

BULLET HOLES AND CHEMICAL RESIDUES IN SHOOTING CASES

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Several new and important objectives are introduced when the medico-legal post-mortem examination of the victim of a gunshot injury is undertaken. In ordinary practice an autopsy is performed to secure information of medical or scientific interest. In medico-legal practice it is performed primarily to determine, for legal purposes, the cause of death. Although both of these objectives are important, many medical examiners and investigating officers are unfamiliar with certain potentially rich sources of information which are extremely useful in the investigation of the crime. To determine the cause of death is, of course, fundamental. But to determine, insofar as possible, the circumstances surrounding the fatal acts is often more useful in the administration of justice. Among others, answers to the following questions should be sought. Was the wound produced by a bullet? Could the injury have been self-inflicted? From what direction was the shot fired? How far was the gun from the victim when the shot was fired? What kind of ammunition was used? What kind of firearm was used?

The answer to these and other questions may depend entirely upon the examination of the body and clothing of the victim. With the legal status of evidence of this kind already established in the higher courts (27), its

value in reconstructing the circumstances surrounding the shooting and in apprehending the responsible person can hardly be over-estimated.

Observations bearing on the answers to questions proposed in the preceding paragraph fall in three categories.

In the first category are the physical characteristics of the wounds. Excellent descriptions of wounds are to be found in many of the more recent textbooks on legal medicine (84) (85). These include descriptions and illustrations of the differences between wounds of exit and entrance; the characteristics of the shot canal which indicate the direction of flight of the projectile; the evidences of explosive effects as are to be seen in contact shots; peculiarities of wounds attributable to the form and velocity of the bullet which produced them; peculiarities of wounds produced by spent bullets or bullets in ricochet.

In the second category are the identifying features of bullets found in, or shell cases found near, the body. The matching of bullets or shell cases for the identification or exclusion of questioned weapons constitutes a highly specialized science which has been adequately presented by many authors (83).

It is with the third category of observations that this paper is principally concerned. This has to do with the identification and interpretation of residues of powder, lubricants, and metals which may be found on the skin or

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clothing of the victim, or in the wound itself. It is necessary first to consider briefly the components of the firearm and the cartridge in order to appreciate the significance of these residues.

Firearm: For the purposes of this discussion only hand firearms (revolvers and automatic pistols) will be included. The barrel is generally made of iron or steel, rifled with from four to seven lands and grooves, twisting to either the right or left. Frequently it is fouled from previous shots, rusted, or oiled. Examination of the interior will usually disclose the presence of metal fragments derived from previous shots embedded in the depressions of the gun barrel. This is particularly true near the breech where erosion of the barrel is likely to be greatest (86) and where the surface of the bullet has been subjected to the greatest stress at its circumference. Here the metal may often be seen to lie in strips at the edges of the lands which impart the rotational thrust to the bullet. Moreover, fouling from the powder charge and primer charge is frequently present and can be easily proved chemically. It is therefore possible that a bullet fired from such a gun may carry with it traces of any or all of the materials present on the interior of the gun barrel—iron, rust, oil and metals, as well as powder and primer fouling of previous shots.

Cartridge Case: The cartridge case in most instances is of brass. Within recent years the primer cap at the base of the cartridge has been nickel-plated. Occasionally one also finds the brass case nickel-plated.

Bullet: The bullet from an automatic pistol cartridge generally consists of a lead core covered with a gilding metal jacket (copper alloyed with 5 to 10% of zinc). This jacket may be bare or plated with tin, or, rarely in this country, nickel. A bullet of this type is designated as "full metal-jacket." In cartridges designed for revolvers the bullet is generally soft. It may be composed of relatively pure lead, lead plated with a thin layer of copper, or lead alloyed with antimony, tin, or with both antimony and tin. Spectrographic analysis of lead bullets shows the presence of other elements in traces: copper, bismuth, silver and, occasionally, thallium (18) (75). Some revolver bullets have a copper or plated jacket extending about halfway back from the tip to the base. The soft metal of the core is exposed on the circumference of the bullet near the base. In others, such as hollow point and soft point bullets, the jacket covers the base and cylindrical portion, leaving soft metal exposed at the tip. In all bullets, including jacketed bullets, the soft metal of the core is exposed at the base, or at the tip, or both.

Lubrication: In general lead bullets designed for revolvers are lubricated by means of a semi-solid waxlike lubricant. Jacketed bullets designed for automatic pistols are not so lubricated (36). Spectrographic analyses conducted in this laboratory have shown that the lubrication is generally contaminated with lead, either mechanically or by the formation of lead compounds.

Powder: Formerly the propellant charge in a cartridge was composed of black powder. Since the introduction of smokeless powder, black powder charges have gradually disappeared, until at present it is rare to find black powder cartridges. Black powder is a mixture of about 75% potassium nitrate, 15% sulfur and 10% charcoal. Upon explosion it yields as solid residues mainly potassium sulfate, potassium sulfide and potassium carbonate, together with traces of the original components and nitrites, thiocyanates, and thiosulfates (39) (68).

Smokeless powder is composed essentially of cellulose nitrate (single base powder) or cellulose nitrate with nitroglycerine (double base powder) (68). The powder grains are generally coated with graphite and are in the form of disks or squares. Upon explosion, smokeless powders leave very little solid residue. That which is left consists of carbonized matter or graphite in the form of a fine dust and unburned or partially-burned grains of powder, ranging in size from large visible particles to fine dust. Nitrites and cellulose nitrate are the detectable chemical entities in this residue.

Primer: Some years ago a typical primer mixture contained mercury fulminate, stibnite (native antimony sulfide), potassium chlorate and powdered glass. Subsequently attempts were made to eliminate mercury and to reduce the rust-producing properties of the residue of potassium chlorate (26). This has resulted in the production of primers in which the mercury has been partially or entirely replaced by lead

compounds, including lead azide and lead styphnate; and potassium chlorate has been replaced by barium nitrate. So where the residue of an old type primer characteristically contains mercury and potassium, the residue of a modern primer characteristically contains lead and barium. Antimony in the form of stibnite is generally found in both old and new primers. Zirconium metal is the latest element to be encountered. Recent analysis of the primer residues of ninety-six makes and types of cartridges representing both old and new ammunition with black and smokeless powder showed that the following elements were present in the percentage of residues indicated.

Element	Percentage of Primer Residues
Barium	90%
Antimony	87%
Lead	75%
Mercury	67%
Potassium	31%
Tin	9%
Manganese	4%
Zirconium	1%

Subsequent information received from cartridge manufacturers indicates that tin compounds are not incorporated in primer mixtures, as the spectrographic analyses of the residues above would imply. Primers leaving tin in the residue of the explosion were therefore removed from the cartridges by the method of Chamot (82). In each instance the primer compound was found to be sealed into the cup with a small disk of soft metal foil. The foil was composed of a lead tin alloy, weighing about 10 mg. The disintegration of this foil upon firing doubtless gave rise

to the tin and a considerable portion of the lead in the residues from these primers.

To summarize, then, it may be ex-

pected that the following substances having origin in the gun barrel and cartridge may on occasion be expelled when the bullet is fired.

Substance

Source

	Gun Barrel	Fouling in Barrel	Cartridge Case	Primer—Residues old	Primer—Residues new	Primer—Sealing Disk	Black Powder Residues	Smokeless Powder Residues	Jacketed Bullets	Soft Bullets
Rust, Iron	X									
Lead		XXX		X	XXX	X			X	XXX
Tin	X					X			XX	XX
Antimony	XX		XXX	XXX	XXX					XX
Mercury	X		XXX	XX						
Nickel	X	X							X	
Copper	X	XXX							XX	
Zinc	X	XXX							XX	
Barium	XX		X	XXX						
Potassium	XX		XXX	X			XXX			
Carbon	XX						XXX	XX		
Nitrates	XX						X	XXX		
Nitrites	X						X	XXX		
Sulfides	X						XX			
Sulfates	X						XXX			
Carbonates	X						XXX			
Thiocyanates	X						XX			
Thiosulfates	X						XX			
Lubricating grease	XX									XX
Cellulose nitrate								XXX		

Note: XXX—Characteristically present.

XX—Frequently present.

X—Occasionally present.

The cross marks indicate the author's estimate of the frequency with which the particular substance occurs in the source mentioned. They have no exact quantitative significance.

In practice it is not to be expected that these substances will be intimately mixed and form a homogeneous pattern when fired from a weapon. Rather it is to be expected that due to their original differentiation, their various states of division and various densities, they will tend to form separate and distinct patterns. This has indeed been shown to be the case by numerous ob-

servers. It is largely upon the basis of the separate characterization of these patterns that valuable information can be obtained.

Is the Hole a Bullet Hole?

This question is apt to arise in every shooting case. It is a particularly important one when there are more holes in the clothing than can be accounted for by the number of shots believed to have been fired, or when the number of wounds in the victim is not in agreement with the number of holes in the clothing.

The question is to be answered upon evidence of two general types: (a) the nature of the damage produced in the material under examination; and (b) the presence or absence in it of traces characteristic of a bullet. Evidence of the first type is of a physical nature; that of the second type, chemical.

The initial entrance of a bullet into fabric is generally circular or elliptical, depending upon the angle of fire. If the bullet has been unbalanced in flight, it may strike with a wobble or end over end; in either case, the hole is likely to be irregular in form. The size of the bullet hole is only roughly characteristic of the caliber of the bullet. If the bullet has met the fabric obliquely, the latter may be abraded on the near edge to present an appearance similar to that of moth-eaten area. This appearance is frequently encountered in loosely-woven woolen garments or garments bearing a definite nap.

The exit of a bullet through clothing is characteristically irregular in shape. The bullet is generally traveling with much less velocity and frequently tipping end over end. Such an exit hole is not generally characterized by an abraded area.

The most outstanding characteristic of initial bullet entrances is the presence of chemical substances wiped off the bullet during its passage through the fabric or tissue in question. These substances compose a dark deposit known as the contact ring around the rim of the hole. On dark or blood-stained garments it is not often visible to the naked eye. The contact ring is more intense with shots fired from a

dirty or oily barrel than from a clean barrel (5) (71). If the shot is a close one, powder grains and particles of wax lubrication may be seen adhering to the fabric or skin. With very close shots a dark smoke halo is present around the hole. However, it is only under the most favorable circumstances that these deposits are readily detected with the naked eye. Dark fabrics, bloodstained and dirty, tend to obscure this type of evidence. To obtain the fullest information it is generally necessary to resort to one or more of the following useful methods: infrared photography, radiography, spectrography, or microchemistry.

Infrared Photography: It has been pointed out by Schwarz and Boller (63), Manczarski (40) (41), Elbel (11) and Beil (2) that many of the products of combustion of both black and smokeless powders are opaque to infrared light, and that by the use of infrared sensitive photographic plates and infrared filters the dark contact ring and smoke halo may be readily photographed, even on dark or bloodstained fabrics. The method is also applicable to skin. The advantages of the use of this procedure are more apparent in actual cases than experimentally, for its reliability is manifested under a great variety of disturbing conditions, among the most frequently occurring of which is the presence of blood and dirt around the hole. Moreover, it is no more difficult and scarcely more time-consuming than ordinary photography. The garment is in no way altered and a permanent visual record is obtained.

Radiography: As early as 1915, Demeter (8) employed X rays for the detection of lead in the path of a bullet through tissue. Eidlin (10) and Manczarski (40) have shown recently that by the use of soft X rays it is possible to radiograph the metallic deposits in fabric or tissue surrounding bullet holes. Since these deposits are very thin, it is necessary to resort to rays of very low penetrating power. This requires the effective use of potentials of 20,000 volts or less. The ordinary X-ray tube, immersed in oil and with a heavy window, will not emit rays at these low voltages. Consequently it is necessary to use a specially designed tube, such as the Grenz-ray tube of the Westinghouse Company. At our suggestion, Mr. H. F. Sherwood of the Eastman Kodak Company applied the stereo-Grenz ray technique, which he had previously successfully employed in the examination of fabrics and other thin objects (65) to this problem. His results have amply confirmed the work of the earlier authors and have indicated that the stereo-technique will aid in characterizing the metal deposits. It has been shown that the contact ring is rich in metal if the bullet is a soft one. This method, like the method of infrared photography, is simple and does not destroy or alter the material in evidence. It likewise produces a permanent pictorial record representing the spatial distribution of one class of elements contributed by the bullet to the object struck. Unfortunately, the equipment is not generally available.

Spectrography: Gerlach and Gerlach

(18) (19), Bayle and Amy (1), Buhtz (7), Schwartzacher (64), Walker (75) and Sannié (59) have used spectrographic methods in detecting metals in the contact ring and smoke halo around bullet holes. It has been shown that by this means it is possible to detect lead and frequently other metals around the entrance of a bullet into fabric. The spectrographic methods have the advantage that they are sensitive and rapid. However, a portion of the fabric must be destroyed.

Microchemical methods: Lochte (35) (36) (37) (38), Jansch and Meixner (28), Brüning and Schnetka (5), Holsten (24) (25), Schmidt (60) and Erhardt (12), and others also, have employed microchemical methods to detect various metals around the bullet hole. By these means lead, copper, antimony, tin, mercury, nickel and zinc have been demonstrated. These methods, sensitive as they are, require considerable technical skill, are frequently laborious, and suffer from the disadvantage that they are not graphic. As with the spectrographic method, a portion of the fabric must be destroyed.

Has the Hole Been Caused by the Entrance Or Exit of a Bullet?

Clearly, the presence of a detectable powder residue pattern or a definite smoke halo or particles of bullet metal or bullet lubricating waxes in a wide area surrounding the bullet hole is each an indication that the hole in question is an entrance. However, when the shot has been fired at a distance this type of evidence is not present. The only indications are to be found on the

rim of the hole, where either the effects of the mechanical action of the bullet or the chemical traces left by the bullet are evidence.

As might be expected, the fibers at the edge of the bullet hole are frequently pressed through the hole in the direction of passage. This finding is not sufficiently constant, however, to be considered with any degree of assurance. The explosive action of the bullet and gases in some instances causes a reversed appearance (73). Generally the clothing has been handled before the expert has access to it, in which case any conclusions as to direction based on the direction of the fibers must be regarded with great skepticism. More significant, however, is the occasional abrasion or moth-eaten appearance of the fibers on the near side. In tracing the path of the bullet through the clothing and through the tissues, materials dislodged by the bullet near the entrance are deposited along the path in the direction of the exit. Thus Strassmann (70) (71) (73) emphasizes the fact that upon microscopic examination fibers abraded from the garments will generally be found in the tissue of the entrance wound in the body. No such fibers are to be found in the exit wound, except where the shot canal is very short (43). Fragments of bone and tissue will frequently be found around the exit hole in clothing. However, this appearance sometimes occurs also in entrances when the explosive action of the gases or projectile causes a back-splashing of these substances (73).

The most characteristic feature of the

initial entrance of a bullet into clothing or tissue is a dark contact ring, made by the physical contact of the bullet (8) (10) (11) (40) (72). This ring may not easily be observed on a dark or bloody fabric. Meixner (42), among others, has emphasized that the contact ring at the entrance wound in skin may be simulated by a ring at the exit having an entirely different origin. He believes the exit ring to be caused by the stretching of the skin beyond its elastic limit, coupled with subsequent increased drying. Strassmann (72) and others (5) (10) (49) have shown that the darkness of the contact ring is largely due to gun barrel oil and fouling carried on the surface of the bullet: a jacketed bullet fired from a clean barrel leaves very little residue around the bullet hole. In confirmation of this, it has been shown by Walker (75) that a bullet fired from a black powder cartridge through a clean gun barrel leaves very little potassium around the bullet hole. However, subsequent bullets fired from smokeless powder cartridges through the same gun barrel without intermediate cleaning leave abundant but decreasing amounts of potassium. This experiment proves that gun barrel fouling contributes a significant portion of the material of the contact ring. The residues of previous discharges, lodged as fouling in the gun barrel, are swept out by the bullet, transported on its surface, and deposited on the first suitable object struck by it.

Lochte (36) and Demeter (8) were the first to show that the contact ring was in part composed of metals. In

the case where a lead bullet was involved, they proved the existence of a heavy deposit of lead at the entrance, with scattered fragments throughout the entire shot canal and at the exit. Other authors (1) (7) (10) (12) (59) (60) have confirmed these results. As Eidlin (10) points out, metals may originally be derived from either (a) the bullet, (b) gun barrel fouling, or (c) the primer. To this may be added (d) powder (15) (75), and (e) cartridge case (12) (15).

Eidlin (10) finds that the metals of the contact ring are largely derived from fouling of the barrel. Bullets fired from new and clean weapons fail to give a typical radiographically-detectable deposit of metals around the bullet hole. Upon the basis of spectrographic analyses of contact rings from lead shots, Buhtz (7) concludes that the lead present in the ring is derived from the particular bullet in only the smallest degree. From similar evidence, Walker (75) believes that the following factors are responsible, in decreasing importance: (1) the bullet; (2) gun barrel fouling; (3) metallic contamination of powder; (4) primer residues. It is very probable that the extent to which the metals from the bullet or fouling are deposited on the object struck will depend on both the hardness of the bullet metal and the hardness and abrasive qualities of the target. The X-ray method is most suitable for the graphic demonstration of lead, but it generally fails to show a deposit when jacketed bullets are used (10).

For the chemical demonstration of

metals, two general methods have been used—microchemical and spectrographic. Earlier attempts to detect hard jacket metals, such as copper, zinc, nickel, by chemical methods in the contact ring often failed (8) (37). Even the detection of lead was not always successful. Brüning (5) has reviewed the more recent methods by which it is generally possible to detect lead and frequently the metals of jacketed bullets. These methods, employing diphenylthiocarbazone for lead and zinc and rubianic acid for copper and nickel, are sensitive to a few micromilligrams of the metal sought. However, as Sannié (59) points out, cloth frequently contains considerable quantities of all of these metals. The mere presence of any of these metals around a bullet hole is without significance; it must be there in appreciably greater quantities than elsewhere to indicate a bullet entrance. Even in the case of lead bullets, where the deposit of lead around the entrance is often very great, care must be exercised. Lead is often scattered throughout the shot canal, as Buhtz (7), Demeter (8) and Schmidt (60) have shown. Eidlin (10) feels that the distribution of lead about the hole, not its quantity, is the most significant criterion for the differentiation of entrances from exits. Occasionally a single flake at the exit may contain more lead than the entire deposit at the entrance. Furthermore, as Schmidt (60) indicates, it is possible that a jacketed bullet might deposit very little lead at the entrance, split while within, and leave a heavy deposit at the exit.

The chemical methods for detection

of metals at the orifice, sensitive as they are, appear to lose much of their usefulness if not supplemented by a graphic method, such as radiography; and, besides, as Sannié (59) states, the methods require considerable skill, are not quantitative, and do not leave a permanent visible result.

Although the spectrographic method first used by Bayle and Amy (1), and subsequently employed by others, is superior to the microchemical methods in several respects, it should be used preferably in conjunction with radiography as a topical (surface) control. Areas may be chosen that are representative; areas contaminated with foreign matter may be discarded. Where a choice must be made, pictorial methods are preferable to purely qualitative or quantitative methods. Any quantitative method, other than one employing the entire area surrounding the bullet hole, is unjustified unless one is able to show, by some means, that the sample chosen is representative of the entire area. The distribution of metals around a bullet hole is certainly not uniform. Milovanovic (46) points out that atypical bullet entrances are not uncommon. It therefore seems advisable that, before any chemical or spectrographic method is undertaken, the bullet hole be radiographed to show the distribution of the metals being sought.

To summarize the methods of distinguishing entrance from exit holes by the presence or absence of traces, it appears that the infrared and soft X-ray techniques are the most simple and the results the most graphic. They

have the advantage that the exhibit is in no way altered. In critical cases the spectrographic method is satisfactory. Where it is necessary to search for only one of a few elements, microchemical methods are suitable.

From What Distance Was the Weapon Fired?

All methods for the determination of distance are applicable to comparatively short distances only. Under ordinary circumstances a bullet wound may be self-inflicted only when the weapon is held with the muzzle within a few inches of the body. The determination of distance is therefore particularly valuable in this region. Fortunately, fairly accurate determinations are possible. All available methods depend upon the presence and distribution of various ingredients of the muzzle blast. It is therefore necessary to distinguish carefully between the contact ring produced in fabric or tissue by the impact of the bullet and the powder residue tattooing and smoke halo produced by the muzzle blast. The halo and tattooing are present only at short distances; the contact ring is independent of distance.

There are five major types of material emitted from the muzzle during discharge of the bullet. These consist of (1) gases, (2) smoke (fine dust, carbonaceous and metallic), (3) residues of partially-burned and unburned powder, (4) metal fragments or droplets, and (5) wax or grease lubrication.

In order to visualize the process more readily and to evaluate the sig-

nificance of each of the above factors, it is desirable to examine the course of events within a revolver subsequent to the moment the firing pin strikes the primer cap. The primer mixture ignites the powder, which under pressure, progressively explodes. The bullet of lead alloy is forced out of the cartridge case into the barrel. In the case of a revolver it must pass through a space between the cylinder and the breech of the barrel. If the chamber is imperfectly aligned with the barrel a portion of the lead of the bullet may be shaved off. In automatic pistols no such action can occur, for the barrel is a prolongation of the chamber. The barrel is provided with lands and grooves which twist either to the right or left. The bullet, being of a somewhat greater diameter than that of the barrel, is compressed and elongated. At the same time it receives an enormous rotational thrust. If the fit of the bullet is not perfect, gases may escape past it and cause a preliminary discharge before it emerges from the barrel (68). Subsequent to the emergence of a bullet further gases will be discharged. While this is in progress, the muzzle is describing an upward arc around the center of mass of the firearm. Thus, in general, matter discharged before the bullet emerges would be expected to reach the target at a point below the bullet hole, and anything discharged afterward, to reach it above (24). Heavy particles and dense particles might be expected to carry a greater distance from the muzzle than light particles and gases.

Gases: The gases of combustion, of

both black powder and smokeless powder, contain carbon monoxide; the former to the extent of about 10% (68), the latter, 38% (44). Palteuf (51) and Meyer (44), as well as others (23) (57) (69), have shown that with contact or near-contact shots, where these gases enter the body, carbon monoxide hemoglobin is formed from the blood. The shot canal becomes bright red. Spectroscopic proof of carbon monoxide hemoglobin in the shot canal would thus serve as a proof of a contact or near-contact shot.

Strassmann (70) reported a remarkable case involving a putrified body, which had remained immersed in water for several weeks. A bullet hole at one opening presented a bright red appearance, in contrast with the corresponding orifice and the rest of the body, which were greenish. In a water extract of the tissue of the red region, "carbon monoxide hemoglobin was clearly shown spectroscopically". In view of the recent work of Schmidt (61) and others on the stability of carbon monoxide in putrified blood, it seems more likely that the carbon monoxide, if present, would be in the form of carbon monoxide hemochromogen, or a similar degradation product. Strassmann concluded that the hole was caused by a bullet fired from short range. No powder smoke or powder grains could be detected.

Smoke: Both black and smokeless powders give rise to a discharge in which carbon and metals are present as a fine dust or soot. The smoke of a black powder discharge is much more dense than that of a smokeless powder

discharge. In either case, if the shot is fired from a comparatively short distance, the fine smoke will be deposited on the target around the bullet hole in a roughly concentric manner. This deposit may take the form of a halo, showing a greater density near its periphery. The diameter and density of the smoke halo serve as an indication of the distance from which the weapon was fired. In general, a definite smoke halo may be detected under most favorable conditions with smokeless powder at muzzle distances as great as twelve to eighteen inches, depending on the type of weapon, the type of cartridge, and other factors. B. Müller (48) believes that an estimate of distance based on the intensity of blackening of the smoke halo is preferable to one based on its diameter. In actual practice it is difficult to measure this intensity. With dark and bloodstained garments infrared photography has proved useful (40) (63). Simonin (67) and Brusatto (6) have pointed out that with contact shots on skin covered with several layers of fabric a modified series of smoke halos or "cocarde" is occasionally formed within the layers of cloth. In this case the examination of the outer garment may reveal very little in the way of a halo, whereas the inner garments may show several concentric rings.

It should be noted here that when an automatic pistol is forcibly pressed against the skin at the moment of firing, a dark stamp mark of the outline of the forward end of the slide may be impressed around the bullet hole (16) (78). The effect is caused by the re-

turn of the slide to its forward position. This appearance, when present, not only serves to characterize a contact shot, but in favorable cases may help to identify the make of pistol. In some cases similar appearances caused by foreign particles in the powder or the ejector rod of the cylinder of a revolver may be encountered (57) (78).

The chemical nature of the smoke halo has been only partially investigated. In the case of black powder, it may be assumed to consist principally of potassium salts and carbon, although it is well known that it is generally contaminated with lead from the accompanying lead bullets. Brüning (4) has shown that in fresh residues much of this lead is in the form of sulfide; in older residues, sulfate.

In the case of halos from smokeless powder cartridges, more work has been done. The halo proper does not necessarily contain nitrites or oxidizing agents characteristic of unburned or partially-burned grains of powder (35). A great portion of the dark material consists of metals (5), the source of which depends upon a great number of factors.

Many authors have pointed to the strongly metallic nature of the smoke halo. The earliest metal to be detected was quite naturally lead. Lochte (36) was able to dislodge lead particles from the area surrounding the bullet hole up to a muzzle distance of $\frac{1}{2}$ to 1 m. in all cases where lead bullets were employed. By polishing the dislodged residues between glass slides or by the use of X rays, Demeter (8) confirmed the presence of particles of lead and

found them to distances as great as 12 m. Lochte felt that the lead was largely derived by the dislodging of the bullet from the cartridge case; Demeter, that it came from abrasion in the revolver barrel. Neither detected any lead in the bullet hole of shots fired from automatic pistols. Demeter noted that the lead was frequently in the form of gray fluid droplets. Jansch and Meixner (28) found lead to a distance of 2 m. by methods similar to those of Lochte.

Eidlin (10) pointed to the fact that on the basis of X-ray evidence the lead around the bullet hole caused by lead bullets fired at short range was in the form of a ring, the diameter of which increased with distance. With increase in distance, the ring changed to an inner and outer ring and, in general, became more punctate.

Buhtz (7), employing a spectrographic method, found that the quantity of lead immediately surrounding a bullet hole from a lead bullet decreased with the shot distance up to 200 cm. By the analysis of the fabric around the hole of near shots, he found the lead content more dense at the center, less dense at the periphery. In one experiment, Rankin (58) found that the lead content of the cloth of the bullet hole decreased regularly up to 100 feet.

Recently the holes produced in linoleum by lead bullets fired at close range from a variety of revolvers were examined microscopically in this laboratory. A large number of splashes of molten lead was found immediately surrounding the hole and extending up-

ward above it. The droplets could be seen clearly, even, in some cases, with the naked eye. Similar shots fired into woolen cloth left the wool fibers stippled with splashes of lead. The disposition of this lead was certainly not concentric with the hole. As the distance of the weapon from the target was increased to six inches, molten splashes of lead were still detected, although less were to be observed. This lead appears to originate in the particular bullet causing the hole. Microscopic examination of the cylindrical surface of the fired bullet near the base at the following edge of each land impression showed a molten appearance and an apparent loss of material. That lead bullets tend to melt from the action of hot powder gases or friction within the barrel has long been known to those concerned with their design. The presence of splashes of molten lead around a bullet hole is, among other things, an indication of a near shot. These droplets, in solid state, probably travel to considerable distances.

The presence of lead in the halo around a bullet hole is not confined to shots from lead bullets (5) (18) (24) (25) (59) (60) (75). At the base of jacketed bullets the lead core is exposed to the action of hot gases. Many modern primers contain lead in the form of the azide, dinitrophenylazide, styphnate, thiocyanate, chromate, nitrate or dinitrobenzoate. The sealing disk in the primer cup may be composed of a lead-tin foil. It may be stated that in actual practice lead from one source or another is present in

the muzzle blast of every type of cartridge fired in a used gun. Holsten (24) (25) has made use of the general presence of lead in modern primers to form the basis for the estimation of distance based on the quantitative determination of this metal in concentric rings around the bullet hole. He employed the sensitive diphenylthiocarbazone method. Wickenhauser (80) criticized Holsten's method as inapplicable to oblique shots. B. Müller (48) states that the quantitative determination of lead for the estimation of distance can be expected to be limited to exceptional cases.

Mercury in the form of the fulminate is present in many primer caps, both old and new. Upon detonation it reverts to metallic mercury. As early as 1907 Georgii (20) observed droplets of metallic mercury in the residues of shots from Flobert revolvers up to a muzzle distance of 20 cm. The propellant powder in cartridges designed for this firearm was composed largely of mercury fulminate at that time. Lochte, with Fiedler (37) and with Danziger (38), was able to demonstrate mercury in the halo by chemical means when Flobert cartridges were fired, but detected no mercury with ordinary mercury fulminate primed cartridges. Schmidt (60), by a more sensitive chemical procedure, detected mercury in the later cases to a distance as great as 25 cm. Piedelievre and Simonin (53) and Journié, Piedelievre and Sannié (29) have been able to show mercury droplets microscopically up to a distance of 20 cm. with mercury - primed cartridges. Gau-

reschi (17) was unable to demonstrate mercury histologically beyond 3 to 4 cm. under similar conditions. Buhtz (7) and Journié, Piedelievre and Sannié (29) have tried the spectrographic method without satisfactory results, although Gerlach (18) claimed that by employing the method of the high frequency spark no difficulty was encountered.

By a spectroscopic method Gerlach (18) noted in several cases a preponderance of iron in the entrance wound. He was unable to establish definitely its origin and differentiate it from physiological iron. Fritz (15) showed that this iron was in fact due to material carried on the surface of the bullet or expelled with the powder. In the smoke halo on the skin it was an indication of a close shot. Fritz used a histological method employing potassium ferricyanide in 10% hydrochloric acid as a reagent.

Buhtz (7) was the first to point out that copper is to be found in the smoke halo of shots fired at short distances. By firing shots from cartridges provided with nickel-jacketed bullets, he found copper in the smoke halo, but not in the contact ring. He reasoned from this that the copper was derived from the cartridge case. Copper was found at distances up to 40 cm. by spectrographic methods. Fritz (15) likewise detected copper histologically in the same manner as with iron. Membranes of brown copper ferrocyanide were formed around each particle by the potassium ferrocyanide reagent. He found copper up to distances of 20 cm. and concluded from an examina-

tion of the powder that the copper was derived from the case. Erhardt (12) determined the copper quantitatively in the smoke halo in clothing of shots fired from automatic pistols. The copper content decreased with distance up to 20 cm., where it reached the blank value for the cloth.

The determination of distance by the quantitation of metals around a bullet hole is a process beset with many difficulties. As early as 1915 Demeter (8) observed that the quantity of lead around the bullet entrance depends upon the material of the bullet, the length of barrel, type of target, quality of barrel wall, construction of weapon, ratio of the caliber to the bullet diameter, and form of the bullet, as well as the distance. And one may add many other less controllable factors, such as the cleanliness of the gun barrel, the manner of firing the weapon (single action or double action with revolvers), and the angle of fire. In addition there is the almost unsurmountable difficulty of accurate and representative quantitation without destruction of the entire bullet hole and its surrounding area. The halo is rarely, if ever, disposed symmetrically around the hole in either form or quantity. A preliminary discharge may cause a heavy deposit below the bullet hole. An after-discharge creates a deposit above. The rifling grooves may cause the formation of radiating areas of greater density in the pattern (55). Flakes or chips of the metal in question, either from the bullet, cartridge case or fouling in the gun barrel, may cause local accumulations that lead to

an entirely erroneous result. Demeter (8) has shown that individual particles of bullet metal travel to considerable distances; in some instances, as great as 10 m. Obviously, then, one runs the risk of an erroneous conclusion if he attempts to determine distance by quantitation in the smoke halo of a metal which is also a constituent of the bullet. Thus the method of Holsten (24) (25) is applicable only to lead-primed jacketed bullets.

Clothing frequently contains lead, copper, zinc, tin and nickel (12) (19) (25) (59) (80), in addition to other metals. If any of these metals is to be used for the purposes of quantitation, the tests must be suitably controlled, or a metal which is not commonly present in fabric or skin should be chosen. A possible approach lies in the employment of a metal commonly present in the primer which is not present in the bullet or cartridge. Barium is such a metal. It has the advantage of not being frequently encountered in clothing. In an experiment in this laboratory conducted to determine the dispersion of the metallic constituents of bullet and primer around a bullet hole in cloth, a shot was fired at close range, using a cartridge with a lead-antimony-barium primer and a lead bullet. A strip of cloth $\frac{3}{8}$ " wide and extending four inches on either side was cut through the bullet hole. This strip was placed on the flat surface of a $\frac{1}{8}$ " copper bar one-half inch by twelve inches. The bar with adhering cloth was used as a moveable lower electrode against a stationary upper copper electrode in the spectrograph. The copper bar was

moved slowly through the spark while the plate-holder of the spectrograph was synchronously lowered. The resulting spectrogram was a series of overlapping individual spectra, in effect a progressive analysis of a diameter of the smoke halo. It was noted that barium, as well as lead and antimony, each increased in quantity toward the hole. This method promises to be useful for experimental purposes. It necessitates destruction of a portion of the bullet hole.

Lubrication: Particles of bullet lubrication, present on the surface or in the cannelure of a bullet designed for a revolver cartridge, may generally be found around the entrance hole in shots at close range from revolvers. These particles are somewhat larger than powder particles and tend to adhere tenaciously to rough fabric. They may therefore occasionally be found on cloth at a muzzle distance as great as nine feet. By means of a warm iron, Lochte (35) pressed tissue paper covered with blotting paper against the garment. Lubrication stains produced on the tissue paper were developed with Sudan III or with iodine or osmic acid vapors.

Powder Residues: Whereas gases and smoke have comparatively limited range, it has long been observed that individual grains of powder, unburned or partially-burned, may travel to somewhat greater distances. Thus, if a smokeless powder cartridge is fired into white cloth, a smoke halo may generally be observed up to a distance of twelve to eighteen inches, whereas powder grains are likely to be found as far as twenty-four to thirty-six

inches. The detection of these particles therefore becomes highly important, for their complete absence tends to place the weapon outside of the suicide range. There is one outstanding exception to this generalization, and that occurs in the case of the absolute contact shot (66). Here one may find no traces of powder residue on the clothing (54), a fact which might carelessly be assumed to necessitate a more distant shot. Due consideration to the nature of the wound, the appearance of fabric at the bullet hole, and in particular the infrared photographs of the smoke halo or stamp mark of the muzzle will readily enable one to distinguish a contact from a distant shot. Highly characteristic of the contact shot is the cross-shaped tear of the fabric. A like appearance is found on skin (68).

In 1911 Wellenstein and Kober (77), advocated the use of a solution of diphenylamine in strong sulfuric acid as a reagent for the characterization of powder residue particles. As is now well known the reagent is a general one, responding to many oxidizing agents. Its response to powder residues, both black and smokeless, is due to the presence of nitrates and nitrites. The production of the characteristic blue color is due to a two-stage oxidation of the diphenylamine; the first stage resulting in colorless diphenylbenzidine, the second in its blue quinoid derivative (60).

Because of the corrosive nature of the sulfuric acid in the diphenylamine reagent, the latter cannot be applied directly to the skin or clothing.

Wellenstein and Kober (77) removed the powder grains with a needle and tested them on a porcelain plate. Various methods of brushing (22), beating (50) (72), scraping (66) or swabbing (66) the subject to remove the powder grains have been proposed. With but few exceptions, none of the methods is sufficiently graphic to permit a reasonable estimate of distance. Strässmann (72) spread that portion of the garment containing the bullet hole face down over a tin or wooden vessel within which rested a shallow glass dish lined with paraffin. The garment, held in place by means of an outer tin hoop, was scraped or scratched. If the distance between the garment and the paraffin surface is slight, the dislodged powder grains will be found in an image of their original location on the garment. They might then either be examined microscopically, tested with diphenylamine reagent, or both. Hilschenz (22) covered the garment with concentric rings of cardboard and brushed out the fabric with a tooth brush, the process being carried out over a dish of diphenylamine reagent. In this way, by successive removal of cardboard rings and rebrushing, the numbers of particles at various distances from the bullet hole could be ascertained. He found that it was difficult to free the grains from long-fibered fabrics. Dyrenfurth and Weimann (9) tried various adhesive bases with the intent of retaining the removed powder particles in their original relative positions. Cardboard was spread with (a) glycerine gelatine, (b) para-rubber solution, or (c) "Mastisol".

The latter was found to be the most satisfactory. The cloth was placed against this material and beaten; the grains which adhered were individually removed and tested. Kochel (33) found the above method too laborious and employed paper spread with water glass. The diphenylamine reagent could be applied directly to this substrate with a glass wool brush.

The non-specificity of the diphenylamine reagent is a source of great uncertainty (10) (21) (22) (28) (35) (37) (57) (60). Oxidizing agents capable of giving a blue color are common. Clothing very frequently contains these substances (22) (48) (60). Therefore, with no satisfactory means of applying the reagent to obtain a true spatial representation of the distribution of the grains around the orifice, great caution should be exercised in drawing any conclusions based upon the finding of a few scattered particles of a substance which responds to the test. On the other hand, the failure to find such particles does not entirely exclude their presence. Infrared photographs show that the brush-out method of removal of powder grains is not complete. For this reason Beil (2) believes that the infrared photography of black powder residues is superior to the method of Hilschenz (22), particularly when the bullet hole is dirty and when the garment is deep-napped.

Foyatier (13) and others prefer brucine in sulfuric acid to diphenylamine. It is more specific for nitrates than diphenylamine (45). Simonin (66) points out that it has a real advantage

when blue cloth is encountered, because of the fact that the test color is red. Both the brucine and diphenylamine reagents suffer from the fact that the colors are fugitive; no permanent visible record of the test can be prepared. The choice between the two reagents appears to be largely a matter of individual preference.

In 1928 Goroncy (21) proposed the use of alpha naphthylamine and sulfanilic acid in acetic acid, for the detection of nitrites present in the residues of smokeless powder. A portion of the cloth is removed and extracted with alcoholic potassium hydroxide. The solution is acidified with acetic acid and the nitrites detected by the production of a red color on the addition of the reagent. The depth of color, under controlled conditions, may be used as an indication of the approximate distance of the weapon from the garment. Contrary to the diphenylamine test, the Lunge reagent is specific for nitrites. The test as conducted lacks specificity for powder residue. The individual grains are not represented spatially, hence information as to distance is at the most vague and uncertain. Furthermore, a portion of the fabric must be destroyed.

Walker (74) has proposed a method of spatially representing powder residue patterns on fabric by printing the pattern against gelatinized paper treated with "C" acid (2-naphthylamine-4, 8-disulfonic acid). Alpha-naphthylamine and sulfanilic acid or "H" acid (1-amino-8-naphthol-3, 6-disulfonic acid) may be used in the same manner. Following is a description of this method:

Ordinary glossy photographic paper is completely desensitized by the usual photographic hypo bath, washed thoroughly and dried. It is then immersed in a warm 5% solution of "C" acid for ten minutes. The treated paper is allowed to dry. A pad of cotton cloth or a towel is laid upon the table, on top of which a piece of the prepared paper is placed face up. This must be of sufficient size to accommodate all of the powder residue. On top of this, face down, is laid the fabric containing the bullet hole. Next are placed a thin layer of dry toweling, a thin layer of toweling slightly moistened with 20% acetic acid, and a final thin layer of dry toweling. The whole pack is then pressed with a warm electric iron for from five to ten minutes.

The prepared photographic paper when removed is found to have impressed upon it a number of dark red spots which correspond to the position of the partially-burned powder grains around the bullet hole. This test is sensitive to black and smokeless powder residue, and is insensitive to all other usual chemicals except nitrites. The test is specific for nitrites and highly indicative of powder residue if consideration is given to the spatial distribution of the particles around the bullet hole. A permanent graphic representation of the powder residue pattern is produced, without in any way destroying or significantly altering the fabric of the bullet hole. Blood stains do not react nor greatly interfere.

There is a general agreement between authors that in actual cases no estimate of distance should be made

without firing a series of test shots from the same firearm, with the same type of ammunition and against the same type of target (32) (33) as were believed to have been involved in the questioned shot. Great variation exists between the various types and calibers of firearms, as well as between the makes and types of cartridges. F. Müller (49) found that the variations in mechanical operation of revolvers greatly affected the character of the powder pattern. Employing a revolver of unknown make, the cylinder of which fitted so poorly that every time the weapon was fired part of the bullet was shaved off, Müller found the powder pattern very irregular. Scarcely any estimate of distance could be made.

Karhan (30) has investigated the effect of burial and submersion in water on near-shot characteristics. He finds that even under the most adverse conditions some traces, either chemical or microscopic, are likely to be found.

Kraft (34) found that a handkerchief held over the muzzle did not appreciably alter the powder residue pattern.

From What Angle Was the Shot Fired?

Any method of graphic representation of the residues surrounding a bullet hole is capable of being used as a means for approximating the angle of incidence of the path of the bullet to the struck surface. Piedelievre (52) has shown that the more inclined the angle of incidence, the longer the wound or abrasion. A shot cannot enter human skin at an incidence angle of 5° to 10° or less. Moreover, where

a grazing has taken place the greatest strain is produced on the entrance side of the wound. This last conclusion is in agreement with the X-ray results of Eidlin (10), who found a heavier deposit of metals in the contusion ring at the near side of the hole. Furthermore, with near shots an elliptical form to the outer metal ring made visible by X-ray photography is a means of estimating the direction. Elbel (11) points out that the smoke halo made visible by infrared photography is also useful for this purpose. Likewise the C-acid print test of Walker may be used. In each case where the evidence is obtained the heaviest deposit is to be expected on the near side of the bullet hole. Considerable caution should be exercised, however, for other uncontrollable factors may give rise to a false appearance of an angle shot. In estimating direction, due consideration should be given to the fact that the clothing is generally free to swing and assume positions other than that of the surface of the body.

Wilson (81) has shown in an actual shooting case that a particular revolver regularly left a denser deposit of black powder residue directly above the bullet hole. He attributed this phenomenon to a premature escape of the gases at the top portion of the barrel, due to faulty manufacture. Although in this particular case this explanation might hold, it is a recognized fact that even with well-constructed revolvers the deposit is more dense above the bullet hole. This is attributed to the discharge of gases subsequent to the emergence of the bullet. In revolvers the muzzle

describes an upward arc while the bullet and gases are being discharged; consequently the after-discharge is located above the bullet hole (55) (83). In automatic pistols the center of mass lies near the axis of the barrel. As a result there is little tendency for the muzzle to rotate upward, and the after-discharge is likely to be found on the target concentric with the bullet hole. Whatever the cause, the regular production of a dense eccentric deposit serves as a means of orienting the position of the weapon with respect to the target. In this laboratory it has been found that the droplets of molten bullet-metal likewise are to be found on the target above the bullet hole. In some cases they range slightly to the left; in others, to the right.

Caliber of the Bullet

It is particularly difficult to estimate the caliber of the bullet from a mere examination of the hole produced by it in an elastic material, such as fabric or skin tissue. Holsten (24) (25) states that the caliber can be estimated in near shots by determining the diameter of the chemically-provable lead-containing smoke halo, where lead primer charges have been used. Buhtz (7) believes that the quantity of spectrographically-detectable lead in the combustion ring is dependent upon distance and caliber; if one can be determined, the other can be estimated. That the dispersion of the smoke halo elements and powder residues is dependent upon the caliber to a certain extent is obvious, but the other factors involved are very numerous. It is doubtful if suffi-

cient exact information of these factors will be available frequently in actual cases.

What Type of Powder Was Used?

In the United States only three types of powder need to be considered—black, smokeless and semi-smokeless. A black powder discharge is characterized by a heavy black deposit, interspersed with dense black or gray particles, or minute spherical sulfur-colored masses. Infrared photographs of the pattern will disclose a typical picture of dense black spots (2). Chemical analysis of one of these spots for nitrates, potassium, sulfate and sulfides definitely indicates black powder residues (25) (31) (37) (39) (56) (68). The sulfides which are present in fresh black powder residues are rapidly converted into thiosulfates and sulfates. Potassium sulfide is lost after four to six hours (45). Black lead sulfide (4) from the lead of the bullet and iron sulfide (45) are converted after several days into light-colored sulfates. These and other changes form a basis for the estimation of time elapsed since a weapon was fired (39) (45). A modification of the C-acid print test can also be employed if the residue is fresh. Incorporation of lead acetate on the gelatinized paper will give a pattern of semi-metallic spots of lead sulfide.

Smokeless powder residues do not give a dense black pattern of individual spots when photographed with infrared light. Neither does the residue contain appreciable quantities of potassium, sulfates or sulfides. Black powder residues are alkaline to litmus;

smokeless powder residues are acid (4) (5) (35) (55) or neutral (26) (39). The acidity of the residue grains is probably dependent upon the internal pressure during explosion; high barrel pressures tend to produce a non-acid smokeless powder residue. Nippe (50) suggests that the distinction between black and smokeless powder residues can be confirmed by the fact that the nitrates of the former are soluble in water. Black powder charges are only occasionally encountered today. They are never met with in ammunition designed for the automatic pistol. We may expect a lead bullet and a bullet lubricant where black powder is encountered. As has been shown elsewhere (75), the presence of black powder residue in the contact ring proper, to its exclusion elsewhere, does not necessitate a black powder charge for the particular bullet in question. It implies a previous black powder charge fired from the same weapon.

Semi-smokeless powder consists of an intimate mixture of the principal components of both black and smokeless powders. The proportion is generally 80% black and 20% smokeless. The grains of the original powder are dull-black, angular particles resembling black powder, except for the lack of luster and more angular appearance. When fired they leave a residue similar to black powder residue in appearance and chemical composition. It is doubtful if a distinction could be made between the two residues in actual cases, unless unburned grains happen to be present.

One of the most characteristic prop-

erties of the muzzle blast from a black powder cartridge is its intense heat. Weimann (76), in a series of experiments, showed that singeing generally occurred to distances of 20-30 cm. and sometimes to $\frac{1}{2}$ m. Tissue and body hairs are singed or scorched, and clothing is frequently ignited. In contrast smokeless powder causes no singeing or burning (10) (14) (22) (35) (44) (57) or at most negligible traces at a distance of a few centimeters (23) (76).

It is possible in some instances to distinguish the various types of smokeless powder. If the combustion has been so incomplete as to leave large particles, their form may be recognized (31) (68). In bulk, double base powder may be distinguished from single base by warming at 100° C. in a shallow dish covered by a watch glass. The nitroglycerine vaporizes and condenses as a fog on the watch glass where it may be tested with diphenylamine reagent. A modification of this method has been found useful in this laboratory. A fraction of a flake of powder or a small particle of residue is placed in a capillary tube, one end of which is sealed. The tube is evacuated (water pump), sealed, and placed in a copper heating block provided with a thermometer. A portion of the tube is allowed to project from the block. The block is heated to 100° C. If the powder is double base, nitroglycerine distills into the cool portion of the tube. It may be observed under a microscope or tested for by breaking the capillary under diphenylamine reagent. It has also been observed that certain smokeless

powders tend to leave very plastic residues. In tests conducted on linoleum with automatic pistols (no lubrication), splashes of powder residue similar to the splashes of molten lead were observed. When the shots were fired into cloth, the powder residue particles surrounded the fibers and assumed the contour of the surface. So far this phenomenon has been encountered only when double base powders have been used.

What Type of Bullet Caused the Hole?

Many attempts have been made to determine the composition of the bullet from the metals present in the halo or contact ring. Schwarzacher (64) analysed fragments of metal found in the vicinity of the bullet hole, while Bayle and Amy (1), Brüning (4), Gerlach (18) (19) and Sannié (59) have analysed the contact ring with this purpose in mind. The assumption must of course be made that the metal deposits are derived from the surface metal of the particular bullet which made the hole. That this is not true in the majority of cases has been shown by numerous investigators. Thus, lead around a bullet hole is often derived from gun barrel fouling or primer residues (7) (24) (25) (60) (75). Copper and zinc can as easily be derived from fragments of cartridge case metal as from the bullet jacket (7) (12) (15). Antimony and tin are constituents of primers as well as of bullet metal (60) (75). Even nickel around a bullet hole does not necessarily signify a nickel-jacketed bullet, for the primer caps of modern cartridges are nickel-plated.

As has been indicated previously, the source of the deposit left on the contact ring is to a large extent dependent upon the abrasive qualities of the target. Soft fabric or skin tissue may merely wipe the loosely-bound fouling from the surface of the bullet; bone or abrasive fabrics may remove the bullet metal. Much will depend upon the circumstances.

It is of course obvious that radiography of the bullet hole will be helpful. Eidlin found no detectable deposit on the contact ring in clothing when jacketed bullets were fired at a distance. If black powder can be proved, a lead bullet is implied. Proof of an automatic pistol necessitates a jacketed bullet.

Was the Wound Self-Inflicted?

Suicide with a firearm held in the hand necessitates a muzzle distance of twenty-four inches or less. Powder residues, and frequently metals, lubrication and components of a smoke halo, are detectable within this distance. Absence of near-shot traces tends to exclude suicide. In shots found to have been fired within two feet, due consideration must be given to the location of the entrance and the anatomical possibilities.

It has long been known that powder residues escape around the breech of a poorly-constructed revolver and are to be observed occasionally on the hand of a person who has recently fired the gun (21) (22) (23) (43) (66). In 1922 Benitez (3) recommended the application of the diphenylamine reagent to the interior of a paraffin mold

of the surface of the right hand as a means of detecting powder residue particles. B. Mueller (47) recently conducted experiments on the presence of powder residues on the hand of the person firing the gun. He came to the conclusion previously reached also by others (22) (43) that a number of revolvers give no residue, and that a negative result on the hands of the victim does not exclude suicide. The occurrence of powder residues is largely dependent on the precision with which the revolver is constructed. Mueller did not use the paraffin mold-diphenylamine method of Benitez (3).

It should be mentioned at this time that if it is necessary to exercise caution in drawing conclusions based on the appearance of a few particles of a substance which responds to the diphenylamine test on the clothing around the bullet hole it becomes even more important to do so when evaluating residues on the hand. Here at most the number is not great, and the human hand is even more liable to be contaminated with foreign substances than clothing. Matches and tobacco, among other common things, give a positive diphenylamine test.

Werkgartner (79) mentions the fact that blisters and pinch marks are to be found on the firing hand on occasion, after the use of automatic pistols. Holding the weapon in the right hand and supporting it with the left hand frequently leaves blood or powder stains on the left hand. In addition the explosive action of the gases during a contact shot may blow fragments of

tissue back on the firing hand. Particles of bone may be expelled with such force as to cause small puncture wounds (78).

Examination of Clothing: Proposed Procedure

In order to employ as many useful methods as possible in a single procedure for the examination of a bullet hole in clothing, the following sequence is proposed:

1. Visual Examination. Note size and shape of hole, disposition of fibers at entrance, evidence of abrasion, evidence of residues.
2. Photography. The use of panchromatic film is recommended for the representation of the appearance of the garment at the hole.
3. Infrared Photography. Use infrared sensitive plate and Eastman # 88A filter to represent smoke halo, black powder residue and contact ring.
4. Radiography. Use soft X rays to visualize deposits of heavy metals in smoke halo and in contact ring.
5. Microscopic Examination. Use binocular dissecting microscope to examine fabric, to locate foreign fibers, tissue or bone fragments in hole, and to find powder particles. Evidence of splashes of molten lead may be seen.
6. Remove questioned traces for testing. Distinguish black from smokeless powder. Remove particles of metal located by radiograph.
7. Press area around hole with tissue paper under a mildly-warm iron. Locate lubrication traces.
8. Perform C-acid print test for pow-

der residue. Add lead acetate to paper if there is a question of fresh black powder.

9. Spectrographic analysis of suitable portion of halo or contact ring as shown by infrared photograph, and radiograph, or—

10. Microchemical analysis, as an alternate or supplement to spectrographic analysis, might indicate muzzle distance or type of bullet.

Examination of Wound: Proposed Procedure

1. Visual Examination. Note size and shape of bullet hole.

2. Photography. General-view photographs of body as well as individual close-up views of the wounds. Panchromatic film is recommended.

3. Infrared Photography. Use infrared sensitive plates and an Eastman #88A filter, to represent the smoke halo, stamp mark or contact ring.

4. Removal of Tissue. Remove the skin surrounding the bullet hole. Stretch it on a board with tacks or pins. Remove portions of the bullet tract and place them in separate small bottles or jars, unfixed.

5. Radiography. Trim away subcutaneous tissue and place on cellophane. Use soft X rays to visualize the metals.

6. Microscopic Examination. Examine the skin and bullet tract under a dissecting microscope. Remove questioned metals, fibers or other particles for testing.

7. Chemical Analysis. Cut out small portions of tissue for spectrographic or microchemical analysis.

8. Cleaning. Wash away the adhering blood. Re-examine the skin for evidence of tattooing.

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