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An Empirical Study of Gunpowder Residue Patterns

The muzzle-to-target distance is often a factor of critical importance in incidents involving gunshot wounds. The degree of concern is dependent on the wound severity and the facts of the event, those facts being of greatest moment in a possible homicide/suicide without witnesses and diminishing in importance in a nonfatal accidental shooting with witnesses. The testimony of an expert witness will attempt, through his experimentation, to establish the minimum distance from muzzle to projectile contact point based on the presence or absence of powder residue patterns on the victim or his garments. It should be understood that in casework, the powder residue examined by the laboratory is seldom the total pattern originally blown into the skin or clothing of the victim, but rather that surviving the victim's fall, first aid ministrations, the physician's examination, and, finally, the investigative and packaging efforts of law enforcement. In some instances, portions of the latent elements can be reconstructed by chemical or infrared techniques. To avoid errors of interpretation the investigator must be aware of the variations in pattern imprints, the causative factors, and their significance as related to distance.

It is a matter of common police experience that an individual apprehended and accused of a shooting death will attempt to justify the act as self-defense. He will claim, among other things, that the deceased attacked him or in some manner forced the accused to fire while grappling for command of the weapon. Such incidents are fertile ground for powder residue studies because the close physical proximity of the combatants is a mandatory requirement in determining the true facts of the incident. Suicides involving firearms will almost always include residue in or about the wound entrance along with other phenomena characteristic of very close range gunshot wounds. The absence of these phenomena is a red light which warns of foul play, since few circumstances will allow a muzzle-to-projectile contact distance of more than 28 in. for self-inflicted wounds.

Testing and experimentation must include both ideal and controlled conditions, taking into account the variables described herein. It is essential to ascertain with certainty the maximum density of the residue pattern and its distribution at graduated and measured points extending from contact to at least 30 in. The material used as the target face should duplicate as closely as possible the fabric or other material worn by the victim. The test weapon and ammunition should also be the same as the suspect's, if not actually taken from the suspect. This similarity-of-materials doctrine is advocated by the authors to minimize variables and to remove the number of possible objections by defense counsel.

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The collation of all experimental data when compared with the crime scene residue patterns, mitigated by the collecting and packaging techniques of the crime scene, should provide the legal investigative body with a muzzle-to-target contact point calculation of ±1 in. from point contact out to a distance of 10 in., ±1½ in. between 10 and 20 in., and ±2½ in. at an interval of from 20 to 31 in. It has been possible with weapons that are in excellent mechanical condition, using "fresh" ammunition, to reduce the distance approximation to within 1 in. out to 14 in.

Factors Affecting Residue Patterns

According to most authoritative texts, powder residue patterns will vary significantly as the result of changes in primer, weight of propellant loading, powder lot, type of powder, target shape, and target composition [1]. This is true; however, all standard textbooks on the subject are deficient in defining precisely what these variations are. As a matter of practical experience the authors have found that there are at least ten principal factors that individually or collectively influence the pattern imprint on the target surface. These follow in descending order of importance:

(1) distance,
(2) barrel length,
(3) propellant burning rate,
(4) propellant type (disk, flake, ball, etc),
(5) caliber,
(6) muzzle-target angle,
(7) target material,
(8) primer (type, size, age, etc),
(9) propellant charge weight, and
(10) weapon type (revolver, autopistol, etc).

The effectiveness of these parameters is variable, depending on the circumstances, combination of variables, etc. Distance is undoubtably the most important single factor and in the final analysis allows the investigator, by a system of comparative backtracking, to arrive at an estimate of the original gunshot range. The accuracy of this estimate, however, depends on the consideration of all the many variables. It was observed, for example, that simply changing the brand or make of ammunition could significantly alter the powder residue pattern at any given distance, because not all manufacturers use the same type of powder in ammunition of the same caliber and bullet weight.

Each of the above factors was individually investigated and evaluated through a series of controlled laboratory firing tests programmed to eliminate all but the considered variable. In order to develop the optimum pattern imprint under each set of firing conditions, a fine weave, smooth, white fabric was used for the target material, except where differences in material were the subject of investigation. Variations of angle or movement of the weapon during firing were eliminated by use of a Lee Engineering Co. handgun machine rest, or an adjustable hand rest.

The same brand, lot, and type of ammunition was used throughout each firing sequence with the same weapon; however, during the caliber experiments it was necessary to use different brands in some of the weapons. Since no anomalies developed in the pattern progression from caliber to caliber, it is assumed that this did not compromise the results.

Barrels mounted with muzzle brakes, flash suppressors, or silencers were not utilized in the testing. Only weapons whose barrels were crowned in the traditional manner were used.

Effect of Caliber on the Pattern Imprint

The caliber of the weapon will most certainly affect the gun gas pattern imprint, but this facet has not heretofore been carefully investigated. The purpose of the caliber-versus-pattern experiment was to define more closely the actual effect of this variable on a pattern at varying distances. For this purpose a total of eight different weapons was used, ranging in caliber from the .22 short rimfire to the .45 autopistol. Calibers were selected on the basis of those most commonly encountered in criminal cases investigated by the Ventura County crime laboratory. Test firings were conducted at distances of 0, 3, 7, 13, 21, and 31 in. (Tables 1 and 2).

TABLE 1—*List of weapons used in the caliber test.*

No.	Caliber	Barrel Length, in.	Weapon
1	.22 short	2.5	revolver, H. Schmidt, Germany
2	.22 long rifle	6.0	autopistol, Ruger, U.S.A.
3	.22 Magnum R.F.	6.5	revolver, Ruger, U.S.A.
4	.25 ACP	2.3	autopistol, Colt Jr., Spain
5	.32 ACP	4.1	autopistol, Colt, U.S.A.
6	9-mm Luger	4.3	autopistol, D.W.M., Germany
7	.38 Special	5.0	revolver, Smith & Wesson, U.S.A.
8	.45 ACP	5.0	autopistol, Colt, U.S.A.

It was observed that the most important single effect of caliber on powder residue patterns is in determining pattern size or diameter at any given distance. There is a definite relationship between the caliber of the weapon and the expanse of the pattern produced. On the other hand, it was also found that changing the type or burning rate of the propellant powder will produce variations in pattern size and density within any given caliber.

Probably the most meaningful and useful observation resulting from the caliber test is that there are five separate and distinct phenomena associated with closeup gunshot residue patterns. These appear and disappear as a function of distance quite independently of caliber, the difference being only a matter of size. In fact, most of these elements are diagnostic of the distance from muzzle to target surface within rather narrow limits. The authors have described and classified these pattern components on the basis of physical appearance as follows: (1) starburst pattern, (2) blossom or petal pattern, (3) carbonaceous film pattern, (4) particulate pattern, and (5) entry hole ring. These elements may occur individually or collectively, depending on distance and other circumstances.

The starburst pattern is a cross rip design (Fig. 1) observed in both skin [*2*] and clothing material of shooting victims, as well as the experimental test boards. It is indicative of contact or near-contact gunshots, usually less than an inch, and occurred in all the contact test shots regardless of caliber. The difference in character was only a matter of size and extent. The diameter of the starburst rip made by the .22 short rimfire was 0.3 in. and that caused by the .45 automatic was 1.2 in. At contact distance, all but a very few particles will be blown into the wound, but if a small gap occurs at the moment of discharge, a small, tight, dense, particulate ring may be present within or surrounding the rip. Bulky or loosely woven clothing may eliminate the starburst, but in such cases the presence of powder particles in the wound is also indicative of very close range.

TABLE 2—*Results of caliber test.*

Weapon No.[a]	Caliber[a]	Distance, in.	Entry Hole Dia., in.	Maximum Carbon Film Dia., in.	Maximum Blossom Dia., in.	Particle Pattern Dia., in.	Approximate Particle Count
1	.22 short	0	0.23	0.37	0.75	0	0
		3	0.23	0.91	1.70	1.9	62
		7	0.21	0.23	0	2.3	60
		13	0.20	0.24	0	4.0	60
		21	0.21	0.23	0	8.0	35
		31	0.23	0	0	9.5	2
2	.22 long rifle	0	0.58	0.58	0.85	0	3
		3	0.23	0.55	4.25	2.3	135
		7	0.21	0.25	0.55	2.8	124
		13	0.24	0.27	0	4.2	132
		21	0.25	0.26	0	6.8	120
		31	0.25	0	0	8.5	43
3	.22 Magnum R.F.	0	0.59	0.60	0.67	0	2
		3	0.31	0.35	3.55	1.5	168
		6	0.25	0.30	1.50	2.5	150
		9	0.25	0.30	0	3.0	140
		12	0.25	0.27	0	3.5	130
		18	0.25	0	0	4.0	110
		24	0.25	0	0	7.0	70
		30	0.25	0	0	8.0	45
4	.25 ACP	0	0.64	0.75	1.50	0	0
		3	0.27	1.10	3.20	1.2	25
		7	0.25	0.28	8.50	1.5	28
		13	0.25	0	0	2.0	15
		21	0.25	0	0	0	0
5	.32 ACP	0	0.43	0.80	0	0	0
		3	0.26	0.77	4.55	1.5	70
		7	0.26	0.30	3.60	2.0	62
		13	0.30	0	0	3.5	68
		21	0.30	0	0	7.5	50
		31	0.30	0	0	8.0	6
6	9-mm Luger	0	0.85	0.99	1.53	0	0
		3	0.31	0.55	5.30	2.60	95
		7	0.35	0.45	5.25	4.00	130
		13	0.36	0	0	4.75	27
		21	0.36	0	0	0	0
7	.38 Special	0	1.05	1.28	1.55	0	0
		3	0.39	1.75	4.50	1.5	12
		7	0.38	0.45	4.00	1.8	58
		13	0.36	0	0	4.3	62
		21	0.36	0	0	7.0	50
		31	0.36	0	0	9.0	10
8	.45 ACP	0	1.25	1.40	2.25	0	0
		3	0.43	1.13	5.00	3.0	68
		7	0.45	0.48	4.50	5.25	52
		13	0.41	0	0	6.5	37
		21	0.41	0	0	7.5	18

[a] See Table 1.

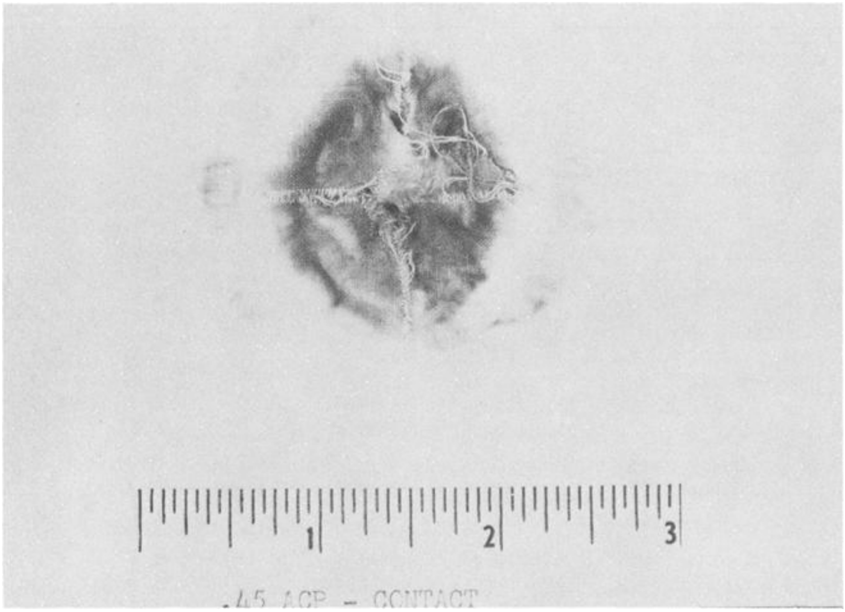

FIG. 1—*Starburst or contact cruciform rip pattern made by a caliber .45 Colt Automatic Pistol using Remington 230-grain fully jacketed bullet ammunition.*

The blossom or petal pattern is a distinctive, fragile, gray floral or petaloid pattern (Figs. 2 and 3) composed of carbonaceous and other fine material resembling the overlapping petals of a flower, such as a camellia. It occurs, regardless of caliber, at distances of less than an inch to approximately 10 in. Its presence is an almost positive indication that the muzzle-to-target-face distance did not exceed 10 to 11 in. Unfortunately, if the target face is rubbed or abraded to any extent the floral pattern is easily obscured, leaving only an irregular gray circle. The blossom occurrence is influenced to some extent by barrel length versus distance, particularly where the barrel length exceeds 6 in. The blossom phenomenon is probably a gas turbulence pattern that attenuates with distance, becoming too weak and dispersed to imprint at distances beyond 10–11 in. It does not show well on dark or coarse material except under infrared examination.

The carbonaceous film pattern (Fig. 4) is a homogeneous gray, carbonaceous staining similar to the blossom pattern, but lacking the petal or floral design and usually of smaller diameter. It commonly occurs within the blossom as a smaller diameter inner circle, immediately surrounding the projectile entry hole. It may, in some instances, disappear at the same distance as the blossom or it may persist after the blossom fails to appear out to a distance of approximately 21 in. Where the carbonaceous film pattern appears alone it usually indicates a firing distance of between 10 and 21 in.

The particulate pattern (Fig. 5) as defined herein includes the "tattoo" effect of other authors. It consists of unburned and partially burned powder grains, carbonaceous particles, bullet jacket material, lead shavings, dirt, or other ejecta from the bore of the weapon. Particulate patterns do not develop at contact gunshots because the solid material is blown into the wound or through the clothing by the high pressure gas column. Particulate patterns begin to form at distances of a few tenths of an inch and increase in diameter at distances out to about 25 in. Occasionally, scattered particles will be noted at distances out to 36 in. or beyond. It is the experience of a reviewer of this article that where ball-type powders are involved, particles may be deposited out as far as 6–8 ft.

The diameter and density of the particulate pattern is an indication of distance, but this is also influenced by barrel length, propellant type, and, to a lesser extent, caliber. At short distances the particulate pattern will be from 1 to 3 in. in diameter and quite dense. At the greater distances it may exceed 10 in. in diameter, but the number of particles will be fewer and more widely dispersed. The longer the barrel, the smaller and tighter the particle pattern at any given range. A change in the propellant can produce a dramatic modification of the particle density pattern. Particulate patterns are subject to severe attrition from crime scene to laboratory and care in handling of clothing and other material is mandatory.

When an excessive quantity of particulate matter is present, it may be due to circumstances or require information not readily duplicated in the laboratory. For example, a revolver that had not received any maintenance attention or cleaning, and that had not been removed from a dresser drawer for 40 years, was used by a husband shooting his wife. The fatal round drove before it 40 years of rust, dust, dirt, etc that defied test pattern reproduction even after expending 50 rounds of ammunition in the attempt.

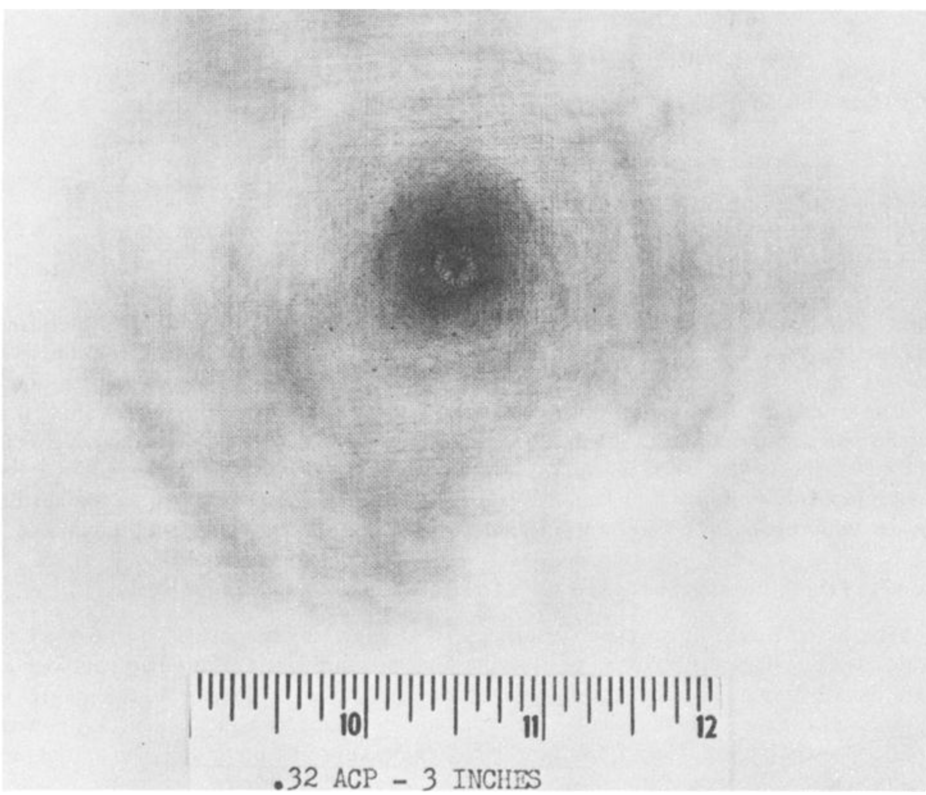

FIG. 2—*Blossom or petal pattern made by relatively "clean" burning powder fired with a caliber .32 ACP automatic pistol and Norma 77-grain fully jacketed ammunition.*

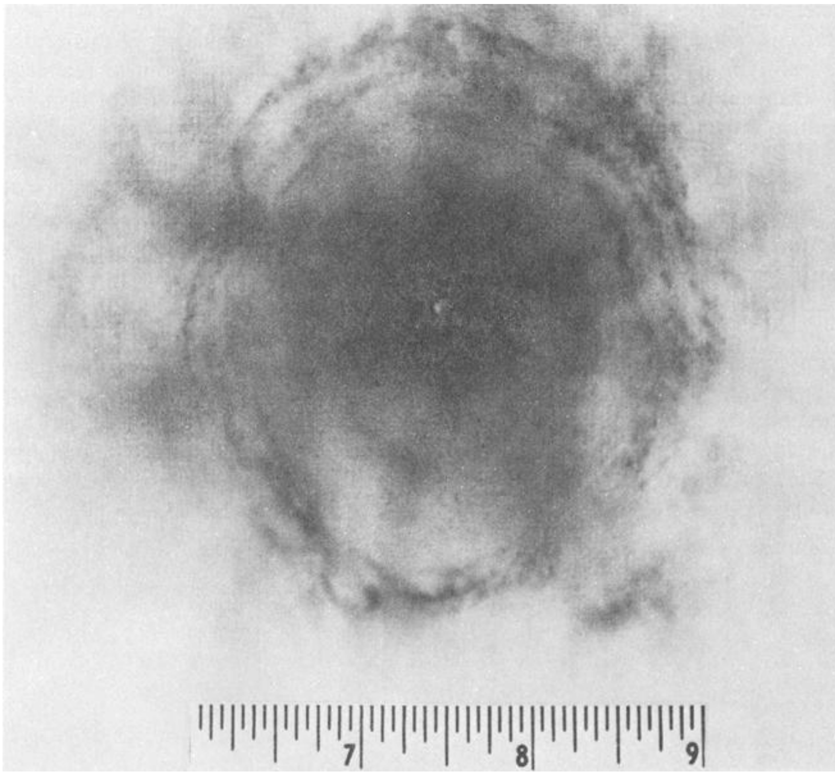

FIG. 3—*Blossom or petal pattern made by "dirty" burning caliber .32 ACP ammunition.*

The entry hole ring consists of a dark gray to black ring of carbon, dirt, bullet lubricant, primer residue, lead, and other material deposited by or wiped from the projectile as it enters the target. The distinctive dark entry ring is present at all ranges except contact, where it may be obscured by other factors. Where the entry hole ring occurs alone it is indicative of a muzzle-to-target distance greater than about 25–30 in. with most handgun propellants. However, where black powder or ball powders are used, residue may be deposited far beyond this distance. When missing, the investigator must be certain the other pattern elements were not removed or deposited on some intervening material.

Barrel Length Investigation

The barrel length of a weapon influences the totality of the powder gas combustion and also the shape of the cone of escaping high pressure gases. These two components are then instrumental in determining the ultimate character of the gas residue imprint at any given distance. The subject of barrel length variations as a factor affecting powder pattern lineation and density, has been largely ignored in the literature. The authors investigated this variable through a series of three controlled firing experiments.

The first of these tests involved the firing of various weapons of the same caliber, but with different barrel lengths, all at a fixed distance. The result of this trial suggested a

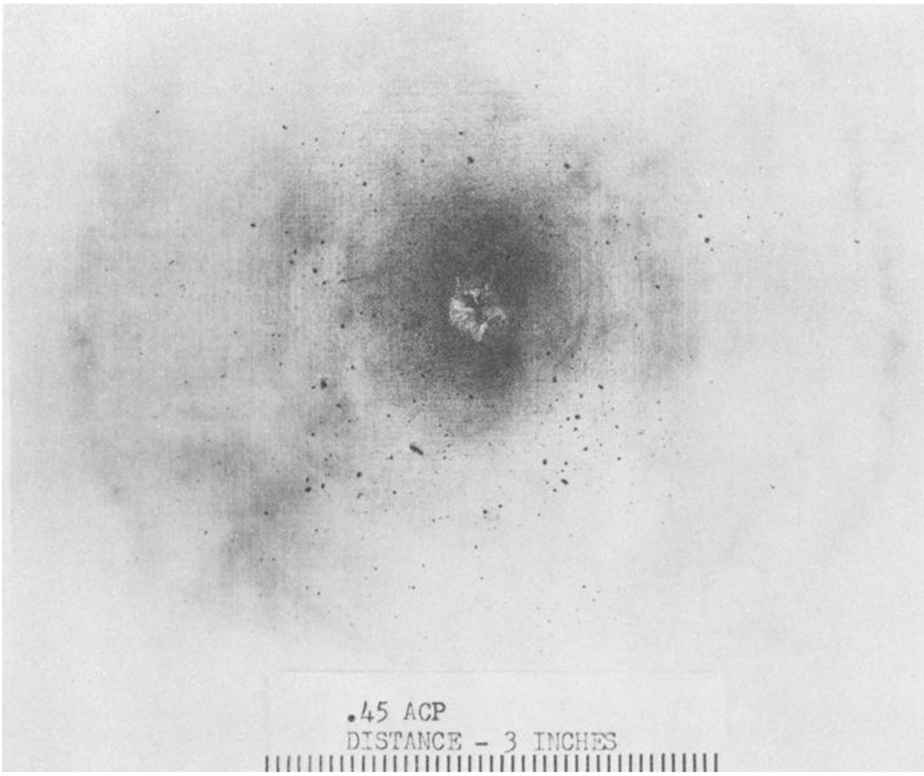

FIG. 4—*A typical carbonaceous pattern combined with a very light blossom and moderate particulate pattern.*

comparative test series employing a single long barrel of rifle length fired at variable distances. Finally, to eliminate every variable except barrel length itself, a test series was conducted with a single weapon at a fixed distance and the barrel was shortened by two inches after each firing. The same brand and lot of .22 long rifle rimfire ammunition was used throughout the entire test series. Patterns obtained from each experiment were compared and cross-checked against other firings.

Barrel Length Test 1

The initial experiment included the firing of four .22 rimfire semiautomatic handguns with barrel lengths of 3, 4½, 5¼, and 6¾ in. For comparison, a rifle of the same caliber having a 22-in. barrel was included in the series. All firing was conducted at a muzzle-to-target distance of 10 in.

In general, it was observed that the shorter the barrel, the larger the diameter of the gas residue pattern and the greater the density of the particles deposited. However, the 22-in. rifle barrel produced a residue pattern that was relatively tight and dense as compared to the handguns, giving the appearance of having been fired at a much closer distance than was actually the case. None of the weapons produced a blossom pattern with the ammunition used at the 10-in. firing distance. The handguns all produced a

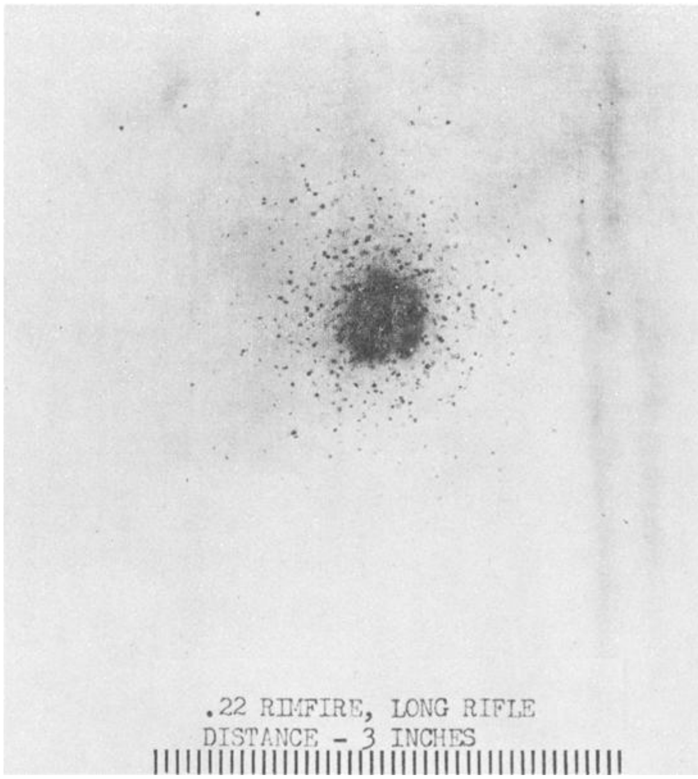

FIG. 5—*A well-developed particulate pattern.*

distinct carbonaceous film pattern, as well as the particulate pattern. There was no carbonaceous film in the rifle pattern and the particulate element was of smaller diameter and of greater concentration than that made by the handguns.

Barrel Length Test 2

As an outgrowth of barrel length Test 1 and the pattern developed by the rifle barrel, it appeared that additional firing tests with the 22-in. barrel length at variable distances would be informative. Therefore, additional patterns were fired at distances of 3, 6, 9, 12, 15, and 21 in. It was evident from these patterns that the longer barrel consistently produced a smaller diameter, more concentrated pattern than any of the handguns of the same caliber at similar distances. However, the particle count was less with the long barrel, indicating more complete combustion of the powder charge, as would be expected. The longer barrel produced the blossom or petal pattern, and at approximately the same distance as the short handgun barrels. At the maximum distance of 21 in., only the entry hole ring was formed in the target face, so testing was discontinued at this point. It was concluded from this test that a very long barrel can create a false impression as to the actual distance from which the shot was fired, if this factor is not known.

Barrel Length Test 3

The final barrel length experiment was directed towards eliminating every possible variable except that of barrel length itself. The purpose was to isolate this effect on gun gas residue patterns. The weapon used was a .22 caliber rimfire rifle with a 24-in. barrel. After the initial firing the barrel was shortened by increments of 2 in. between each firing down to a final length of 2 in. of remaining barrel. All shots were fired at a muzzle to-target distance of 10 in. (Table 3).

TABLE 3—*Barrel length test. Weapon—J. C. Higgins (Sears) bolt action, single shot rifle; ammunition—Eley High Power, .22 long rifle rimfire; distance—10 in., muzzle to target face.*

Test Shot No.	Barrel Length, in.	Entry Hole Dia., in.	Maximum Carbon Film Dia., in.	Maximum Blossom Dia., in.	Maximum Particle Pattern Dia., in.	Approximate Particle Count
1	24	0.22	1.2	0	1.8	185
2	22	0.22	1.2	0	1.6	160
3	20	0.22	1.1	0	1.6	155
4	18	0.22	1.1	0	1.6	130
5	16	0.22	1.2	0	1.6	87
6	14	0.22	1.2	0	1.9	105
7	12	0.23	0.4	0	2.3	105
8	10	0.23	0.4	3.8	2.3	98
9	8	0.23	0.3	3.3	3.0	125
10	6	0.23	0.3	3.3	3.0	140
11	4	0.27	0.3	0	4.0	165
12	2	0.27	0.3	0	4.5	185

The character of the gas residue patterns remained relatively unchanged from the original 24 in. down to a remaining barrel length of 16 in. Resultant residue patterns averaged approximately 1½ in. in diameter and included well-developed carbon and particulate patterns, but no blossom. The particle count remained fairly constant for each shot and recordable differences in pattern character in the first 8 in. of barrel shortening were negligible. There was a slight reduction in the particle count between 14 and 18 in. of remaining barrel.

The first significant change occurred when the barrel was shortened to 12 in. and fired. At this point the diameter of the pattern increased from 1½ to 2½ in. and the carbonaceous area decreased from 1 to ½ in. in diameter. The second significant change occurred when the barrel was shortened to 10 in., at which point the classic blossom pattern developed and remained in evidence down to 6 in. of remaining barrel, after which it again disappeared. The blossom pattern averaged about 3½ in. in diameter for the three barrel lengths (10, 8, and 6 in.) where it occurred. At 6 in. of barrel another significant change was noted in the diameter of the residue pattern, which increased from 2½ to 4 in. It remained at about that size down to the final barrel length of 2 in. The character of the pattern at the 6, 4, and 2-in. barrel lengths was similar to those for the caliber .22 rimfire handguns cited in Test 1.

At 8 in. of remaining barrel, the particle count increased and continued to do so to the final length. In general, the particle count did not follow a distinct increase or decrease corresponding to changes in barrel length until only about 6–8 in. of barrel remained. It is possible that differences in charge weight or combustion of the charge between rounds had a greater effect on the particle count than the diminishing barrel length, at least with the brand of ammunition used. In any event, this particular element followed an irregular pattern.

The barrel length experiments demonstrated conclusively that differences in barrel length do have a significant effect on gunpowder residue patterns, thus emphasizing the necessity of knowing the original barrel length when attempting to duplicate crime scene residue patterns. A long barrel will produce a residue pattern that appears to have been fired at a closer distance than a shorter barrel fired at the same muzzle-to-target interval, thus the possibility of error.

Most handguns do not have barrels longer than 7½ in., but illegally converted weapons made from cut-down caliber .22 rimfire rifles may have barrels of 10–12 in. or even greater lengths. Differences imposed by barrel length on residue patterns can be of paramount importance in cases involving cartridges that are interchangeable with and common to both rifles and handguns. This is true not only of the caliber .22 rimfires, but also such common center-fire cartridges as, for example, the caliber .30 Carbine, caliber .32-20 Winchester, caliber .38 Special, caliber .357 Magnum, 9-mm Luger, caliber .44-40 Winchester, and the caliber .44 Magnum. These are the most prominent, but there are others. The powder residue pattern imprinted by one of these cartridges when fired from a rifle will not be the same as that made by the identical cartridge fired in a handgun.

Influence of Propellant Powder on Residue Patterns

Various authorities refer to the importance of the propellant powder as a determinative factor in the development of gunpowder residue patterns. However, this is never clearly defined. The importance of the propellant powder as an influence on residue pattern imprint was confirmed during the caliber and barrel length experiments, where changing brands of ammunition introduced alterations of the pattern and this was traced to variations in the powder type. Actually, the problem is more complex than that of a simple difference in powder type or charge weight.

There are at least five variable characteristics of gunpowder that influence residue pattern imprint, and these are: (1) powder type (black, smokeless, single base, etc), (2) grain geometry (flake, ball, disk, etc), (3) chemistry (presence of inhibitors, deterrents, etc), (4) charge weight, and (5) burning rate (relative quickness factor). Propellant powders are divided into two main types, black and smokeless. The smokeless or nitrocellulose powders are further subdivided into single base (straight nitrocellulose), double base (containing a percentage of nitroglycerin), and cordite, a double base stick type with a high percentage of nitroglycerin. Grain geometry alludes to the grain structure, such as ball or spherical, flake, rod, disk, and tubular. Chemistry refers to the total composition, including various grain coatings used to establish specific burning characteristics, flash inhibitors, and other chemical additives. Charge weight is self-explanatory and is usually given in grains or grams. The burning rate is usually expressed as fast, medium, or slow, but is actually a function of the relative quickness factor used by the manufacturers. This is defined as the burning rate under standard conditions relative to some arbitrarily chosen standard, usually another powder [*3*]. Each of these factors can individually cause variations in the residue pattern, but they seldom act alone, being merely a contributing element in the overall effect. Probably the two most important factors are the chemistry and the burning rate.

It should be understood that commercial ammunition is loaded to a predetermined performance level or standard and the charge weight of each lot of powder is adjusted to achieve this level. Difference in charge weight between different lots of the same powder is probably a negligible factor in its effect on powder residue patterns. However, no effort was made to measure the magnitude of this particular factor during these experiments. On the other hand, the introduction of a different type of powder or one with a different grain structure can cause a profound alteration of the residue pattern. Any factor or variable which affects the burning rate and pressure characteristics of gunpowder may result in a powder pattern variance [4].

This is a matter of importance because the manufacturers can and do change the type of powder used in loading ammunition of the same caliber and bullet weight at various points in time. Commercial ammunition may change considerably over a period of years without the label on the ammunition changing at all [5]. The recent shift from disk and tubular powders to ball powder is one example.

Hand or home-loaded ammunition may vary widely in powder type and charge weight from similar commercial ammunition, creating a situation that can not be duplicated in the laboratory without samples or specific knowledge as to the powder-charge-bullet combination used. However, in the authors' experience handloaded ammunition is very seldom a factor in homicides.

In order to evaluate the specific effects of the propellant powder on residue patterns, the authors fired patterns with different brands of ammunition of the same caliber and bullet weight, after first examining and establishing the various types of powder with which they were loaded. Handloaded ammunition with powder of known type and burning rate was also prepared and used as part of the test. The powder charge weight was adjusted to duplicate commercial ballistic specifications in order to make a valid comparison with commercial brands. Where the powder type or burning characteristics differed from commercial ammunition of similar caliber and bullet weight, the powder residue pattern was also different.

Examination of commercial and military ammunition powder charges revealed that the manufacturers use several different types of propellants for ammunition of the same caliber. The powder varies from ball through disk, flake, rod, and tubular. Most American-made handgun ammunition is loaded with either ball or disk powder. British or European loaded ammunition may be charged with flake or very small rod powders. These differences in powder type account for significant residue pattern variations when different brands of the same ammunition are tested under identical conditions.

For example, Norma caliber .38 Special ammunition (loaded in Sweden) proved much cleaner burning and produced substantially less residue than American-made caliber .38 Special ammunition manufactured by Remington-Peters, Winchester-Western, or Federal. Comparative patterns made using Norma ammunition appeared to have been fired at a much greater distance than American-made ammunition when both were tested under identical conditions, a result of the comparative lack of residue. The character of the residue pattern can be altered at any given distance by simply changing the brand of ammunition, where this introduces a different powder type or configuration.

In another experiment, caliber .38 Special ammunition was handloaded by the authors with fast and slow burning disk and ball powders. The disk powders used were Hercules Bull's-eye and 2400; the ball powders were Winchester-Western 230P and 295HP. Comparative residue patterns were fired through a Smith & Wesson caliber .38 Special revolver with a 5-in. barrel. All shots were fired at a muzzle-to-target distance of 10 in.

In general, the relatively fast burning powders produced smaller diameter patterns with a distinct blossom, whereas the slower burning powders made a larger, denser pattern with almost double the particle count, but no blossom. It was also obvious that the ball powders were much dirtier burning and produced darker, more carbonaceous patterns as compared to the disk powders. In comparing the patterns made by the different powders, three latent factors became patently clear; it would have been impossible without prior knowledge to have determined that (1) all were the product of the same weapon, (2) they were all fired from the same caliber weapon, and (3) all were fired at the identical distance.

The type of powder fired in a weapon can usually be determined by microscopic examination of the particulate residue. However, some ball powder consists of flattened, irregular spheres and the end product is not always easy to differentiate from disk or flake when reduced to residue.

An interesting sidelight developed while testing different brands of ammunition when an old lot (probably at least 35 years old) of caliber .32 ACP ammunition was located. When test-fired it functioned flawlessly, but due to either powder deterioration, faulty ignition, or a different chemistry of powder or primer or both, this ammunition produced residue patterns quite different from any fresh or modern ammunition, even of the same brand. The carbonaceous, blossom, and particulate elements were present, but were much darker and more distinct than any modern ammunition. The particle count was also 3 to 5 times greater. It would appear that age, date of manufacture, and even storage conditions could effect the residue pattern produced by some ammunition. It is unlikely that such a dramatic change could be accounted for by a change of powder lot.

Another observation during the course of the barrel length, caliber, and propellant powder experiments is that approximately 5 to 15 percent of the available powder charge is not completely consumed, being blown out of the muzzle with the hot powder gases. There does not appear to be any commonly used barrel length that results in complete combustion of the available powder charge. This statement holds true for both handguns and rifles. The absence of unburned or partially burned particles in a perplexing gunshot case can not be attributed to its all having been consumed in the barrel of the weapon; it must be the result of other causes.

Over-bore capacity, too short a barrel, incomplete ignition, insufficient case-neck pressure on the bullet, insufficient wad pressure, or poor crimp (shotshells) and powder burning rates are some of the reasons offered to explain the unconsumed powder phenomenon. Undoubtedly, all of these factors can and do affect the degree of combustion efficiency. However, the authors have observed unburned or partially burned powder grains under ideal conditions where there was no satisfactory explanation.

As a corollary to the above, it is known that recovered projectiles will occasionally have unburned powder grains adhering to the base, or more often they will display the imprint of unburned powder grains on the base [*6*]. This is more pronounced with lead base bullets than fully jacketed ones and ball powders produce the most distinct and identifiable prints. This fact can often assist the investigator in efforts to establish the type of propellant used where samples of the original ammunition are not available

Summary and Conclusion

Close contact gunshots produce characteristic gunpowder residue patterns that contain elements indicative of the true muzzle-to-target distance at the moment of discharge. The importance of reliably establishing a muzzle-to-bullet-contact-point distance in incidents involving gunshot wounds is well established. Experiments conducted under controlled conditions, utilizing the suspect weapon and ammunition, will provide the maximum data available in this form of physical evidence. The results of the authors' experimentation disclose that:

1. First and foremost, with the exception of a contact wound, there can be no meaningful approximation of muzzle-to-bullet-contact distance without first conducting controlled firings utilizing the suspect's weapons and ammunition, or ammunition of the same make and lot.

2. Distance between the bullet contact point and the muzzle affects the powder residue pattern configuration, size, and density.

3. Variation in the propellant powder charge character and quantity, in the same caliber and when fired through the same barrel, will alter the powder residue pattern even though fired at a constant, measured distance.

4. No matter what the powder charge (weight) in any given handgun caliber that is propelling a projectile of prescribed weight, approximately 5 to 15 percent of the powder charge is not completely consumed on firing. The unburned and partially burned powder fragments pattern themselves out to a distance of between 30 and 36 in. for most types of smokeless gunpowder. However, with ball powder this distance may be increased to 6 or 8 ft.

5. The caliber of the weapon will effect both the size and character of the powder residue pattern at any given distance.

6. The barrel length of the weapon will effect the size and density of the residue pattern at any given distance.

7. Test-firing under controlled laboratory conditions will produce the optimum results consistent with maximum distances of muzzle to target, and thereby establish the parameters for evaluating crime scene data, witnesses' statements, and subsequent courtroom testimony.

8. Any approximation of distance based solely upon entrance hole diameter and powder pattern without first firing comparative residue patterns is patently unreliable, because of the unlimited pattern changes available through the manipulation of powder type, charge, chemistry, etc (a condition of manufacturing differences and product improvement) and barrel lengths in the same caliber.

The extent or degree of exactitude required by a particular gunshot case will vary according to the circumstances. In most instances it is sufficient that the investigator be able to state that a shot could or could not have been fired within some interval, rather than at a specific distance. However, it is necessary for the investigator to be aware of the variables involved in order to evaluate or duplicate more accurately the crime scene conditions.

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