (Fig. 2). The filled cylinder (weight: approximately 52 mg) is then inserted into the enlarged hollow point with the open end down (Fig. 3). The components and construction of the Devastator projectile (weight: approximately 34 grains or 2.2 g) are shown diagrammatically in Fig. 4.

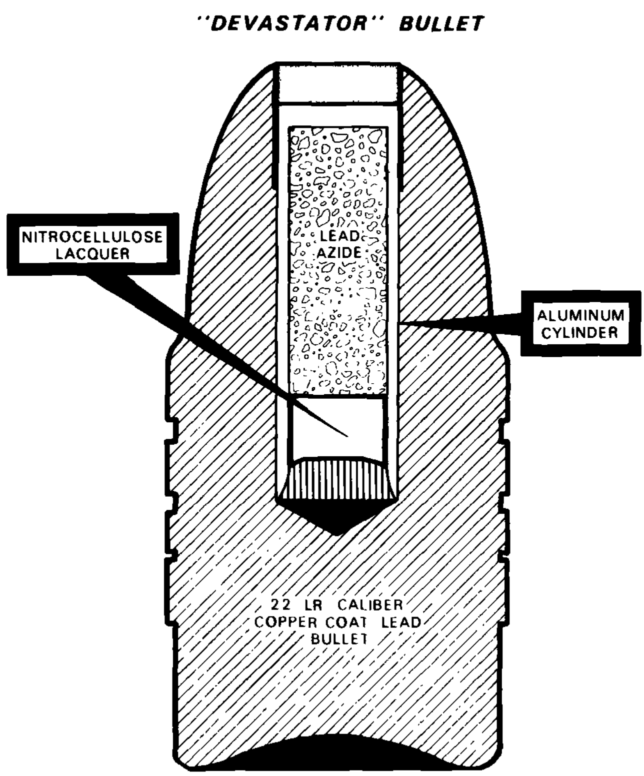

FIG. 4—*Schematic of cross section of a .22 caliber Devastator bullet.*

Velocity and Distance

The velocity of the Devastator bullet increased with longer barrel lengths as expected [6], and ranged from approximately 210 to 390 m/s (700 to 1300 ft/s (fps). Based only upon these measured velocities and the bullet's weight (34 grains), the kinetic energy (KE) produced by the Devastator bullet varied from 1.6 to 5.4 J (37 to 128 ft-lb). The Devastator bullet, when fired perpendicularly, detonated upon impact at all velocities reached in this study.

Increased muzzle-to-target distances had no noticeable effect on explosion of the Devastator bullet. Using the RG-14 revolver (44.5-mm [1-3/4-in.] barrel), detonation of the bullet occurred at distances up to 9.2 m (30 ft).

Cavitation and Penetration

The Devastator bullets that exploded upon impact with the gelatin blocks fragmented into mulitple small particles (Fig. 5). Temporary cavities formed measured between 5 and 8 cm in diameter (Fig. 6). The cavity size generally increased with higher velocities (longer barrel lengths). Control bullets and the Devastator bullets that failed to detonate produced temporary cavities measuring 2.5 to 4 cm in diameter (Fig. 7). The Devastator bullets that detonated penetrated the gelatin blocks to depths between 2.5 and 4.8 cm. The control bullets and Devastator bullets that failed to detonate penetrated from 14 to 15.2 cm.

In addition to forming large temporary cavities, the explosion of the Devastator bullets also produced large shock waves (see Fig. 6) which traveled the length of the gelatin blocks. The control bullets and Devastator bullets that failed to explode produced much smaller shock waves.

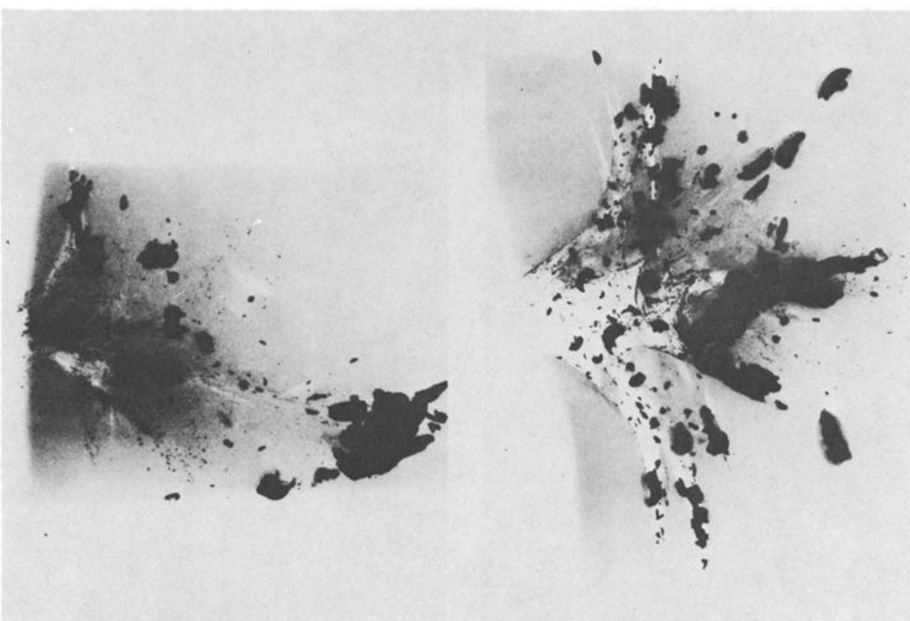

FIG. 5—(left) *Radiograph of Devastator bullet fired from RG revolver, Model RG-14 (44.5-mm [1.75-in.] barrel). Gelatin penetration: 4.5 cm; X2.* (Right)—*Radiograph of Devastator bullet fired from Anschutz bolt-action rifle, Junior Varminter Model 552.5-mm [21.75-in.] barrel). Gelatin penetration: 3.8 cm;* ×2.

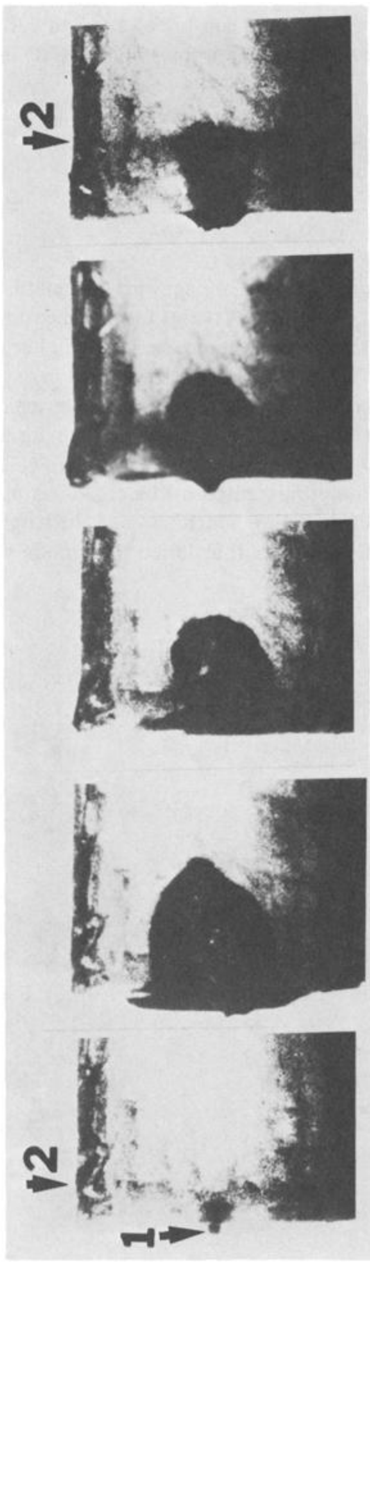

FIG. 6—*Partial sequence of exploded Devastator bullet fired from RG-14 revolver that formed a temporary cavity 6.5 cm in diameter and 4.3 cm in length. Arrow 1 indicates bullet's entrance into gelatin block. Arrow 2 indicates shock wave. Photo speed: 8000 frames per second. Gelatin block: 12.7 by 12.7 by 36 cm.*

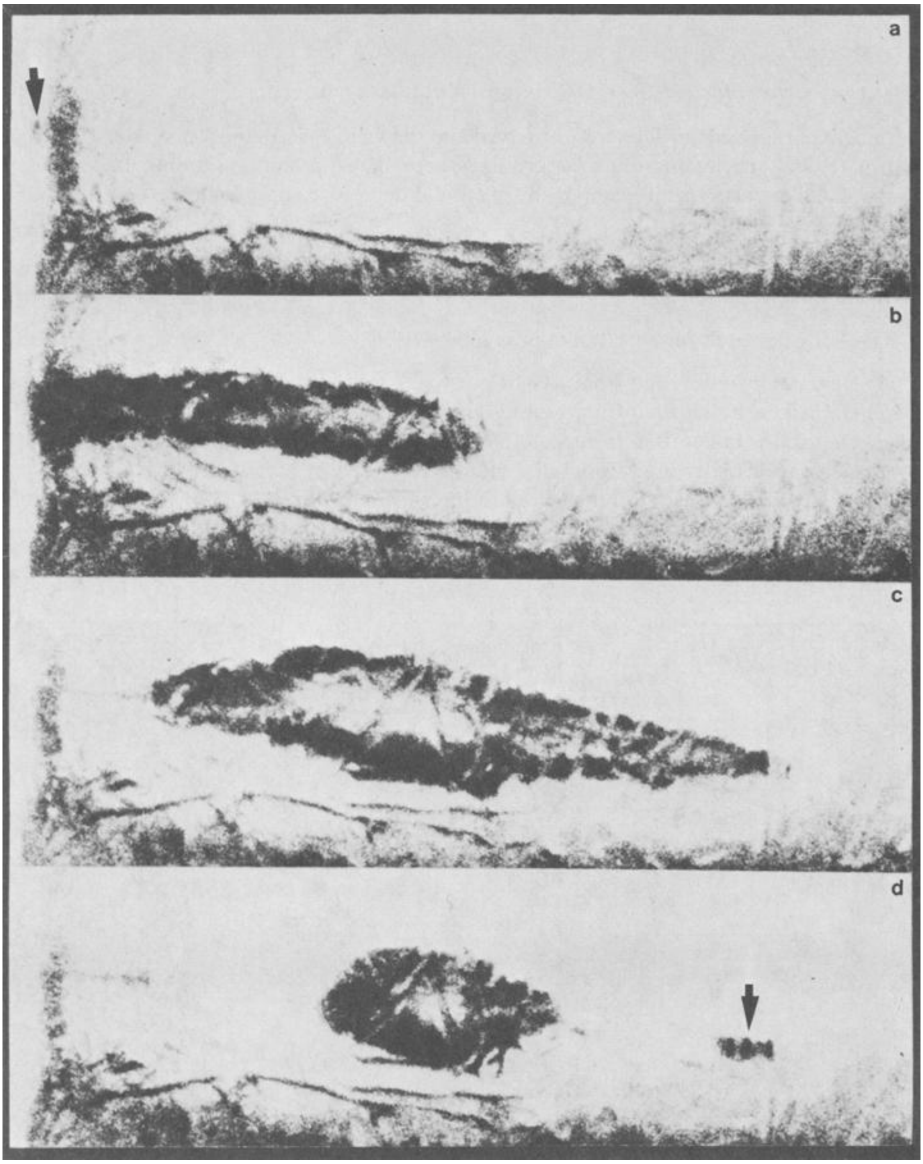

FIG. 7—(a) *Initial sequence for bullets that did not explode and produced temporary cavities 2.5 to 4 cm in diameter. Arrow indicates bullet's entrance into gelatin block. Photo speed: 8000 frames per second. Winchester (Super-Speed) bullet.* (b) *Temporary cavity of control bullet.* (c) *Temporary cavity of control bullet.* (d) *Temporary cavity of control bullet. Arrow indicates bullet at rest (18 cm from entrance point).*

Impact Angle

The Devastator bullets were fired into the blocks at impact angles of approximatley 90, 80, 70, 60, 45, and 30°. Reliable detonation occurred only with the bullets fired at an angle of 90°.

Electron Microscopy and Energy Dispersive X-Ray Analysis

Images of rounded particles were observed and shown to contain the element lead. Polygonal platelike particles showing fracture lines were shown to contain aluminum. Some of these platelike particles also contained spheroidal deposits containing lead. Fig. 8 through 11 show these images.

Relative Incapacitation Index

The RII calculated for each bullet is as follows:

(1) Devastator bullet fired from RG-14 revolver—2.34;
(2) Devastator bullet fired from Colt (241.3-mm [9-1/2-in.]) revolver—8.09;
(3) Devastator bullet fired from Colt (304.8-mm [12.in.]) revolver—5.93;
(4) Devastator bullet fired from AR-7 rifle—7.96;
(5) unexploded Devastator bullet fired form Colt (241.3-mm [9-1/2-in.]) revolver—1.66;
(6) Winchester (Super-Speed) bullet fired from RG-14 revolver—2.15; and
(7) Omark-CCI (Mini-Mag) LR hollow point fired from RG-14 revolver—2.08.

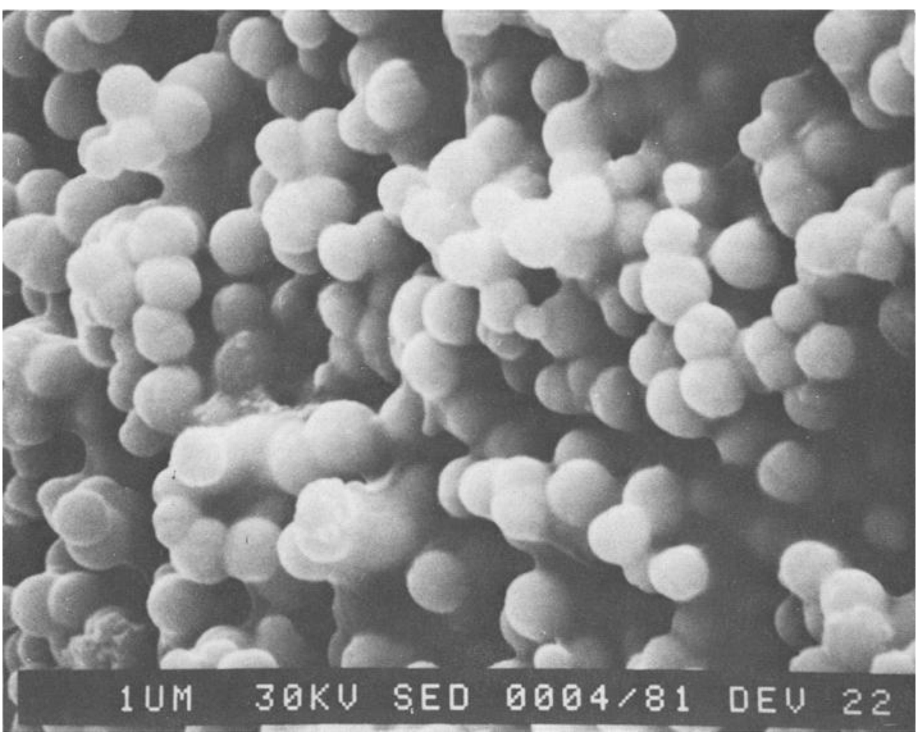

FIG. 8—*SEM Image of rounded particles from exploded Devastator bullet track. EDX revealed presence of lead. Magnification:* ×5000.

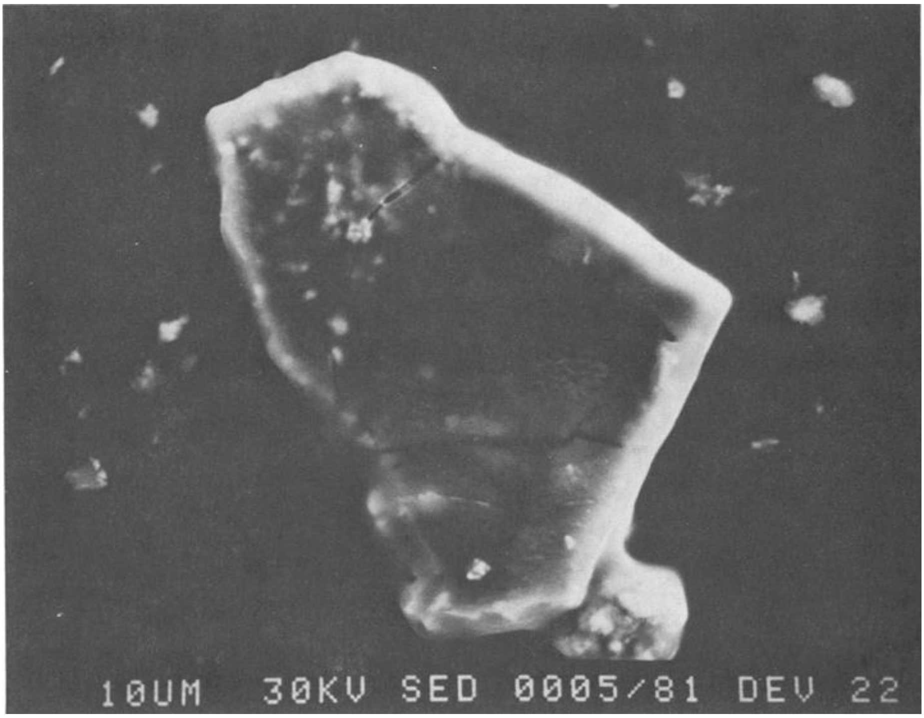

FIG. 9—*SEM image of polygonal plate-like particle with fracture lines. EDX registers presence of aluminum. Magnification:* ×160.

Discussion

This was a limited study on the effect of .22 caliber rimfire exploding bullets (Devastator) in gelatin blocks. Twenty-percent gelatin blocks have been found to approximate human soft tissue [*6-8*]. It was found that this bullet exploded in the gelatin blocks, in most instances, when impacting perpendicularly at the distances tested (0.6 to 9 m [2 to 30 ft]). Explosion of a bullet occurred only in one instance when fired at an angle of less than 90°.

The wounding effect of a bullet is determined not by the amount of kinetic energy it possesses, but rather by the amount of energy it transfers to the body. Major factors accounting for the transfer of kinetic energy by a bullet to tissue include the bullet's shape and construction, the impact velocity, and the change in its presenting area while passing through the tissues [*9*]. Thus, the explosion of the Devastator bullet, by changing its shape and increasing greatly its presenting area, would be expected to transfer quickly more energy to the tissue. This is manifest in the much larger temporary cavities produced in gelatin blocks by the exploded Devastator bullets as compared to the cavities produced by the unexploded Devastator and control bullets. The Devastator bullets that did explode did not penetrate into the gelatin blocks as far as unexploded and control bullets, but they did transfer their kinetic energy more quickly. Therefore, the wounding effects would probably be much greater with explosion. This is well demonstrated by the RII calculated for several of the bullets tested.

The RII of the Devastator bullets that exploded was greater as bullet velocity increased (that is, RG-14, 30 J [717 fps], RII 2.34; Colt 241.3 mm [9-1/2 in.] 46.4 J [1104 fps], RII 8.09). For comparison, the RII of a .38 Special 110 grain bullet fired at 36 J (857 fps) is 11,

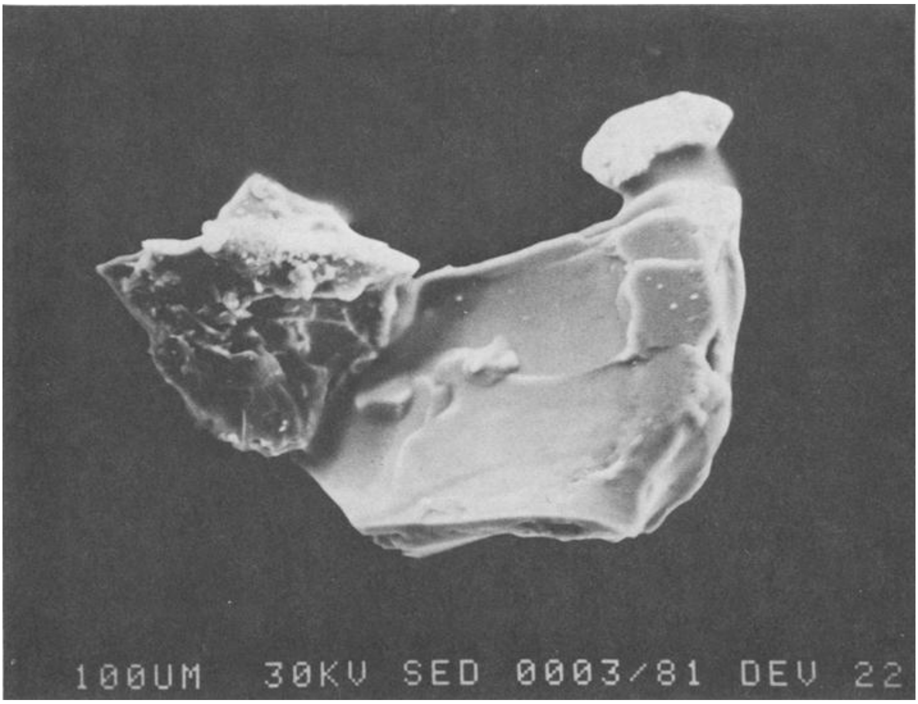

FIG. 10—*SEM image of polygonal plate-like particle with spheriodal deposits containing lead. Magnification:* ×160.

and that of a .357 Magnum 140-grain bullet at 47 J (1125 fps) is 35 [5]. The RII calculated for the Devastator bullet shot from the RG-14 revolver was slightly greater than the RII of the control bullets shot from the same firearm (2.34 versus 2.15 for the Winchester lead cartridge (Super-Speed) and 2.08 for the Mini-Mag LR hollow point). Even more marked is the difference in RII (8.09 versus 1.66) between exploded and unexploded Devastator bullets fired from the Colt 241.3-mm (9-1/2-in.) revolver with both bullets having the same velocities. This indicates that the explosion of the Devastator bullet, especially at the higher velocities, increases greatly its RII.

The fragments of the exploded Devastator bullet are too small to be useful for comparison purposes in bullet identification. The aluminun particles found in the bullet track with SEM and EDX indicate that this may be a way of identifying the Devastator bullet after it has exploded. The problems incurred by physicians in cases of human wounding by exploding bullets can be found in publications by Eckert [*10*], Clark et al [*11*], and Amatuzio and Coe [*12*].

Acknowledgments

The authors wish to thank J. J. Durrick, Jr., Senior Medical Photographer, Armed Forces Institute of Pathology, for photographic work and J. L. Becker, Bureau of Alcohol, Tobacco and Firearms and Jean T. Lawson, Armed Forces Institute of Pathology, for typing assistance.

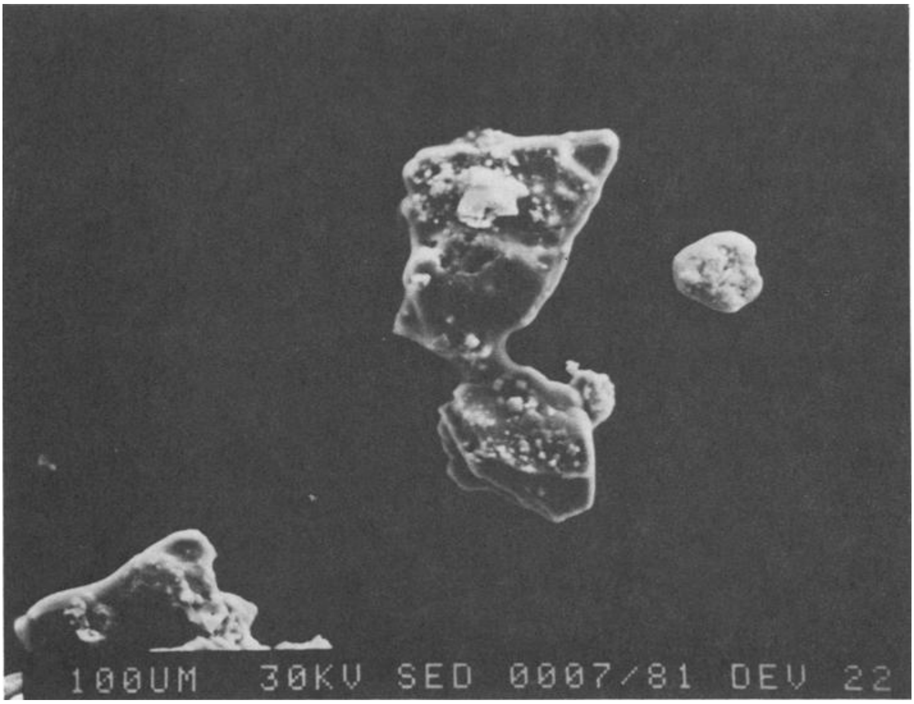

FIG. 11—*SEM image of polygonal plate-like particles with spheroidal deposits containing lead. Magnification:* ×160.

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