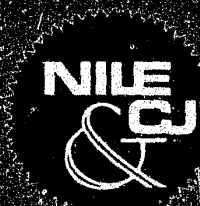


# Flight Characteristics and Stain Patterns of Human Blood



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# Flight Characteristics and Stain Patterns of Human Blood

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By

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## PREFACE

The overall objective of this investigation was to provide knowledge into an area of forensic science that has not heretofore been adequately documented. Examination of evidence at the scene of any occurrence sufficiently violent to have resulted in bloodshed should in every instance include a detailed study of every detectable bloodstain. Observations made during such a study often can, and sometimes do, provide sufficient information to reconstruct the conditions at the moment of bloodshed. This, in turn, may allow conclusions to be reached in answering vital questions regarding the nature of the act itself. Ultimately, these answers should assist a jury in resolving the matter as murder, accident, or suicide. Information contained in this report provides the investigator with basic knowledge allowing him to interpret bloodstain evidence with greater understanding and accuracy than in the past.

It must be emphatically stated, however, that this report contains both rules and guides for the interpretation of blood pattern evidence. Careful distinction must be employed in understanding that the guides are just suggestions, and not firm rules. They will in many instances be of great help in assisting the investigator to decide upon a further course of action; but rarely will they be conclusive in and of themselves. For example, many times a range of limits will be suggested as being representative of a particular bloodstain pattern. This does not imply that stains of some other origin could not have produced a similar pattern in one small portion of their overall bloodstain pattern. Given a sufficiently large bloodstain, however, firm conclusions may often be drawn regarding conditions that were required for its formation. It is emphasized and will be re-emphasized that a conclusion should never be drawn from a limited sampling of bloodstain evidence, especially if it consists only of small spots.

Little attempt has been made to express data in this report in a statistical manner. While a considerable number of measurements were taken, final conclusions should be considered from the legal viewpoint of "proof within a reasonable scientific certainty" rather than the mathematical equivalent of employing confidence limits. This choice was made in consideration of many factors including the ultimate usage of any physical evidence—the courtroom. Likewise,

the expression of measurements in both the English and the Metric system has been adopted because of the general public acceptance of the former and, in small measurements, the greater accuracy of the latter. It is hoped that this departure from the more academic decimal system will not seriously mar the acceptance of an otherwise scientific treatise. If the material herein contained proves useful to others in arriving at a better understanding of prior events through the study of bloodstains then this investigation shall have served its purpose.

### Acknowledgments

The author would like to extend his sincere appreciation to Mrs. Lorraine F. Bialousz for her capable assistance throughout this research. Corning Hospital of Corning, New York is acknowledged for supplying most of the human blood used, with special thanks to Mrs. Lyna B. Emerson and Dr. John B. Poore. The help of Dr. D. T. Baker with special phases of this study is most appreciated. Credit is given to Frayne B. Johnson of the Minnesota Bureau of Criminal Apprehension and to Stuart S. Kind of the Northern Forensic Science Laboratory, England, for supplying the photographs used as Figures sixty-four and sixty-eight, respectively.

HERBERT L. MACDONELL

31 October 1970

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## *I. INTRODUCTION*

Although it would seem that prior investigations of physical evidence would have resulted in a wealth of knowledge regarding the significance of bloodstains, such is not the case. Literature searched by the author contains little beyond elementary rules for establishing the direction of travel or simple correlations of general character as a function of the distance a drop falls (1-8). Perhaps the most comprehensive source of accurate information on this subject to date is the 1955 affidavit of the late Dr. Paul L. Kirk regarding his investigation of the Dr. Samuel Sheppard murder case (9). Apparently, nothing else has since been published that treats this subject in depth. In fact, in 1967, Dr. Kirk himself suggested that blood was still a neglected area in criminalistics (10). Because of the deficiency in documented knowledge regarding bloodstain evidence the present research was initiated. It also represents a continuation and extension of experiments that have been conducted by the author over the past several years.

Two terms have been used throughout the remainder of this report that have been adopted as standard nomenclature. These terms, target and impact site, might easily become confused without a lengthy and unnecessary explanation each time they are used in an experiment. The reader is urged to understand their correct usage from the definitions that follow:

Target—the object, usually white cardboard, onto which blood is splashed, spattered, projected or dropped. It is the collector for the items which constitute the purpose of this investigation—bloodstains.

Impact Site—usually that point on a bloody object which receives some form of blow or gunshot. In the absence of an impact which in some way causes blood to spatter, impact site could also mean that spot or area on the surface of a target which is struck by blood in motion.

When considering bloodstain evidence, two questions become apparent. First, what might we reasonably expect to learn from an examination of the physical characteristics of bloodstains? Secondly, which properties of bloodstains may best be used to provide an answer

to the above question? Logically, the answer to question number one is:

- (a) distance between target surface and origin at the time blood was shed,
- (b) point (s) of origin (s) of blood,
- (c) type and direction of impact that produced bloodstains,
- (d) movement and directionality of persons and/or objects while they were shedding blood,
- (e) the number of blows, shots, etc.
- (f) position of victim and/or objects during bloodshed,
- (g) movement of victim and/or objects following bloodshed.

The second question could be rephrased to ask what is there about bloodstains that can be observed and/or measured? The answer to this is quite simple: the number of spots, their location, size, and shape, and the surface characteristics of the material upon which stains are deposited are all that are ever available for physical examination. Their study in combination is especially important. Considering that bloodstains are usually the result of forces acting upon liquid blood, it is well to look first at this material before attempting to interpret any stains that it might produce.



## *II. CHARACTERISTICS OF LIQUID BLOOD*

Properties of human blood that are of interest to this research are limited to physical considerations. Specific gravity, viscosity and surface tension are important to an understanding of what happens to blood once it is removed from a body. It should be noted that when blood leaves a body by spatter or drop, its behavior will follow laws of the physical sciences, specifically that of ballistics—the science of projectiles in motion. Therefore, interpretation of the significance of bloodstain evidence should be restricted to the physical scientist and not the pathologist whose expertise is generally limited to blood within the body.

Most measurements of physical properties of blood, as well as physiological properties, have previously been reported by many other investigators and will not be repeated here. However, the volume of a single drop of blood was not found in the literature searched and was therefore determined experimentally. Samples from both sexes, age range from 2 years to 89 years of age, and both fresh and complexed blood were used for experiments. Volume of a single drop of blood was determined as 0.05 ml using a simple volumetric technique. The 95% confidence limits for this value are 0.0495–0.0516. High speed photographs of single drops were taken as an independent method and confirmed this range.

No measurable differences were detected in any experiment when freshly drawn blood, which was always used within two or three minutes, was compared to samples containing EDTA, citrate, or oxalate as a complexing agent for calcium. For this reason samples containing EDTA were generally used if the experiment could not be completed within one or two minutes.

The terminal velocity of a drop of free falling blood had been determined by the author on a previous occasion. This value was confirmed as  $25.1 \pm 0.5$  feet per second for a single drop in air. Figure 1, page 31, shows a graph obtained by plotting velocity as a function of distance fallen by a single 0.05 ml drop of blood. While the significance of this information may at first appear only academic, its practical application is illustrated later by a case example in section XIII of this report. The value 25.1'/sec is an absolute maximum for falling drops in air. It was recorded by drops measured between falling dis-

tances of twenty to eighty feet. Drops having a volume of less than 0.05 ml will have maximum terminal velocities less than that of the normal drop. Several smaller samples were measured using multiple flash stroboscopic photography. Results of these experiments are listed in Table 1. A plot of these data allow extrapolation to estimate

TABLE 1—*Characteristics of Free Falling Human Blood.*

Drop volume	Observed diameter	Terminal velocity	Distance to reach terminal velocity
0.000613 ml	1.06 mm	7.5'/sec	20-26"
0.001195 ml	1.32 mm	10.9'/sec	33-39"
0.005020 ml	2.12 mm	15.4'/sec	8-10'
0.050600 ml	4.60 mm	25.1'/sec	14-18'

the terminal velocity of any droplet within the experimental range. Figure 2, page 32, illustrates such a plot. Contrary to popular belief a single drop of blood will not break up into smaller droplets by simply falling through air. It must either strike an object or be acted upon in some manner if it is to sub-divide.

If we had considered only blood that is either falling or that is projected through the air, our study would have been one of flight characteristics. More specifically, it would have been limited to ballistics. However, it is seldom that an investigator is privileged to be present when blood is in the process of being shed. Therefore, a study of the static aftermath of a scene is all that is of practical importance to the criminalist. The report that follows reflects some of the parameters that must be considered before the investigator attempts to reconstruct events and/or circumstances that were required to produce specific bloodstain evidence.

### *III. BLOODSTAIN CHARACTERISTICS— SIZE OF SPOT*

Information contained in most forensic textbooks regarding the relationship between the size of a spot of blood and the distance it fell is, for the most part, either incomplete, inaccurate, or both. Generally, it would have been better to have omitted the subject altogether rather than treat it so lightly. Most authors completely neglect or inadequately describe an essential fundamental consideration—the nature of the target surface. As will be shown later, overall size and the edge character of the spot are far more dependent upon the texture of the target surface than they are upon the distance fallen.

Nevertheless, worthwhile correlation between blood spot diameter and distance fallen is possible if the target surface is characterized and included. One such set of data is illustrated in Figure 3, page 33. These measurements were made on hard, smooth cardboard targets. Similar data was obtained on other like surfaces such as floor tile, glass, porcelain, etc. For practical purposes, the diameter of a normal drop of human blood will range between 15 mm ( $\frac{5}{8}$ " ) and 19 mm ( $\frac{3}{4}$ " ).

#### *IV. BLOODSTAIN CHARACTERISTICS— SHAPE OF SPOT*

Surface texture is of paramount importance in the interpretation of bloodstain evidence and correlation between standards and unknown will be valid only if identical surfaces are used. Generalization of "spines," spatter, and edge character as a function of distance fallen is not possible unless the target substance is well defined. For example, blood spots on glass will be consistent but "wood" or "paper" are quite another matter as they permit wide variations in surface texture. Different thicknesses of otherwise identical cardboard will, for example, produce noticeable variations in edge characteristics at the same dropping distance. The only accurate way to estimate dropping distance is to conduct a series of blood drops vs. distance experiments on the specific surface in question and to use these known standards for a direct comparison to the unknown. Final conclusions must be stated in a range of values broad enough to include any reasonable error in interpreting edge characteristics. Directionality may be determined from the shape of a single blood spot with considerable accuracy. This subject is discussed in detail in section VI.

## V. TARGET SURFACE CHARACTERISTICS AND SPATTER

The surface upon which a drop of blood falls has a decided effect upon the extent of its spatter. In general the harder and less porous the surface, the less spatter results. This is of course due to the fact that the surface of the drop, while undergoing considerable geometric shift upon impact, remains intact as a result of flexibility permitted by the relatively high surface tension of the fluid. Protrudances, such as are present on irregular and porous surfaces, can rupture a drop's surface and result in spatter. This condition is not unlike a rubber balloon filled with water—it may be “teased about” on a smooth surface to great degrees of geometric distortion, however, the same balloon will be torn and discharge its contents in all directions if placed upon coarse sandpaper.

Consideration must be given to both hard and soft porous surfaces. For example, raw wood and asbestos board are certainly porous, but they are also quite hard in contrast to newspapers or paper hand towels. Likewise, the degree of irregularity of the surface is an important factor and must not be overlooked. Consider, if you will, the two sides of a sheet of singularly corrugated cardboard. Both surfaces are of the same composition but differ markedly in texture.

Estimations of dropping distance from the extent of spatter will usually be erroneous if surface texture is not considered. For example, the spot stain shown in Figure 4, page 34, was produced by a drop of blood that fell eighty feet before striking a hard, smooth, glossy, cardboard surface; no spatter occurred whatsoever. In contrast, the spatter shown in Figure 5, page 34, resulted when a drop fell onto a blotter from only eighteen inches! Cardboard, very similar to that used in Figure 4 except that it was not glossy, produced the pattern shown in Figure 6, page 35, when a drop of blood fell sixty-eight feet. These three figures are typical of the variety of spatter and stain shape that result when blood strikes surfaces with different texture. In these examples distance was exaggerated to emphasize the point. In Figures 7 through 12, pages 35-38, the blood dropping distance was maintained at 42" from above each surface. Study of these figures should convince the reader that any attempt to describe

the character of a spot of blood is absolutely meaningless without considering the surface texture of the target.

Finally, the unique situation wherein a drop strikes the juncture of two dissimilar surfaces may also be encountered and must, therefore, be examined. This condition will cause a rupture of the drop's surface by protrudances in the porous surface and yet result in more extensive spattering of the drop in the harder or smooth surface area. As previously described, blood will spatter to a greater extent on porous surfaces than on smooth surfaces. However, if something causes a rupture of the drop's surface it is more likely that greater spatter will occur in the smooth surface portion of the stain. This is true simply because capillary effects are absent in the smooth area. Figure 13, page 38, illustrates the result of a blood drop striking such a dual surface, in this case flocked wallpaper. Dropping distance was the same in this example as in the previous set of figures, 42 inches.

## *VI. EFFECT ON HORIZONTAL MOTION*

Measurements are not necessary to determine flight direction, but they must be made for height and angle determinations. As a result, it is probable that fewer errors have been made in establishing directionality from blood stains than in estimating either dropping distance or impact angle. Directionality is usually obvious as seen in Figure 14, page 39, where the drop was traveling from right to left when it struck the hard, cardboard target.

The pattern in this figure is twofold but resulted when a single drop struck a target surface traveling at about eight feet per second after falling about four inches. At this velocity a drop frequently breaks up at impact and a smaller droplet is "cast off" in a backlash or "whip" action. The smaller droplet is formed similar to the breaking of the crest of a wave and travels in the same direction as the original drop, just above the target. It streaks across the surface ultimately terminating in a pattern similar to an exclamation mark whose dotted portion represents the extent of travel. In Figure 14, page 39, the stain above the 3 inch mark is the original drop and the longer, narrow stain streaked over the 1 inch mark is the "cast off" or "throw off" portion. Other smaller cast off stains are also evident. These will increase in number as the initial drop falls a greater distance and are actually a result of horizontal, low level, spattering. An example of this more-or-less undirectional streaking is shown in Figure 15, page 39. This stain resulted from a drop of blood traveling at about four feet per second right to left horizontally, and falling two feet to the hard, cardboard target. The many "exclamation points" that are produced differ greatly from normal spatter that occurs when a drop falls vertically onto either a flat or angular target. Compare this figure with Figures 19 through 22, pages 43-46, of Section VII. Note that almost all small cast off droplets originated from the outside edges of the primary drop in Figures 19 through 22 whereas the majority of cast off droplets in Figure 15, page 39, originated from the center of the primary drop. This may be verified in each figure by holding a straight edge parallel to the smaller spatters and tracing their origin. This difference allows a conclusion to be drawn from a bloodstain as to horizontal motion of a drop, such as might fall from a person walking or running, in

contrast to a drop that fell straight down and struck a tilted or angular target. Unfortunately, this phenomenon is only reproducible on hard, smooth surfaces. Horizontally projected blood drops striking a soft, porous, surface do not obey this rule. Figure 16, page 40, displays the result obtained when a drop of blood strikes a blotter after falling two feet and traveling at about three feet per second right to left horizontally. It is important to note that the sharper or pointed end of small, tadpole-like spatters always points back toward their origin. In contrast, the independent droplet stain always points ahead toward its direction of travel.

While the determination of horizontal motion from bloodstains may be highly significant in certain cases, it is usually more important when such motion results from impact of one type or another. In these cases the normal drop of blood, 0.05 ml, is no longer formed and smaller droplets are produced. These will be discussed in detail in sections X-XIII.



## VII. IMPACT ANGLE CONSIDERATIONS— VERTICAL DROP/ANGULAR TARGET

Blood dropping to a flat surface that is not horizontal will produce an elliptical rather than a circular stain. The degree of circular distortion is indirectly proportional to the angle of incidence. That is, as the angle decreases from 90° to 0°, the stain becomes more elongated. This progressive elongation is evident in Figures 17 through 25, pages 41-49. These figures show the change that occurs in the overall appearance of a blood drop as a function of striking angle. In all cases the falling distance was 42" to a hard, smooth cardboard surface. Figures 26 and 27, pages 50-51, demonstrate the relative independence of this characteristic to the target surface. These bloodstains were made on a blotter and, although there was greater spatter, the degree of elliptical distortion is almost identical for corresponding angles on either surface. Ratios may be calculated to establish the impact angle with reasonable certainty. For example, plotting the height to width ratios of blood spots against their respective impact angles of incidence produces a reasonably good working curve for many surface types. Typical data is shown in Table 2. Average values are plotted as the upper broken curve in Figure 28, page 52. Note that the height to width ratio is quite independent of the characteristics of the target surface.

TABLE 2—Height to Width Ratios of Stains Produced by a Single Drop of Human Blood Striking Various Surfaces at Known Angles.

Impact angle	Hard cardboard	Smooth cardboard	Cotton cloth	Blotter	Glass	Average
90°	1.00	1.00	1.01	1.00	1.01	1.00
80°	1.01	1.01	1.01	1.05	1.00	1.02
70°	1.06	1.06	1.16	1.09	1.08	1.09
60°	1.19	1.15	1.23	1.20	1.20	1.19
50°	1.36	1.35	1.45	1.44	1.37	1.39
40°	1.55	1.59	1.65	1.61	1.65	1.61
30°	1.91	2.01	1.89	1.78	2.16	1.95
20°	2.42	2.82	2.98	3.10	lost	2.83
10°	5.97	6.34	6.10	6.25	6.69	6.28

Greater accuracy in estimating impact angle is possible when blood falls on a non-porous surface and dries before the object is moved. This usually permits measurement of what, for want of a better term, is called the dense blood height or "DB" value of the spot. This value is obtained by measuring the height of the darker, or thicker, portion of the stain. The basis for this measurement is obvious in Figures 18 through 25, pages 42-49. Data of this type is shown in Table 3. A plot of spot height divided by DB value

TABLE 3—Height to Dense Blood (DB) Ratios Produced by a Single Drop of Human Blood Striking a Non-porous Surface at Known Angles.

Impact angle	Total height	"DB" height	Ratio of height/DB
90°	17.5 mm	17.5 mm	1.00
80°	17.5 mm	8.0 mm	1.03
70°	17.0 mm	6.5 mm	1.06
60°	20.0 mm	7.0 mm	1.18
50°	21.2 mm	6.5 mm	1.32
40°	24.0 mm	6.0 mm	1.60
30°	27.0 mm	6.0 mm	2.08
20°	26.2 mm	5.0 mm	2.62
10°	38.5 mm	5.5 mm	5.50

vs. known impact angle is made in Figure 29, page 52. This figure provides another curve for the estimation of impact angle of an unknown blood spot which is especially good at higher angles where Figure 28, page 52, is less accurate.

## *VIII. IMPACT ANGLE CONSIDERATIONS— ANGULAR DROP/HORIZONTAL TARGET*

The same height to width ratios that were reported in the preceding section may be used for estimating impact angle when examining a horizontal or vertical surface. Valuable information may usually be established from these relationships regarding the limit of nearness to a bloodstain a victim could have been at moment of bloodshed. As an example, assume that a bloodspot is detected, examined and measured on the floor of a room. Assume further that its direction of flight was from right to left and downward forming an impact angle of  $50^\circ$  with the floor as shown schematically in Figure 30, page 53, line AB. The victim could have been standing in the positions indicated as X, Y, or Z, or at any reasonable distance that would place the point of injury to the right of line AB. He could not have been standing at W or in any position that would place the point of injury to the left of line AB, however, since this would require an impossible recurved flight path of the falling drop of blood. The same reasoning may be correctly applied to vertical walls or ceilings provided gravitational effects are considered. Little reasoning is required to understand that the origin of any bloodspot that stains a ceiling will always be below a projection of its angle of incidence. The same is true for blood that strikes a wall independently of whether the drop is falling or is spattered in an upward direction. In every case, blood that produced a stain on a ceiling or wall will always have originated from a source below the angle of incidence. Examples of these conditions are shown diagrammatically in Figure 31, page 54. A study of these examples should convince the reader that care must be exercised in correctly determining directionality of a bloodstain on any surface if its impact angle limitation is to be accurately estimated.

Several experiments were conducted to determine if data obtained in Table 2, page 11, is applicable to situations wherein a drop of blood was not falling in a straight line. To achieve this evaluation blood drops were projected horizontally and allowed to fall onto flat cardboard targets. The angle of incidence at impact was accurately measured using multiple flash stroboscopic photography for each drop covering the range of  $22^\circ$  through  $70^\circ$ . Height to width ratios from

these measurements are plotted as the lower broken curve in Figure 28, page 52.

The solid curve in Figure 28 represents the median of the two broken curves and may be used to estimate the impact angle at which a drop of blood strikes any surface from its height to width ratio. Allowing a tolerance of  $\pm 7^\circ$  the confidence limits for this estimate exceed 95%.

## *IX. SPLASHED BLOOD*

Blood may be considered as splashed when it (1) is larger than 0.1 ml in volume, and (2) is subjected to minor impact or, in the absence of impact, is allowed to fall at least four inches. As would be expected, considerably more spattering occurs when larger volumes of blood are allowed to fall onto a flat impact site. Very fine "satellite" spatters are usually produced similar to those found around single drops when they yield spatter. That is, their "tails" point towards their origin, the impact spot, rather than toward their direction of travel.

Blood that is splashed by falling will produce most of its spattering in the form of long narrow streaks with very few small round spots. A pattern of this type is shown in Figure 32, page 55, which resulted when 1 ml of blood was allowed to fall 48" to a horizontal, hard, smooth cardboard target. The spot diameter in this figure is about  $1\frac{1}{2}$  inches. Experiments were conducted to determine the distribution of spatter from splashing 1 ml of blood downward onto a flat target. In all cases, less than ten percent of all splattered blood was projected higher than  $40^\circ$ . That is, very little spatter was directed back towards the origin of falling blood, but rather, it essentially sprayed out over the horizontal target. Blood that is splashed is considered very low velocity, approximately 5'/sec. or less.

## *X. PROJECTED AND "CAST OFF"*

Blood that is projected in a volume of 0.1 ml or more will cause extreme spattering around the major bloodstain impact area when the target is reasonably close. Blood drops or droplets that result from a "cast off" of larger volumes can also produce similar spatter patterns. If a volume of blood is projected downward in some manner at a rate in excess of its normal gravitational terminal velocity, it will produce spatter which is markedly streaked with a very irregular, spine-like edge around the large, central bloodstain impact site. This condition is shown in Figures 33 and 34, pages 55-56. Compare the overall pattern of Figure 33 with that of Figure 32, which is identical in scale, volume of blood used, and distance between blood origin and target. Figure 34 is a closer view of the central bloodstain in Figure 33. Note especially the edge characteristics in this illustration.

Another example of large volume blood projection occurs when a pool of blood is stepped into very quickly, as though running. Results of such an act are shown in Figure 35, page 56. The sole of the shoe, which struck the pool of blood is to the left, the heel to the right in this figure. It should be observed that blood "squirted out" in all directions some of which struck the front surface of the heel with sufficient force and volume to splash or "ricochet" further. This condition may be seen more easily in Figure 36, page 57, an enlargement of the instep area. Note the sharp reverse "ricochet" of approximately 60° at the top of this illustration. Secondary splashing or "ricocheting" of blood at angles of less than about 120° can only occur with large volumes of blood. Single drops of 0.05 ml. or less cannot produce this condition as their lower energy cannot overcome surface tension to the degree required.

Blood that has been "cast off" or flung from an object produces drops much smaller than the normal 0.05 ml drop and stains having a diameter of  $\frac{1}{4}$  inch or less. Usually a fairly uniform distribution of spot size will result as is illustrated in Figure 37, page 58. This pattern was produced when a hand was covered with blood and then flung in a left to right sideward manner approximately 30 inches in front of the target.

Frequently, both flung or cast off blood and spatter will occur

as a result of a single action. This is a frequent and almost inevitable circumstance when a very bloody object strikes the target surface. For example, a person that is holding a wound might collapse or fall in such a way that his hand strikes the floor with a sharp, slap-like impact. The resulting pattern is a combination of spots from blood drops thrown from the fingers, and spatters that occur when the bloody hand strikes the floor. The pattern in Figure 38, page 58, was produced in just this manner with the back of the right wrist striking at the left and the fingertips at the right. A similar pattern may be seen in Figure 39, page 59. In this case a hatchet blade was covered with blood and then three blows were struck to a small ( $\frac{3}{4} \times 1 \times 4''$ ) piece of wood that was resting on the target. The sequence of blows is obvious from the relative amounts of cast off blood; bottom, top, and middle, respectively. The reader should carefully study the differences between Figures 38 and 39, pages 58-59, as there is essentially no spatter in the hatchet pattern. It must be remembered that the blood covered hatchet blade struck the wood  $\frac{3}{4}$  of an inch above the target whereas the bloody hand struck the target itself.

Blood cast off from an object that has been swung overhead will always produce characteristic ceiling patterns which contain valuable information. The nature of striking an overhead blow should be examined to understand why these patterns are so reproducible. As a person raises a weapon he does so in a somewhat continuous motion. As he approaches the limit or peak of his backswing, the rapid deceleration of this movement causes some blood on the object to be cast off in a short but finite interval. Duration of this interval, and extent of the arc it covers will determine the "length" of bloodstain pattern that is produced overhead on the ceiling. Those drops that are cast off first will almost always strike the ceiling at about  $90^\circ$  whereas those cast off last will strike at much more acute angles.

Practically no blood will ever be cast off from a weapon after the backstroke has been reversed and becomes a forward and downward swing. The "snap" or "whip-like" termination of a backstroke will remove blood from an object far more effectively than centrifugal forces generated by a subsequent forward motion. In effect, blood is projected or cast from an object when its motion is rapidly terminated. A forward swing that is designed to cause injury will never produce the same blood pattern as a backward overhead swing, even when the weapon being swung contains the same quantity of blood. The reason for this is straightforward—the forward blow lands to deliver its energy to the object being struck, and the backward motion is not a blow at all but merely a reversal of the swing. In essence, the former terminates instantaneously and the latter decelerates gradually without an abrupt stop. Similar reasoning may be applied to blows that project or "cast off" blood in a horizontal plane. Naturally, there

are two possibilities, a swing from right to left and a swing from left to right. Considering the physiological nature of a man, a forceful horizontal blow can only be executed by a so-called "backhand" swing. If given a choice, therefore, a right handed person will swing from left to right starting from what could be considered a "cross draw" position. Conversely, a left handed person would swing from right to left when delivering his hardest horizontal blow (11). If the reader wishes to confirm these conclusions he should extend either arm out sideways and attempt swinging horizontally to deliver a blow ahead of him. This should be duplicated swinging the same arm in both a backhand and forehand delivery. If this exercise is repeated several times the subject will most likely compensate for the weaker outside-to-inside or forehand swing by gradually adding a downward "chopping" component to his swing. A pattern of cast off blood produced in this manner would reveal its departure from true horizontal and further aid the criminalist in concluding whether the person was right or left handed.

Directionality of cast off blood drops may easily be established from the progressive elliptical nature of their overall pattern, and usually from single elliptical spots as well. This information should allow an accurate estimation as to the position of the person at the time he swung the weapon. Figure 40 shows the bloodstain pattern that was produced on the ceiling when a bloody  $\frac{1}{2}$ " diameter steel rod was raised overhead and then brought back as to strike a downward blow. The person holding the rod faced the right side of the figure with his back to the left. Three overhead swings were made with a bloody hatchet resulting in the ceiling pattern shown in Figure 41, page 60. In this illustration the person faced left and slightly shifted his overhead arc following the first downward "blow". The sequence of swings is again evident from the amount of cast off blood; bottom, middle, top, respectively. No such conclusion regarding sequence could be drawn from a pattern unless it is known that no additional blood was added to the weapon as a result of or during one of the downward strokes.

In his affidavit on the Sheppard case Dr. Kirk reported on several experiments he conducted to obtain bloodstain patterns. He covered various objects with blood and caused them to cast it off under controlled conditions. His selection included a ball peen hammer, two cell flashlight, steel bar, brass bar, and brass rod. He also described different characteristics of bloodstains that result from various types of impact (9). In all instances the current investigation has verified both the accuracy and conclusions of Dr. Kirk's earlier work. The reader is urged to review this document if he wishes additional data on bloodspatter experiments.

Blood that is projected or cast off is considered low velocity of no



more than five feet per second. It differs from spattered blood in that the blood itself is in motion before it strikes a target. Spattered blood is static prior to receiving some sort of impact.

It is sometimes possible to satisfy both conditions with a single action. The situation described earlier wherein blood was stepped into is an example of just such a case. Some blood was spattered out from the sole in small volumes, and simultaneously, a large mass of blood was projected back towards the heel. Spattered blood was static before the shoe struck it, and projected blood was in motion before striking the heel.

Whenever very large volumes of blood, for example 10 ml, are projected onto a target, a variety of patterns usually results. Even so, often it is possible to establish certain facts regarding conditions that produced the stain pattern. The large bloodstain in Figure 42, page 61, was produced when 10 ml of blood were thrown at this target from three feet. Motion was directly into the target, but also slightly upward from lower right to upper left. It is evident that the greater spattering occurred in the 9 to 11 o'clock portion of this overall stain pattern. The large volume of blood that produced the bloodstain shown in Figure 43, page 62, was not discharged in a round mass. The resulting pattern shows a well defined "tail" with several drops that followed it as it was projected towards the target. This blood was directed upward into the target with a slight right to left component.

Large volumes of blood that are projected along a surface rather than directly into it, as in the two preceding examples, will often permit directionality to be accurately estimated. Figure 44, page 63, shows the pattern that resulted when 10 ml of blood were thrown over a target from a distance of two feet and a height of four inches. Direction of the blood mass discharge is obvious from left to right. The clean trailing edge is characteristic of blood that has been flung a short distance nearly parallel to the target it strikes.

## *XI. SPATTERED BLOOD— MEDIUM VELOCITY*

When some strong force impacts upon an exposed area of an individual, blood will usually be spattered. Almost any blow falls into this classification: club, axe, hammer, brick, etc. In these situations blood is broken up into many small droplets of  $\frac{1}{8}$ " diameter or smaller. Spatters produced in this manner are easily distinguished from large spots produced by a normal drop, or from very small "satellite" spatters that will be found surrounding and/or projected from a larger bloodstain. When only a relatively few spots are available it is sometimes impossible to differentiate between medium velocity bloodspatters and stains that were produced by a cast off from some bloody object. Figure 45, page 64, shows a distribution of blood spots that were produced by a 25' /second impact to a 2 ml pool of blood. These spots, shown enlarged in Figure 46, page 65, were spattered a distance of six inches to a vertical cardboard target. The same apparatus and conditions were used to produce patterns in Figures 47 and 48, pages 65-66, except that the target was parallel to and just below the direction of spatter. It is evident from these figures that when a true impact spatter occurs, almost all of the resulting spots will be very small. Larger spots will only result from "puddling" of smaller drops, splashing blood, arterial bleeding or some combination of these. It cannot be overemphasized that while the interpretation of spattered blood from medium velocity impact is not difficult, it demands both study and experience to develop proficiency. The problems associated with surface texture, though still important, are somewhat diminished when medium velocity spatters are encountered.

Although force is usually present, such as a smashing blow from a rock, great force is not essential to produce medium velocity blood spatters. For example, once a wound is open and blood is exposed a blow from a fly swatter will most assuredly spatter blood. Medium velocity spatters result from impact of from 5 to 25 feet per second.

## XII. SPATTERED BLOOD—HIGH VELOCITY

The same characteristics are found in high velocity blood spatters that are present in medium velocity blood spatters. This type of impact, usually from gunshot, will produce an extremely high percentage of very fine specks of blood. The result is a mist-like dispersion similar to an aerosol spray. The term "atomized" could also be used to describe this effect. Because of their low mass, particles of these speck-like dimensions will seldom travel a horizontal distance of over three or four feet.

In addition to the fine particles, larger droplets, but essentially all under  $1/8$ " diameter, will also be produced. These droplets may be, and frequently are, projected several feet from the impact site.

A motor driven device was constructed to produce medium to high velocity blood spatters under reproducible laboratory conditions. Blood that was impelled from this apparatus had an initial horizontal velocity of thirty feet per second regardless of drop size. Five large targets were placed in line with and 24" below the flight path. Unfortunately, it is not practical to reduce these large targets to a size that could be included in this report. To do so would reduce the very fine "speck-like" bloodstains far below the resolution limits of the reproducing medium. A small central portion of each target has been enlarged, however, and these are shown as Figures 49 through 53, pages 66-68. Several bloodstains were measured and their averages are listed in Table 4. This data is plotted as a function of distance traveled in Figure 54, page 69.

TABLE 4—Average Bloodstain Spot Diameter for Medium to High Velocity Bloodspatters at Various Distances: Initial Velocity of 30'/sec.

Average Diameter	Distance from Origin
0.0057"	20"
0.0137"	49"
0.0430"	78"
0.0781"	106"
0.1715"	133"

Initial experiments involving gunshot as a high velocity spatter mechanism were recorded by high speed stroboscopic photography.

Most gunshot experiments were conducted with .22 calibre rifles clamped to insure accuracy and safety. The impact site consisted of a small block of soft pine covered with a layer of  $\frac{1}{8}$ " thick polyurethane foam which was present to hold blood. Immediately prior to firing, the polyurethane was saturated with blood applied from a medicine dropper. The photograph shown in Figure 55, page 70, was taken about 5 milliseconds after impact. While photographs of this type were helpful in some respect, considerably more information on blood spot size, shape and distribution was obtained by using white cardboard targets. Placing these targets normal to the path of the bullet allowed specks of blood to be trapped both behind and in front of the point of impact. A typical target placed 6" behind the point of impact is shown in Figure 56. The extremely small size of the blood stains that were produced, as well as their vast number, may best be noted in Figures 57 and 58, page 71, successive enlargements of the same target.

When back spatter was to be recorded both sides of the polyurethane foam were saturated with blood. Considerably less spatter is directed back towards the rifle as would be expected. This ratio is best illustrated from shooting into blood soaked polyurethane foam suspended just above a horizontal target. The bullet travels above and parallel to the target and all spattered blood is recovered on the target. Figure 59, page 72, shows the result of one such experiment in which the shot was fired from left to right. Targets were also mounted in front of the point of impact between the rifle and bloody polyurethane foam. The bullet, of course, had to pass through the back-spatter target before it struck the blood mass. These targets usually received very limited spatter when placed 24" or more ahead of the impact site.

Another series of measurements were taken when targets were placed in the third and final configuration. That is, the cardboard was held vertically and the bullet traveled parallel to its surface. Resulting bloodstain patterns gave a cross-sectional representation of the distribution of blood spots. An example of this distribution is shown in Figure 60, page 72. If the reader will compare this target to the blood drops shown in actual flight in Figure 55, page 70, he will quickly agree that the static aftermath is a superior representation of the overall spatter distribution.

As with medium velocity impact, both experience and experimentation are necessary before one acquires proficiency in correct interpretation of blood spatter patterns. All drops, droplets, and specks must be carefully examined before a decision is reached regarding the impact velocity that produced them. Texture of the target surface is of minor consideration to the interpretation of high velocity spatters. Specks of such small size change very little regardless

of the surface they strike. Impact of 25'/sec. and over is considered high velocity. All gunshot wounds are characterized as high velocity.

Although freshly drawn human blood was used for several of the experiments described in the preceding sections, most data could be considered "laboratory" rather than "practical" in nature. To broaden the scope of this research, and at the same time to verify the practical application of laboratory data, a limited number of high velocity impact experiments were conducted with living animals. Dogs were obtained that were to be disposed of for other reasons. They were anesthetized using a smaller dosage of sodium pentobarbital than would otherwise have been administered for euthanasia. The animals were clipped around the chest area and strapped on their backs in a manner that would allow a bullet to make a clear passage through the heart. Targets were placed in a variety of positions to obtain the maximum information from each experiment. Only one shot was fired through any one dog. All resulting bloodspatter patterns were consistent with those obtained and described in this and previous sections. One target, shown as Figure 61, page 73, is of particular interest because of the variety of patterns it contains. This target was laid flat with its bottom edge about 6 inches behind and about 55 inches below the point of impact. A 12-gauge shotgun slug was fired through the dog's chest and heart ultimately passing over the target shown in this figure in a bottom to top direction. Splashed blood, spattered blood, projected blood, and high velocity spatters are all evident on this target as are examples of directionality.

### *XIII. APPLICATIONS TO SELECTED CASES*

Tracing the flight path of bloodstains with the aid of tape and string may often establish spatial origin through convergence. In a recent shooting case bloodstains were present on a bedroom ceiling. Their small size was characteristic of impact. Most were consistent with larger drops that travel several feet from a point of gunshot impact but, of course, other forms of medium velocity impact such as a smashing blow could not be completely ruled out. Their radial configuration was immediately apparent although anyone not specifically looking for such a pattern would probably not have detected it. To determine the origin of spatter one end of a string was held immediately beside one of these spatters whose directionality was clearly evident. The other end was moved in a horizontal arc along the ceiling until the string was parallel to the directionality of the bloodstain. In this configuration both ends were taped to the ceiling. The string was cut long enough to extend from a point just beyond the bloodstain back across the ceiling until it terminated at a wall. This procedure was repeated several times with other bloodstains as shown in Figure 62, page 73.

A general convergence of strings is obvious in this illustration although small bloodstains are not resolved in such an overall view. At this point another string was taped to the center of the convergent area and allowed to hang freely as a plumb line. This additional string is shown in Figure 63, page 74, which is a photograph taken from the right side of Figure 62. With such good agreement between nine strings it is certain that the ceiling bloodstains radiated from an origin located within a few inches of this vertical plumb. Additional bloodstains on walls and draperies allowed a conclusion regarding the most probably height of impact. Combining this information establishes the location of the head at the moment of impact.

Type and direction of impact is usually evident in suicide cases as nothing is done to alter or destroy evidence. There could be no doubt as to what occurred in the scene shown in Figure 64, page 75, even if the body had been moved.

Location of bloodstains can sometimes establish the position of a movable object at the moment of impact. Likewise, the absence of bloodstains may also be significant. Dr. Kirk pointed this out when

he pinpointed the position of the murderer in the Sheppard case by detecting a void in the otherwise uniformly bloodspattered bedroom (9). Although Dr. Kirk did not testify at the first Sheppard trial in 1954, testimony on the interpretation of bloodstain patterns was received into evidence as early as 1957 in the Carter case in California (12). In this trial it was ruled that such testimony was admissible because, from his training and experience, the expert was able to determine the source of blood spots from an analysis of their size and shape (13).

In the Dr. Stephen Shaff murder case bloodstains were extremely significant in establishing the validity of the defendant's account of the events. Dr. Shaff maintained that the victim had telephoned and threatened him. Shortly thereafter a Microbus drove into Dr. Shaff's driveway. According to the doctor he thought only of protecting his children and ran out to stop the intruder. He carried with him a loaded shotgun that he had grabbed from a front closet. Dr. Shaff testified that they argued until the driver, whom he held at bay in the Microbus, thrust the vehicle's door open in an effort to knock Shaff down. Dr. Shaff insisted that the door struck the muzzle which caused the shotgun to discharge resulting in the death of the intruder. There were no eye witnesses to confirm or deny Dr. Shaff's testimony (14).

An examination of the vehicle disclosed very fine blood spatters on the outside of the wrap around bumper. An overall view of the bumper is shown in Figure 65, page 75, and a closer view of the bloodspots in Figure 66, page 76. Very fine speck-like bloodstains present on the bumper are not resolved in either of these figures. A comparison of these stains to similar stains produced by gunshot spattering is made in Figure 67, page 76. Laboratory or known spatters are circled in this composite whereas those on the bumper are not. A few smaller bloodstains are also evident in this illustration but the extent of very fine spots cannot be resolved by these photographs. After a detailed examination of the entire right end of this bumper it was concluded that they could only have resulted from gunshot or high velocity impact. Their path was traced to determine the minimum opening of the door when the bloodspatters fell or were projected downward. The maximum door opening was determined from two known points of impact and found to be considerably less than that necessary for the path of bloodspatter. From these facts, experiments on minimum rates of swinging open a Microbus door the required distance, and the known dropping rate of blood in air (as reported earlier in section II), it was possible to establish the limits within which the shooting and bloodspattering occurred. It was concluded that the shooting had to take place while the door was rapidly opening, exactly the version Dr. Shaff had

proposed. Additional fine bloodspatters were discovered along the inside edge of the door in an area completely protected when the door was closed. This fact alone disproved the prosecution's contention that the door was closed at the moment of shooting.

Movement of a victim at some time after approximately two hours following death can usually be established by the inconsistencies between body position and postmortem lividity. Bloodstains on the exterior of a body may also be used to prove similar movement if inconsistencies are present and properly evaluated. In Figure 68 note that blood ran down in front of the victim's left ear, clotted and dried in one continuous streak or "run". When found the victim was on her back as shown and, therefore, must have been moved from the upright or sitting position necessary for this type of bloodstain (15).

Necessity for a thorough investigation cannot be overemphasized. Everything regarding a case should be checked as it may have an influence on an otherwise obvious but erroneous conclusion. A recent hunting accident took the life of an eleven year old boy. His father attempted to unload a pump action shotgun which was resting with its stock down on the floor of a two door sedan. The boy was leaning forward when, according to the father, the shotgun accidentally discharged. The deer slug entered his son's right eye and exited through the back of his head. It continued on striking the vehicle's ceiling approximately one inch above the rear window. During an investigation of the vehicle no bloodstains whatsoever were detected around the torn fabric entrance hole in the ceiling. At first this absence of even a trace of blood strongly suggested that the shooting could not have occurred in the sedan as reported by the father. Nevertheless, he was telling the truth. The reason there were no bloodstains was easily explained—the son was wearing a heavy, quilted hood which trapped all bloodspatter and essentially wiped the slug as it penetrated the fabric.

Undoubtedly, there are hundreds of other cases that could be used to illustrate the importance of bloodstain evidence. Those cited above were selected as they each represent a different aspect of interpreting this type of physical evidence.



## *XIV. CONCLUSION*

Bloodstain evidence often results from crimes of violence. Frequently, it is possible to reconstruct the events which must have occurred to have produced certain bloodstains. To achieve this, consideration must be given to all available stains and their relative size and shape, not just isolated areas. Some general rules that should be followed when examining bloodstain evidence are listed below. Many specific details that have been included in earlier sections are not repeated.

- (1) Spots of blood may be used to determine the directionality of the falling drop that produced them. Their shape will frequently permit an estimate as to their velocity and/or impact angle and/or the distance fallen from source to final resting place.
- (2) The diameter of a blood spot will be of little or no value in estimating the distance it has fallen after the first five or six feet. Beyond this distance the change is too slight to be reliable.
- (3) The edge characteristics of blood spots have absolutely no meaning or value unless the effect of the target surface is well known. This is especially true when attempts are made to estimate distance from the so-called scallops around the edge.
- (4) The degree of spatter of a single drop will depend far more upon the smoothness of the target surface than the distance the drop falls. The more coarse the surface the more likely the drop will be ruptured and spatter. A blotter, for example will cause a drop to spatter to a considerable extent at a distance of eighteen inches whereas a drop falling over a hundred feet will not spatter at all if it lands on glass or other smooth surfaces.
- (5) No conclusion as to the cause of a very small bloodstain should ever be drawn from a limited number of stains. Very fine specks of blood may result from an "overcast" or cast off satellite from a larger drop or droplet. In absence of the larger drop, however, and when hundreds of smaller than  $\frac{1}{8}$ " drops are present (often down to a few  $\frac{1}{1000}$ ths of an

inch in diameter) it may be concluded that they were produced by an impact. The smaller the diameter of the drops, the higher the velocity of the impact. The difference between medium velocity impact, such as an axe or hammer blow, and high velocity impact, such as a gunshot, is sufficient for differentiating the two provided adequate sample is observed by someone thoroughly familiar with evidence of this type.

- (6) Directionality of a small bloodstain is easily determined provided the investigator recognizes the difference between an independent spatter and a cast off or satellite which has been thrown from a larger drop. Small independent stains will have a uniform taper resembling a teardrop and always point toward their direction of travel. Cast off droplets produce a tadpole-like, long narrow stain with a well defined "head". The sharper end of these stains always points back towards their origin. Since these satellite spatters only travel a very short distance the larger drop can almost always be traced.
- (7) The character of a bloodstain, either made by drops or smaller droplets, or by larger quantities of blood up to several ounces, may reveal movement both at the moment of initial staining, or later if a body or other stained surface is moved from its original position.
- (8) Depending upon the target and impact angle, considerable back spatter may result from a gunshot wound. Range of back spatter is considerably less than that occurring in the same general direction of the projectile, however. This is especially true with exit wounds when expanding type slugs are used.
- (9) Blood is a very uniform material from the standpoint of its aerodynamics. Its ability to reproduce specific patterns is not affected to any significant degree due to age or sex. Likewise, since blood is shed from a body at constant temperature and is normally exposed to an external environment for such a very short time, atmospheric temperature, pressure and humidity have no measurable effect on its behavior. Naturally, some exceptions could be imagined such as a drop of blood falling several thousand feet, or splattering outside in a rainstorm, or falling onto a very hot or very cold target surface. If, and when, they occurred, the unusual nature of such exceptions would certainly dictate their individual evaluation.

Considerable information is contained in the graphs included in this report. Their usage, however, must include a tolerance for

sampling or measurement errors. Likewise, the shape of most curves will usually allow a greater confidence at one level than another. Correct utilization of these graphs, therefore, will be limited to those persons who pursue this subject further and determine their own level of confidence for each measurement that may be of interest.

It is the author's opinion that before anyone is qualified to render expert testimony on the significance of bloodstain patterns, they must have conducted a variety of experiments under known conditions using human blood, preserved their results as standards for reference, and have made a detailed study of these standards. Hopefully, they will also have studied this report but it is neither presumed nor suggested that the reading of this document alone will qualify the student as an expert. Those who have carefully examined bloodspatter evidence and/or prepared standards resulting from gunshot impact are aware of the fine detail that cannot be reproduced in any report of this type. Photographic illustrations, for example, must always be a compromise between scope and detail. In this respect it could be concluded that the study of bloodspatter evidence is similar to examining a large mural. If the viewer stands close enough to study the detail of brush strokes and surface characteristics, his scope is very limited. Conversely, if he stands back far enough to see the painting in its entirety, he cannot possibly resolve the fine detail as before. Obviously, the only satisfactory examination includes both scope and detail. This analogy is remarkably accurate and is sufficient reason why actual experience is an essential requirement for the qualification of any true expert.

## XV. REFERENCES

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## LIST OF FIGURES

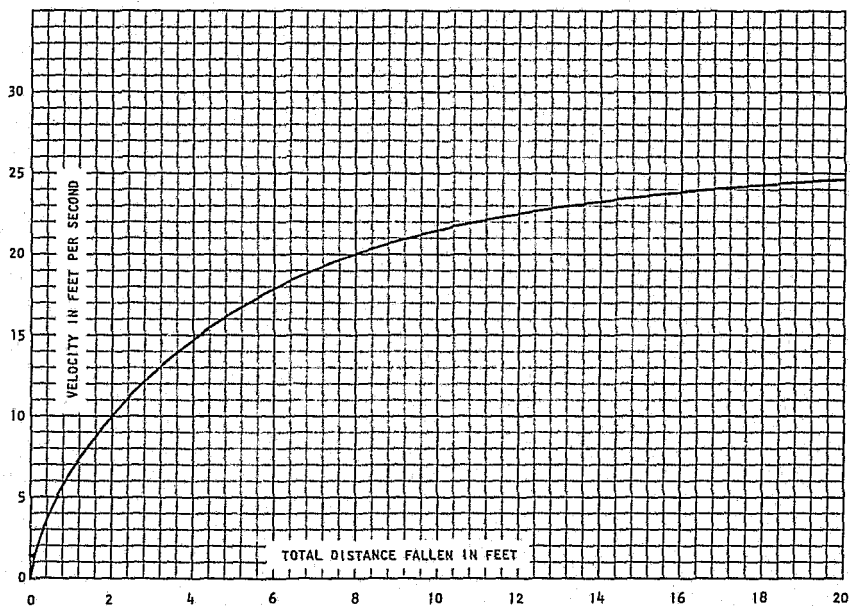


FIGURE 1.—*Velocity of a single drop of human blood as a function of distance fallen.*

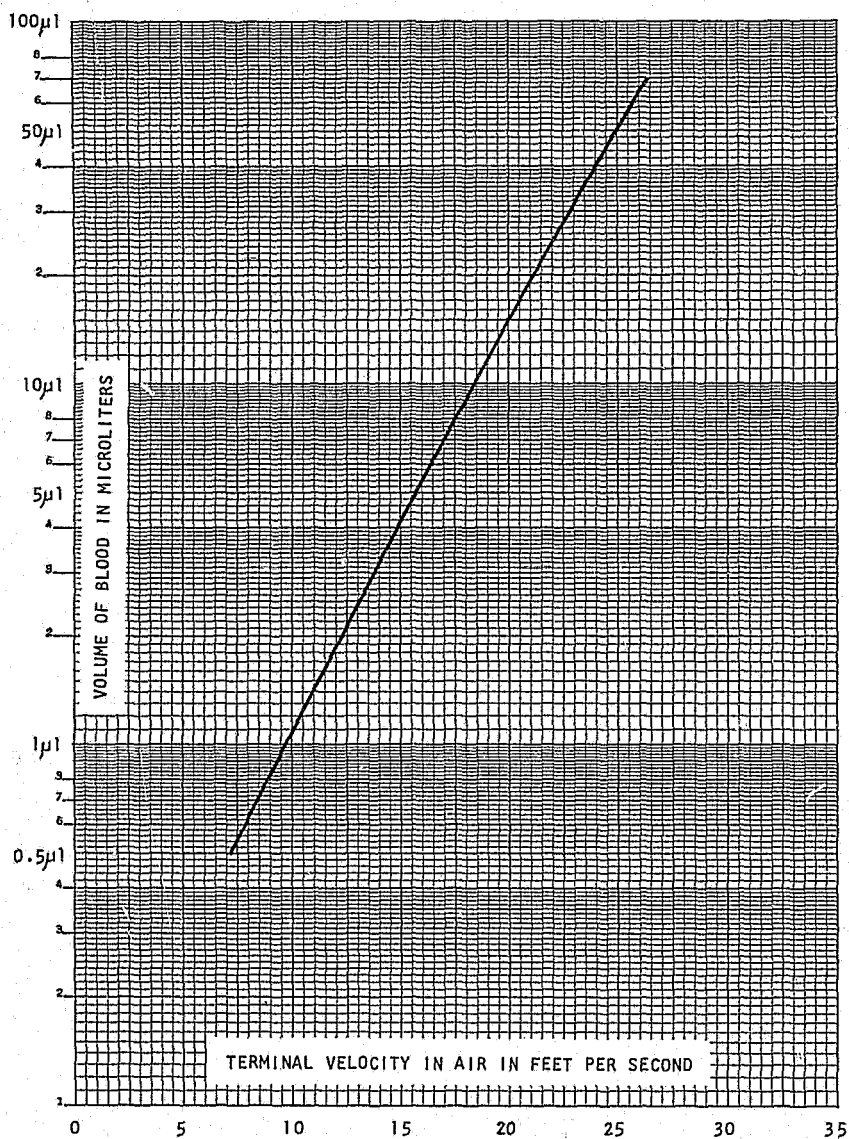


FIGURE 2.—Terminal velocity of a drop of human blood as a function of its volume.

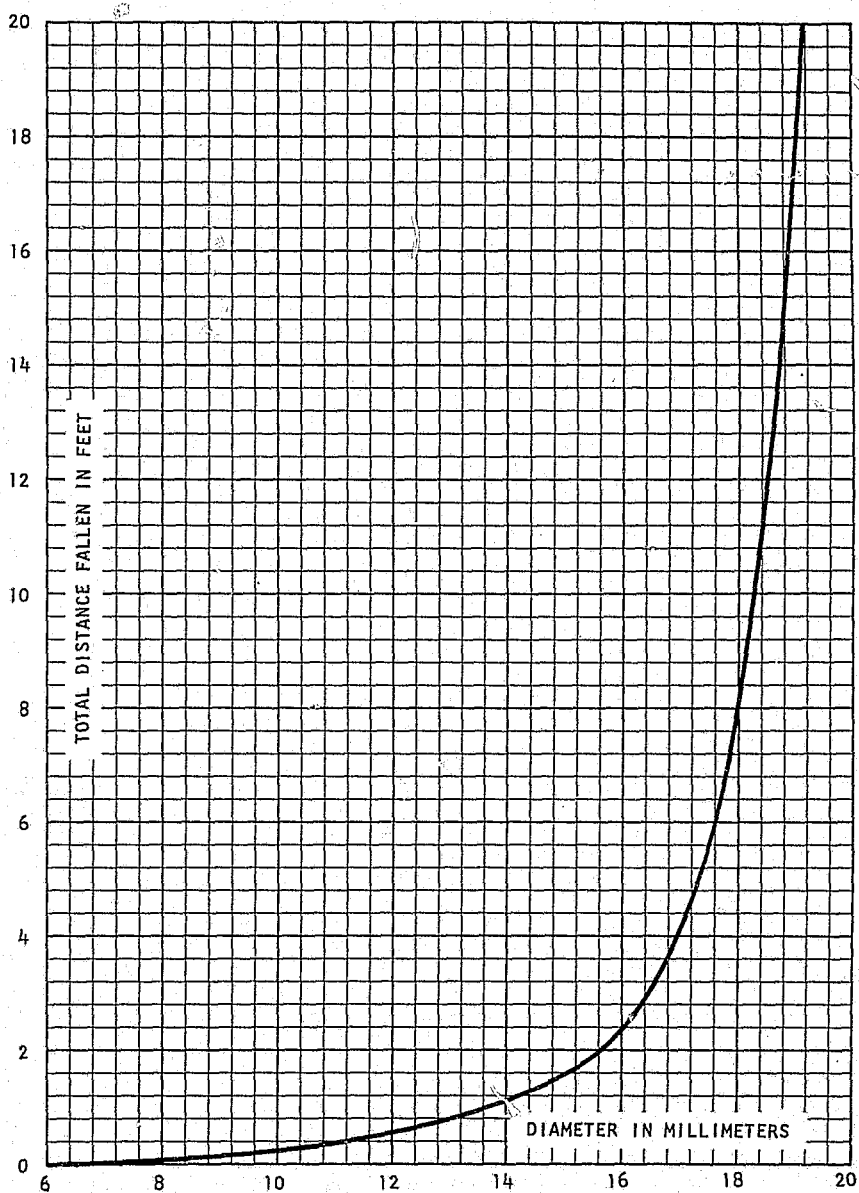


FIGURE 3.—*Diameter of a bloodstain from a single drop of human blood as a function of distance fallen.*

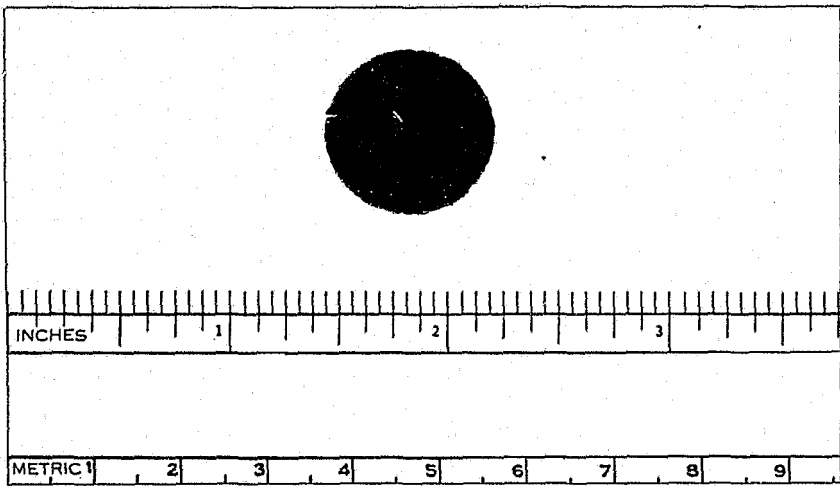


FIGURE 4.—Bloodstain from a single drop of human blood that struck a hard, smooth, glossy, cardboard surface after falling eighty feet.

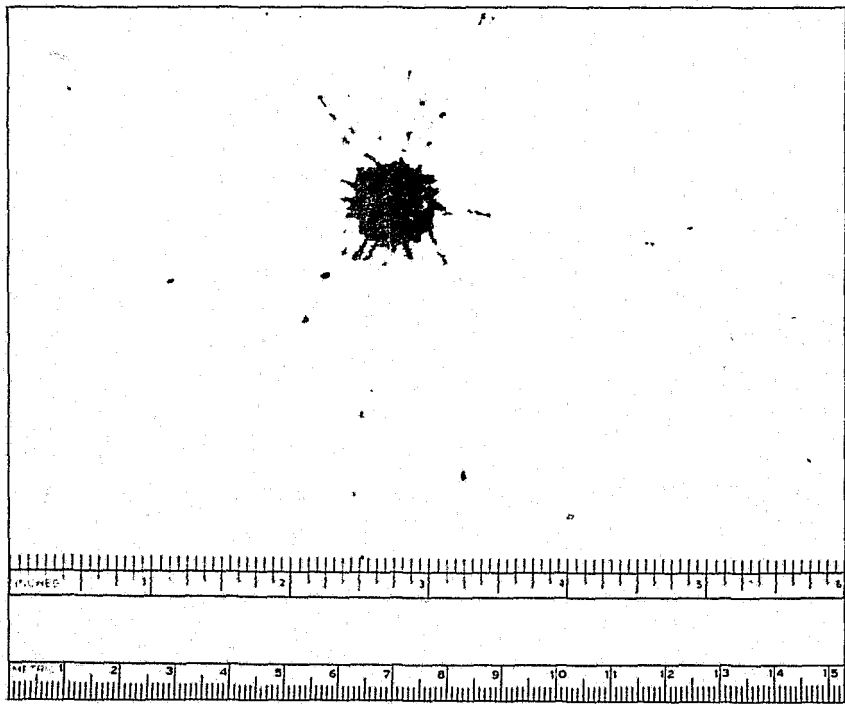


FIGURE 5.—Bloodstain from a single drop of human blood that struck a blotter after falling eighteen inches



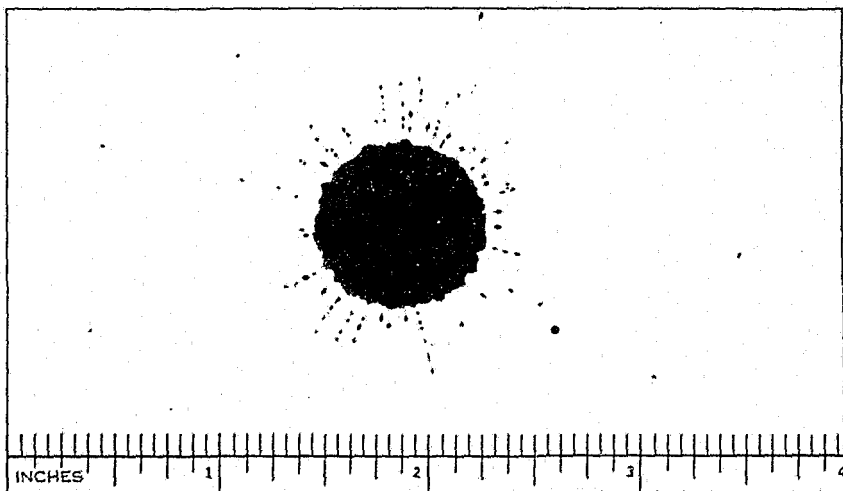


FIGURE 6.—Bloodstain from a single drop of human blood that struck a hard, smooth, cardboard after falling sixty-eight feet.

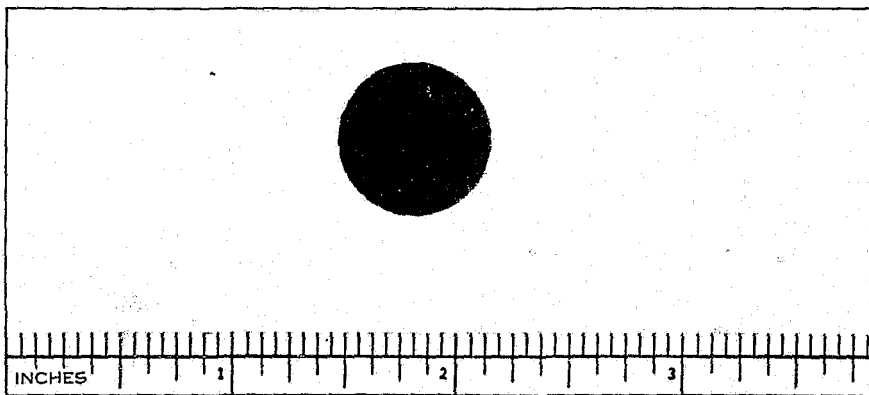


FIGURE 7.—Bloodstain from a single drop of human blood that struck a sheet of polyethylene plastic after falling forty-two inches.

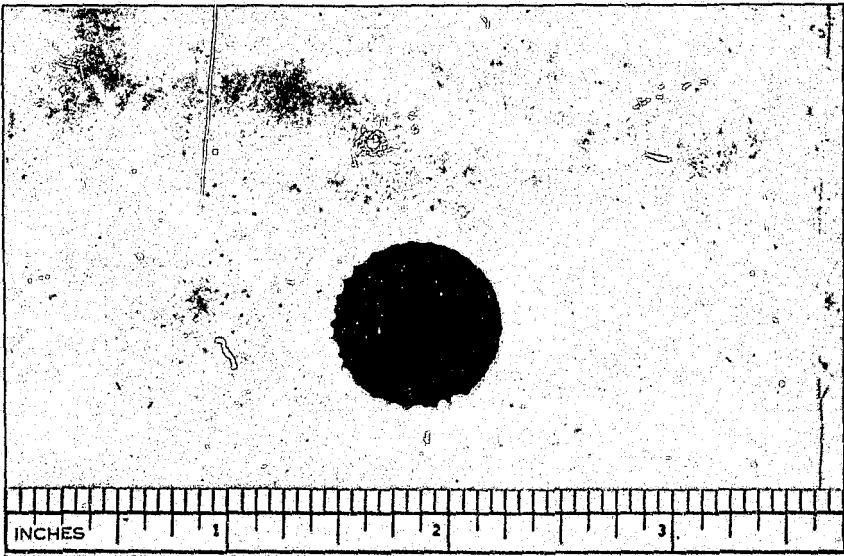


FIGURE 8.—Bloodstain from a single drop of human blood that struck a plastic wall tile after falling forty-two inches.

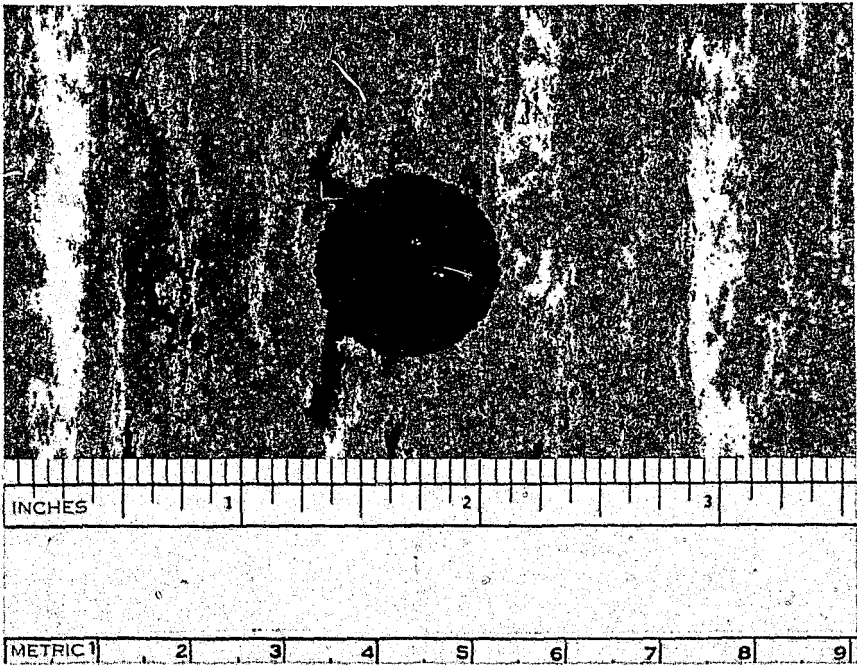


FIGURE 9.—Bloodstain from a single drop of human blood that struck an asbestos floor tile after falling forty-two inches.

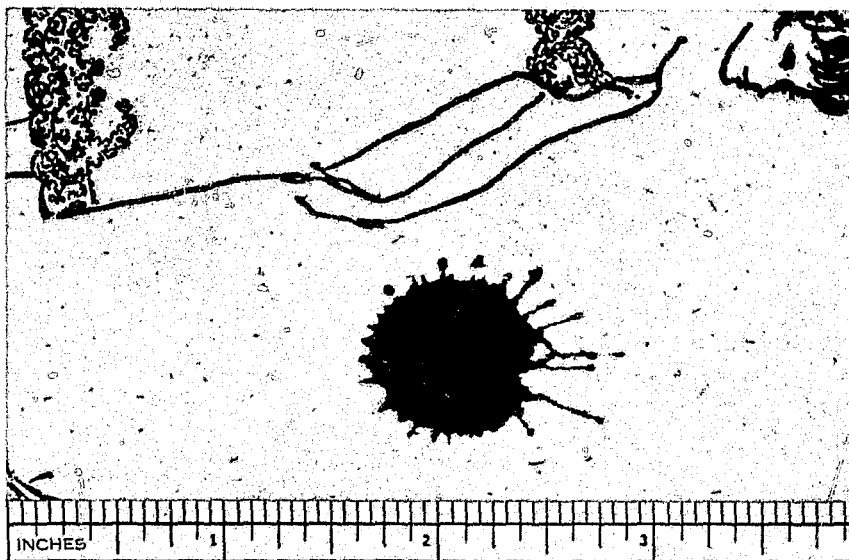


FIGURE 10.—Bloodstain from a single drop of human blood that struck a newspaper after falling forty-two inches.

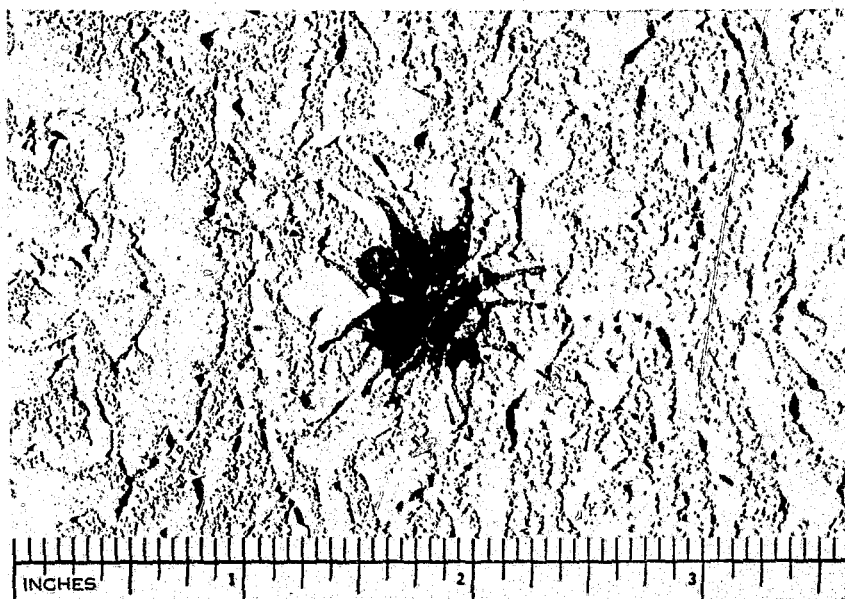


FIGURE 11.—Bloodstain from a single drop of human blood that struck a heavy, irregular, textured wallpaper after falling forty-two inches.

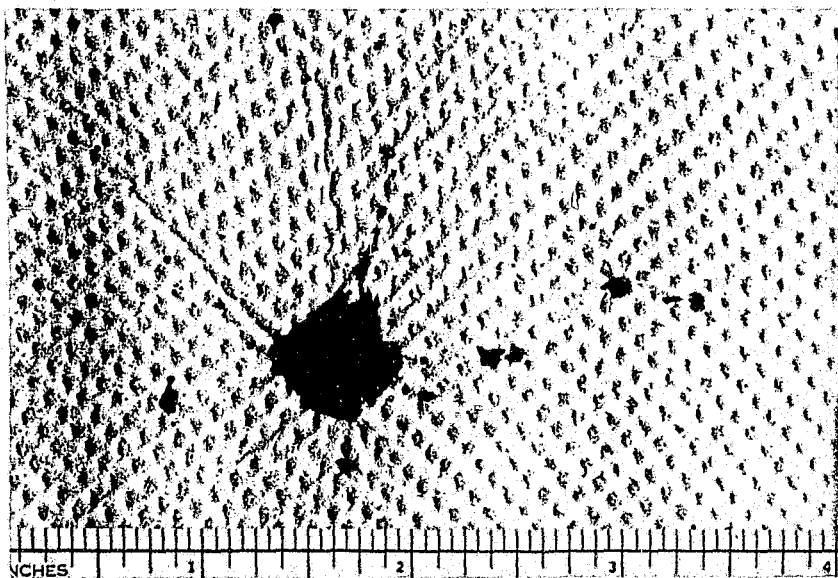


FIGURE 12.—Bloodstain from a single drop of human blood that struck a dimpled kitchen towel after falling forty-two inches.

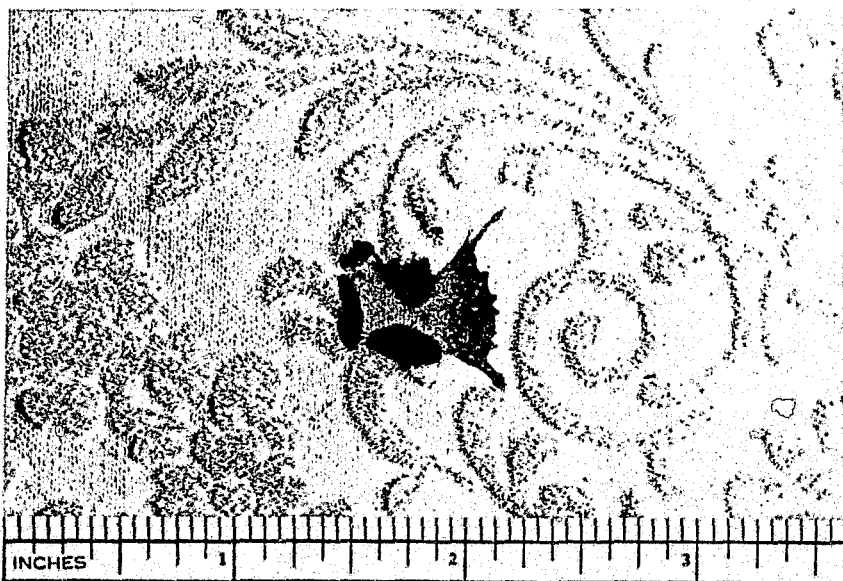


FIGURE 13.—Bloodstain from a single drop of human blood that struck soft, flocked wallpaper after falling forty-two inches.

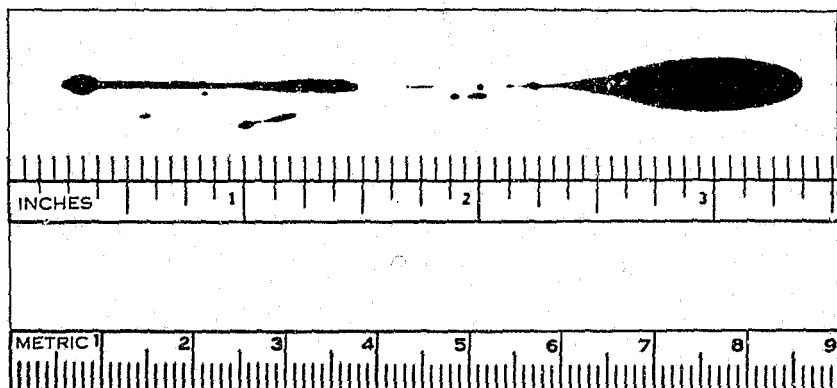


FIGURE 14.—Bloodstain produced by a drop of human blood striking hard, smooth cardboard with a horizontal motion of about ten feet per second at an angle of approximately sixteen degrees.

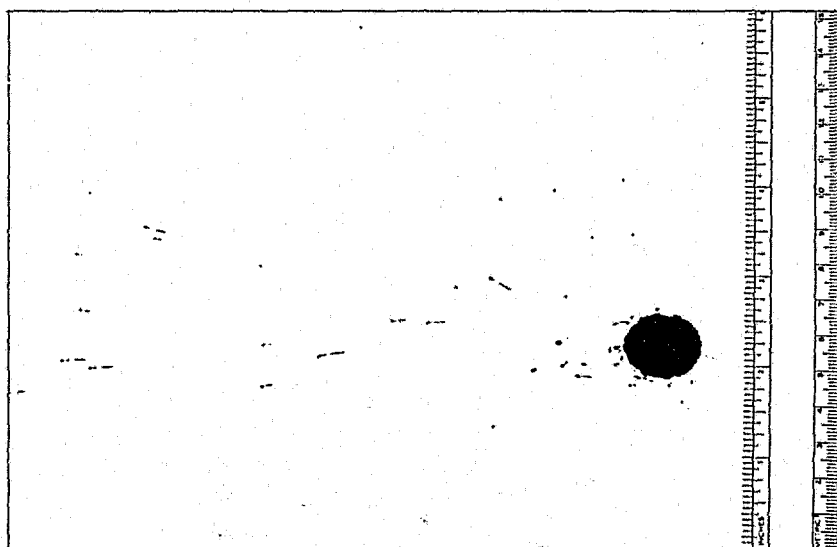


FIGURE 15.—Bloodstain produced by a drop of human blood striking hard, smooth cardboard with a horizontal motion of about four feet per second at an angle of approximately fifty-six degrees.

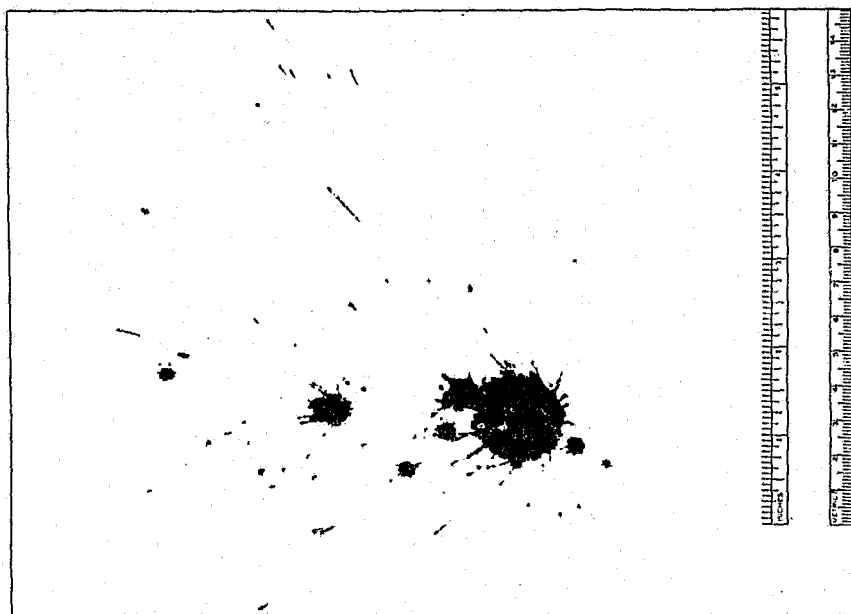


FIGURE 16.—*Bloodstain produced by a drop of human blood striking hard, smooth cardboard with a horizontal motion of about three feet per second at an angle of approximately sixty-eight degrees.*

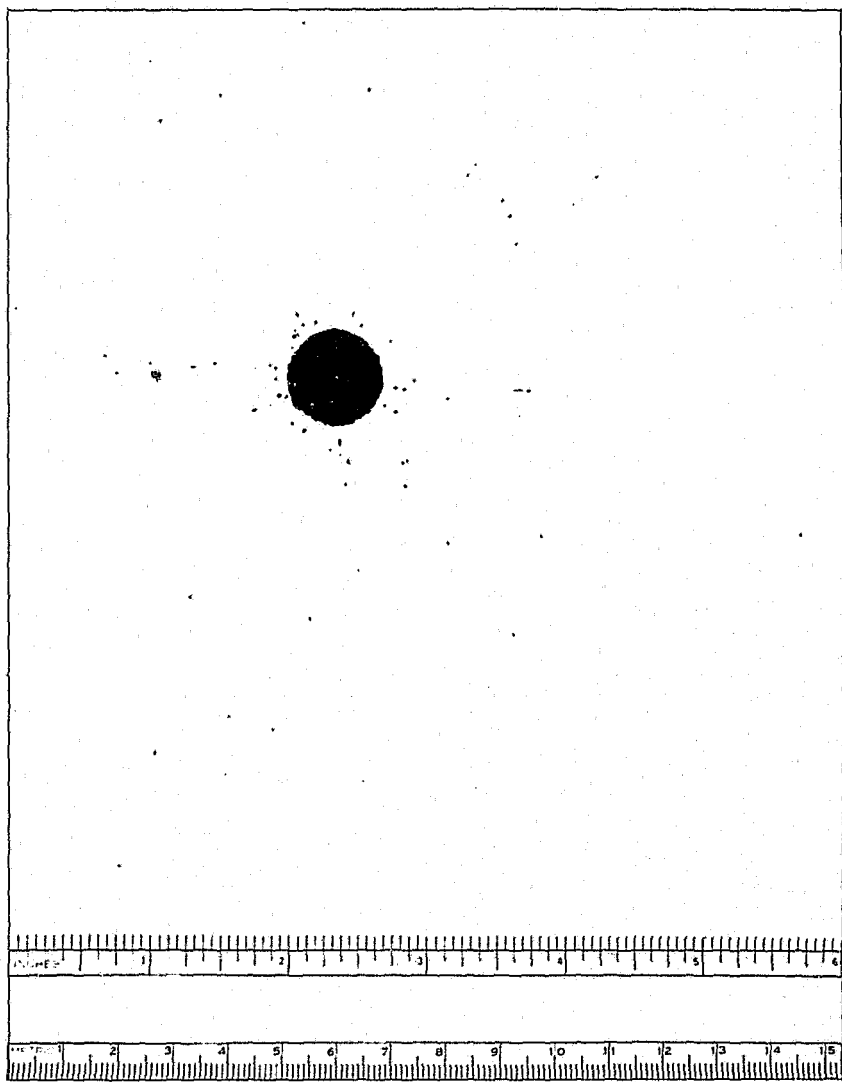


FIGURE 17.—*Pattern of a single drop of human blood that fell forty-two inches and struck hard, smooth cardboard at ninety degrees.*

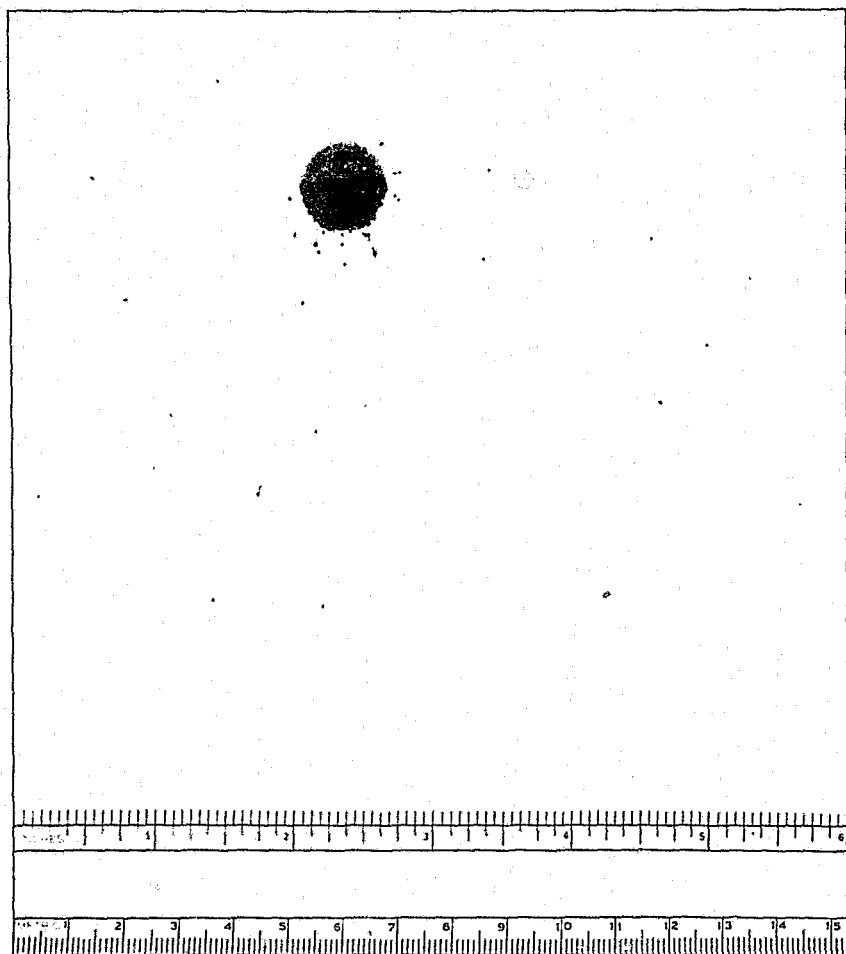


FIGURE 18.—*Pattern of a single drop of human blood that fell forty-two inches and struck hard, smooth cardboard at eighty degrees.*



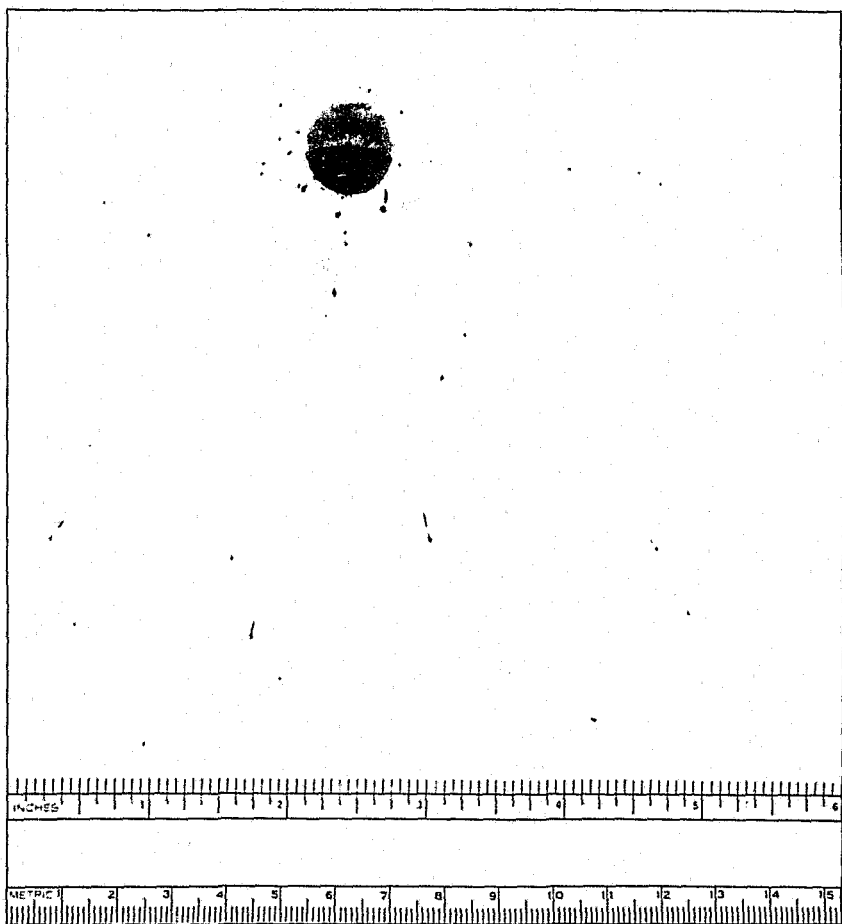


FIGURE 19.—*Pattern of a single drop of human blood that fell forty-two inches and struck hard, smooth cardboard at seventy degrees.*

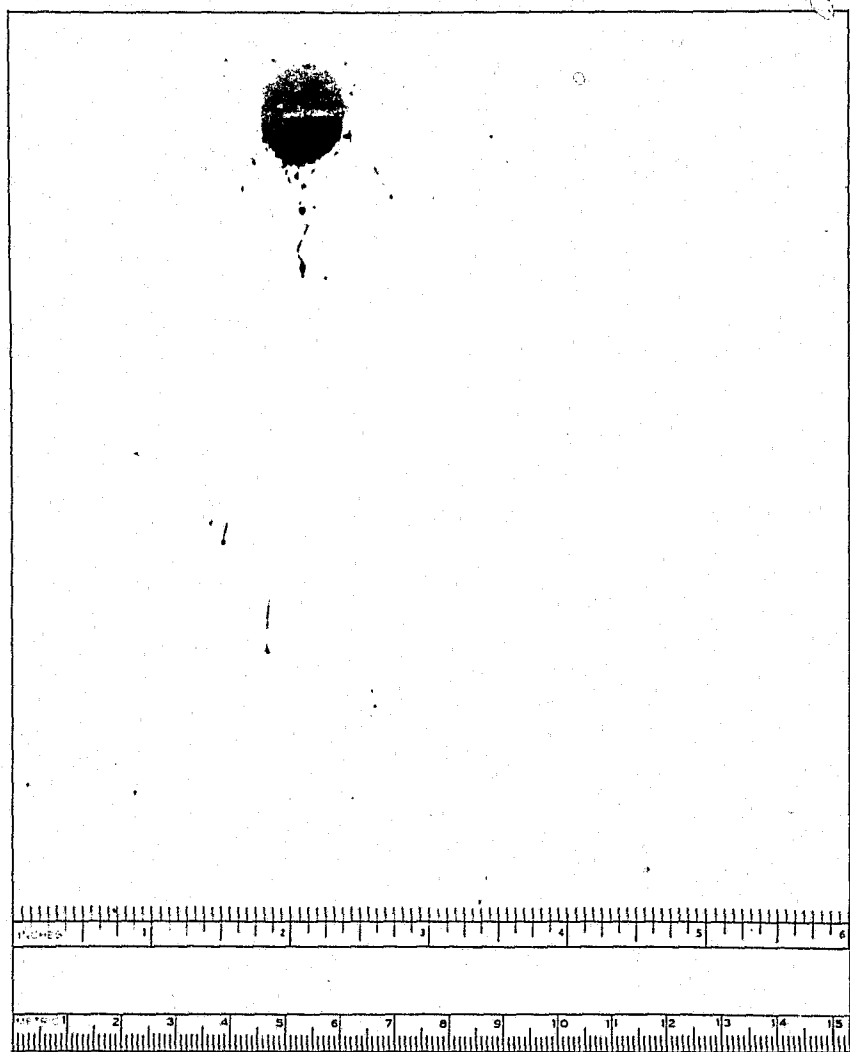


FIGURE 20.—*Pattern of a single drop of human blood that fell forty-two inches and struck hard, smooth cardboard at sixty degrees.*

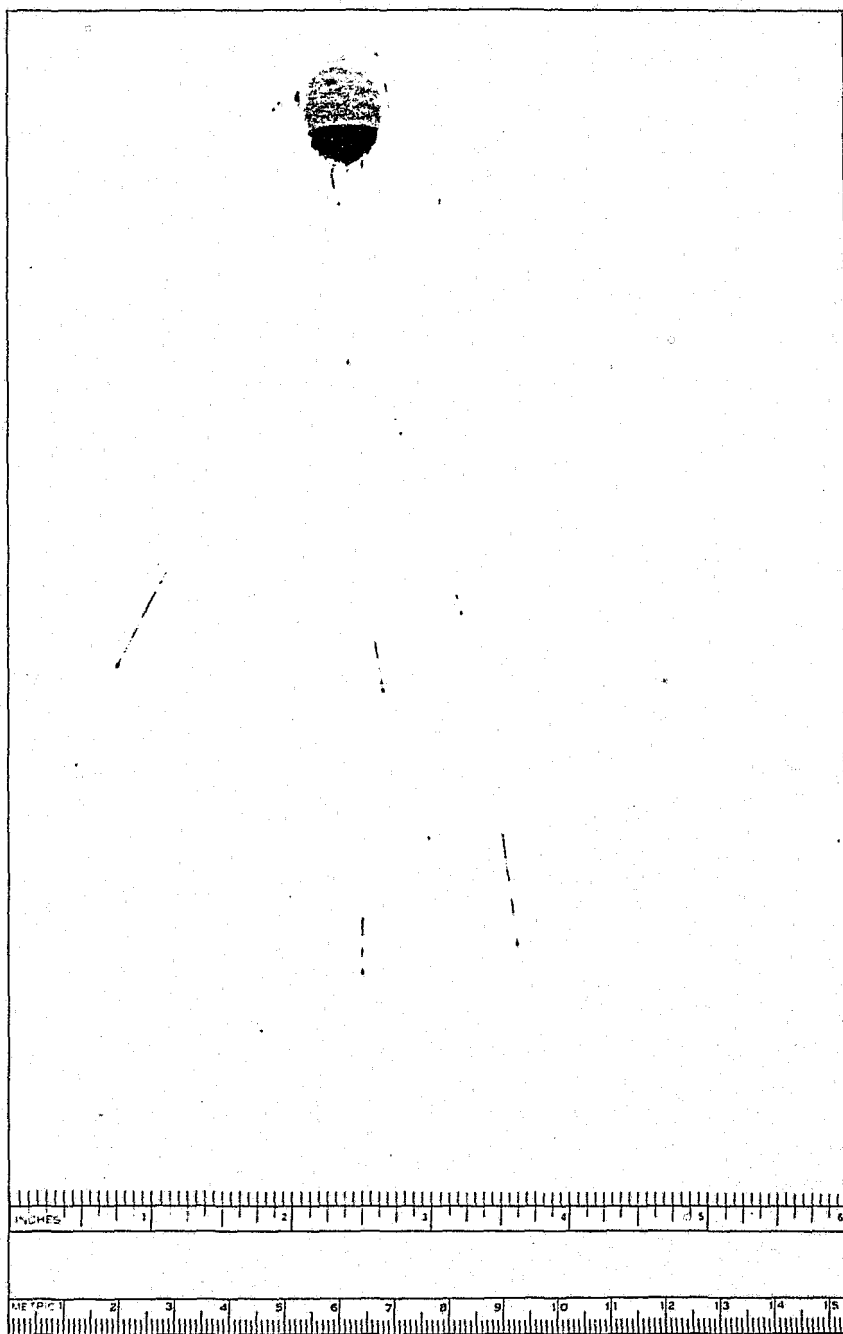


FIGURE 21.—Pattern of a single drop of human blood that fell forty-two inches and struck hard, smooth cardboard at fifty degrees.

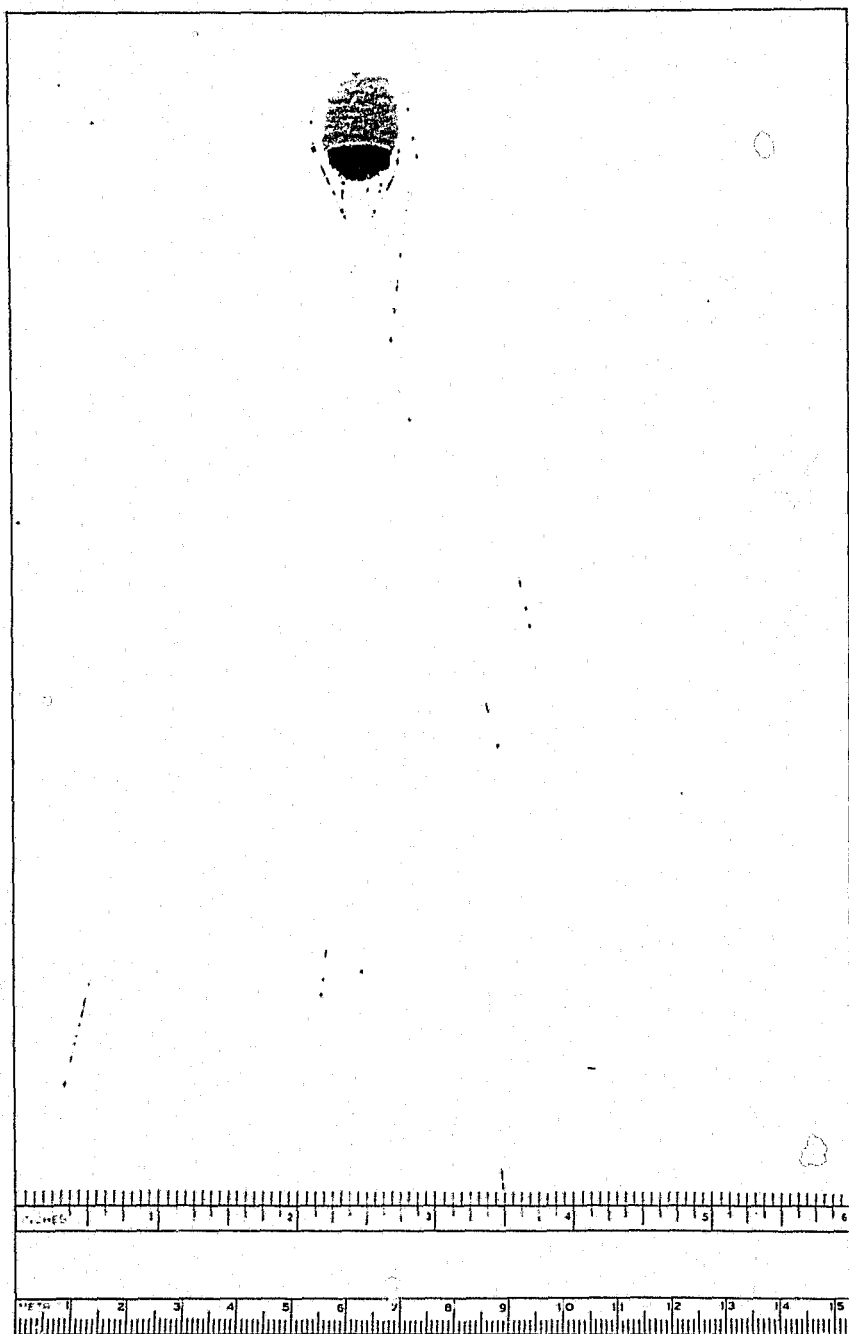


FIGURE 22.—*Pattern of a single drop of human blood that fell forty-two inches and struck hard, smooth cardboard at forty degrees.*

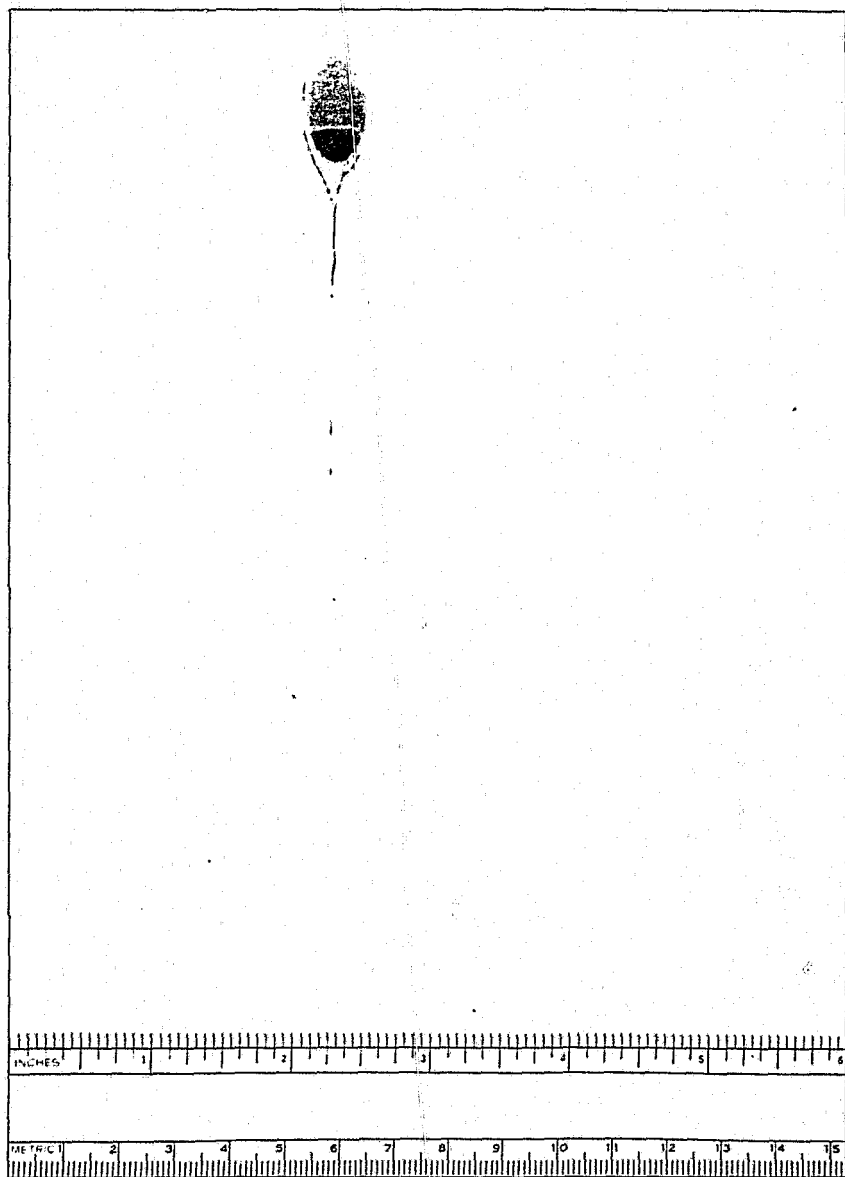


FIGURE 23.—*Pattern of a single drop of human blood that fell forty-two inches and struck hard, smooth cardboard at thirty degrees.*

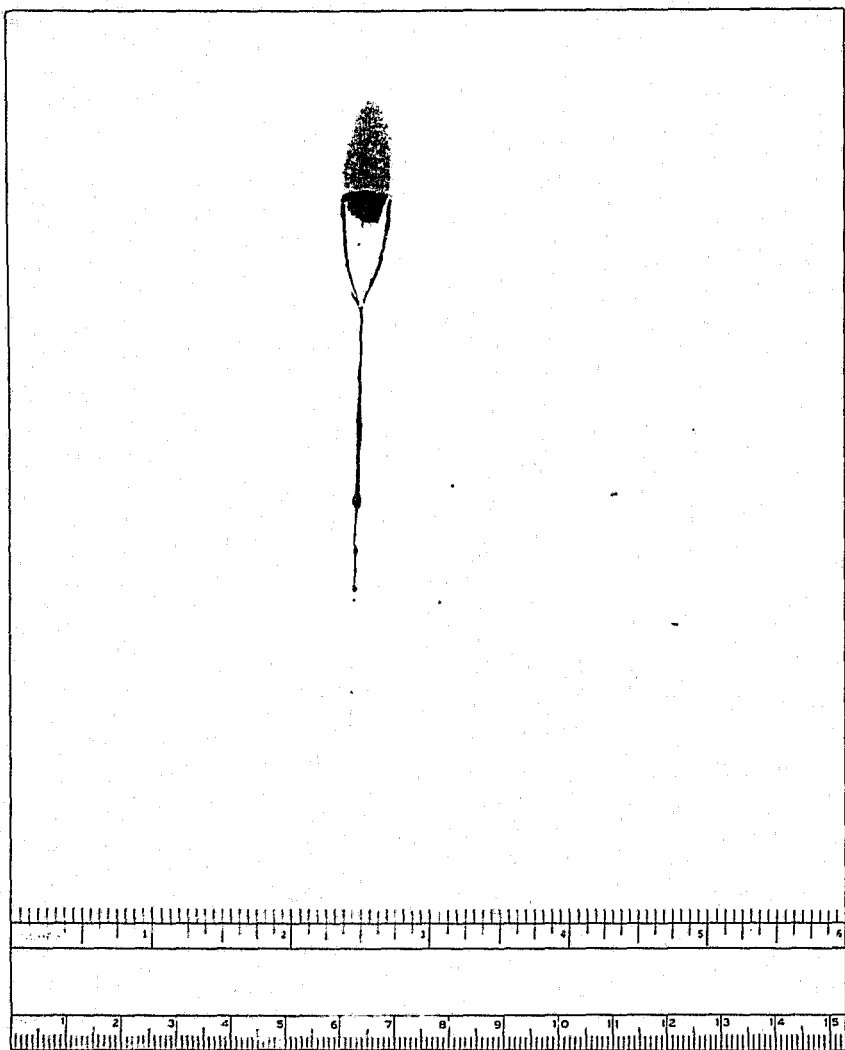


FIGURE 24.—*Pattern of a single drop of human blood that fell forty-two inches and struck hard, smooth cardboard at twenty degrees.*

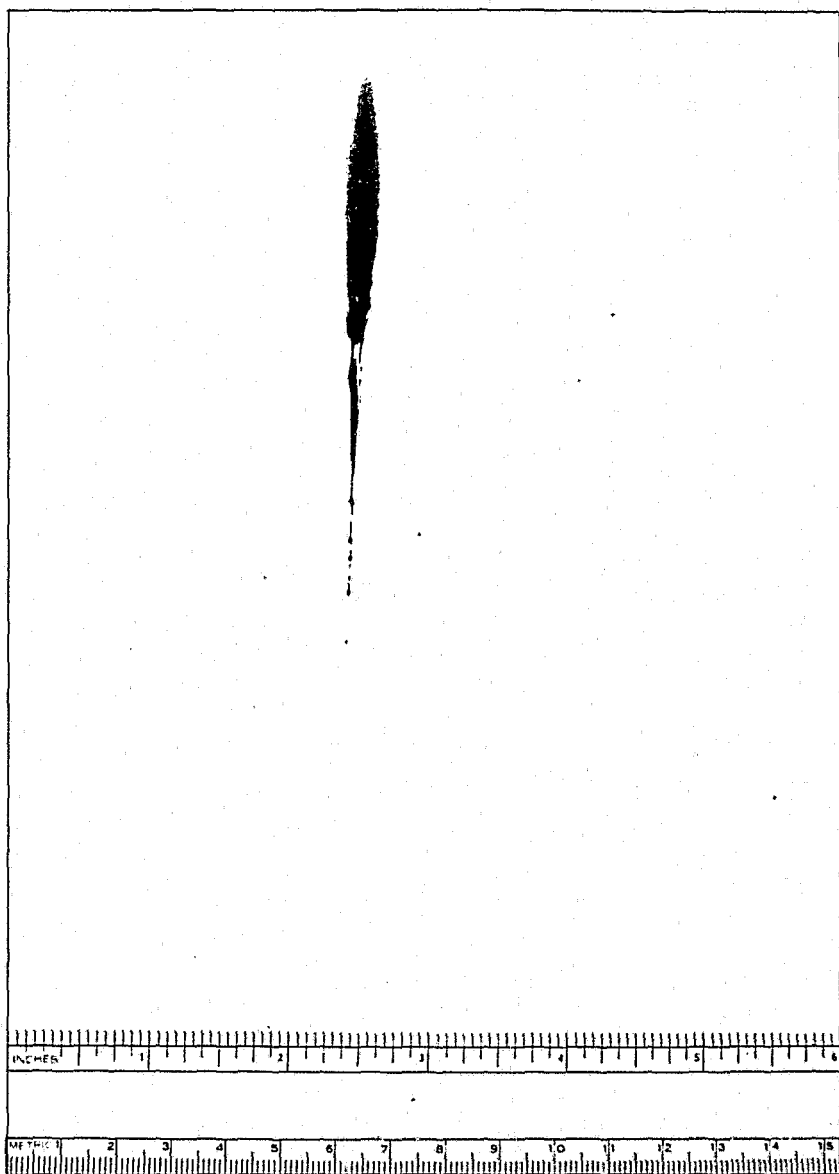


FIGURE 25.—*Pattern of a single drop of human blood that fell forty-two inches and struck hard, smooth cardboard at ten degrees.*

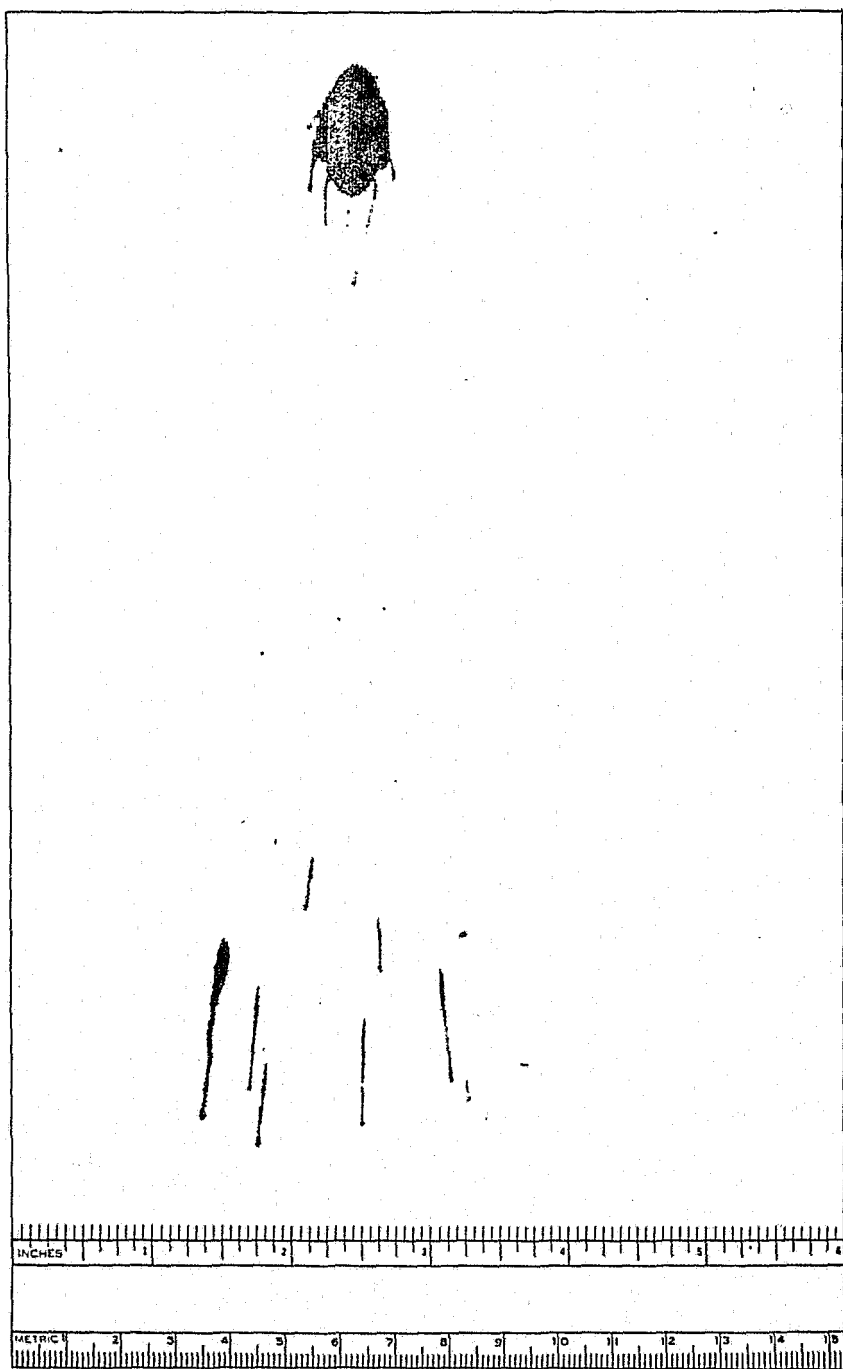


FIGURE 26.—*Pattern of a single drop of human blood that fell forty-two inches and struck a soft blotter at thirty degrees.*



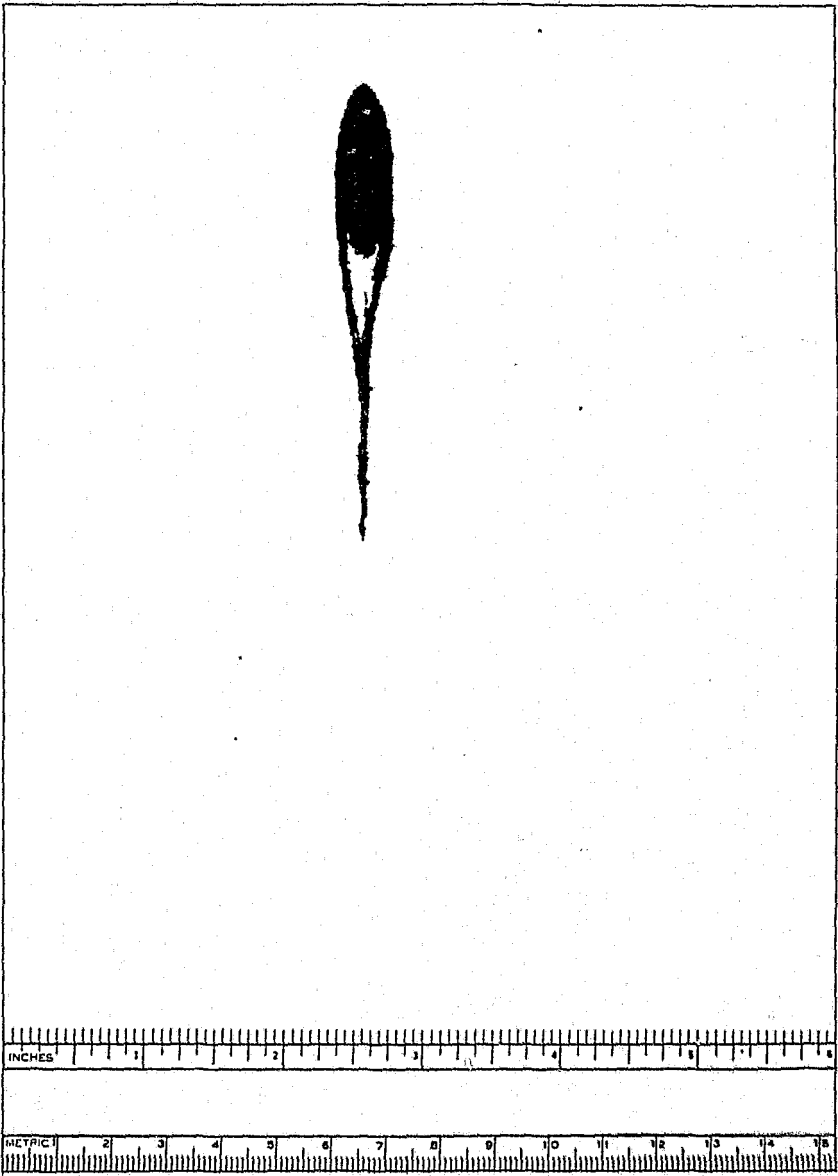


FIGURE 27.—*Pattern of single drop of human blood that fell forty-two inches and struck a soft blotter at twenty degrees.*

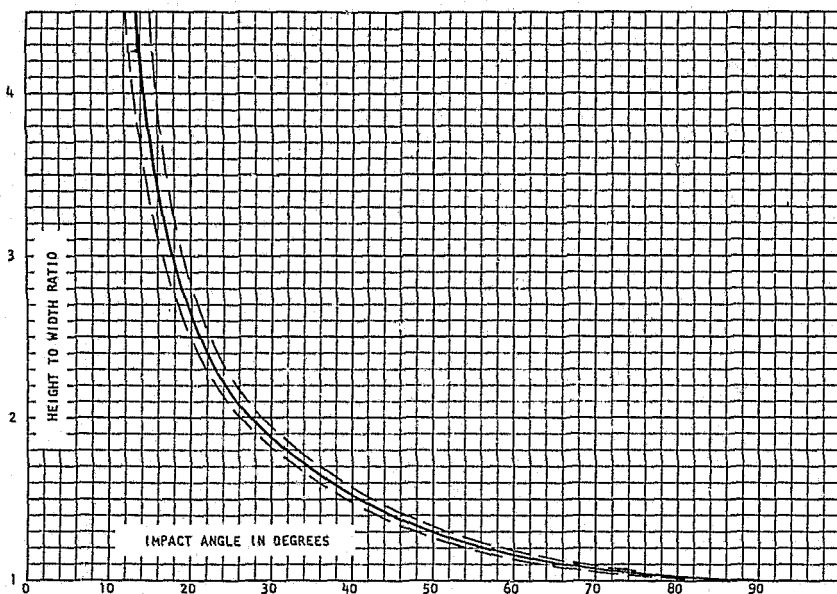


FIGURE 28.—Height to width ratio of bloodstains from single drops of human blood as a function of impact angle.

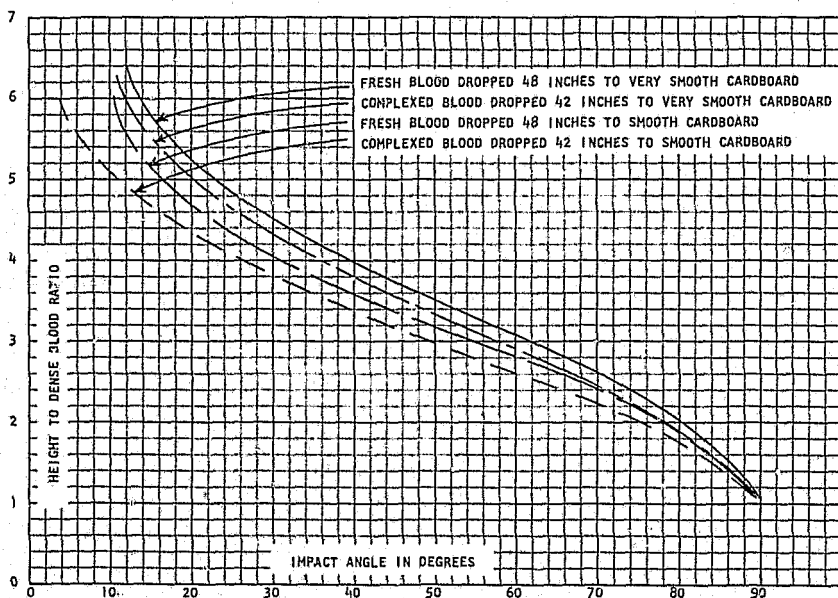


FIGURE 29.—Height to dense blood ratio of bloodstains from single drops of human blood as a function of impact angle.

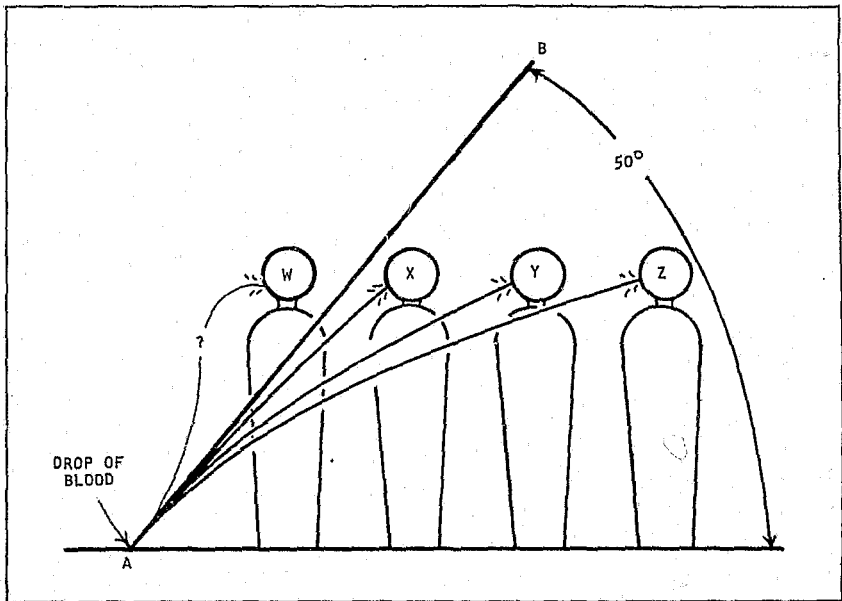


FIGURE 30.—Proposed position of a victim from a bloodstain found on the floor. All to the right (x, y, z) of the impact angle are possible, the one to the left (w) is not possible.

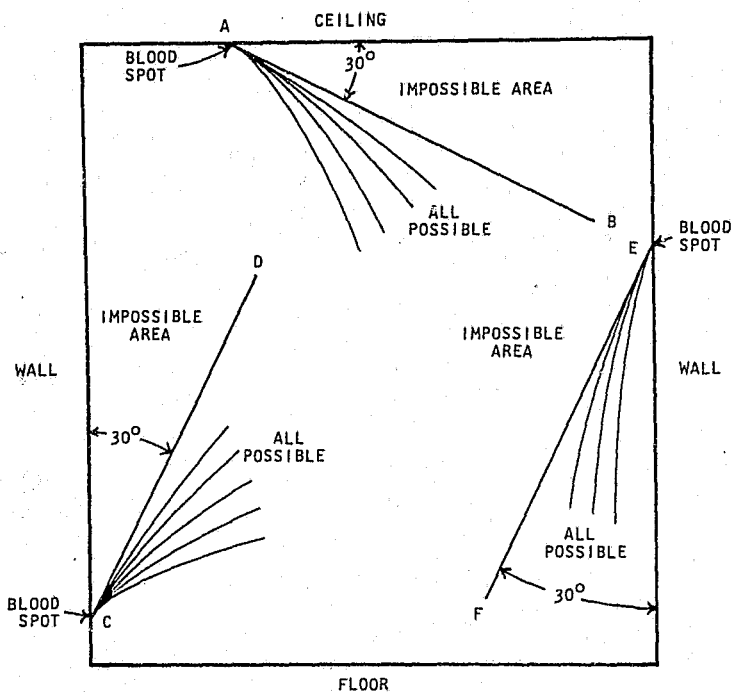


FIGURE 31.—Diagrammatic representation of possible flight paths that could result in thirty degree angles of incidence. Ceiling bloodspot angle of incidence projection (line AB) for an upward spatter; downward or falling wall bloodspot angle of incidence projection (line CD); upward or rising wall bloodspot angle of incidence projection (line FG).

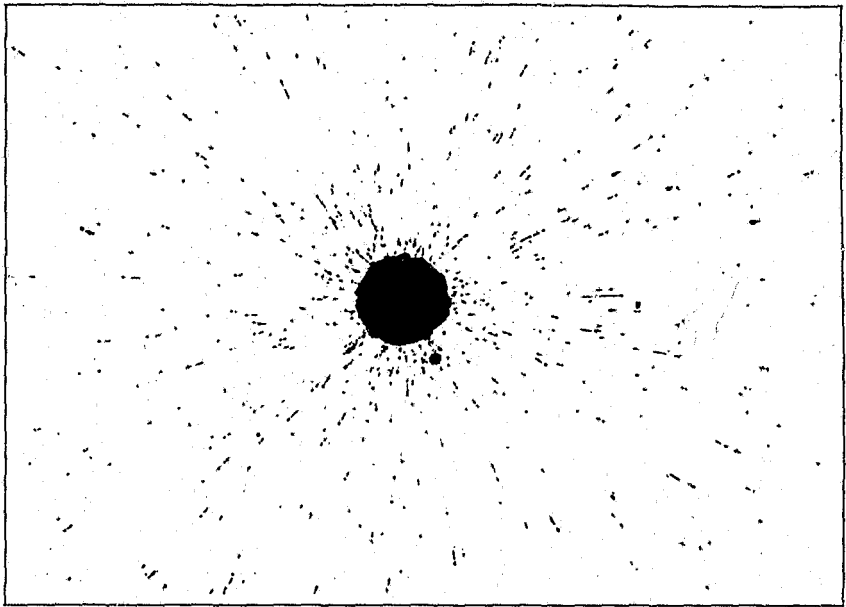


FIGURE 32.—Bloodspatter pattern resulting when 1ml of human blood fell forty-eight inches to a horizontal, hard, smooth, cardboard target.

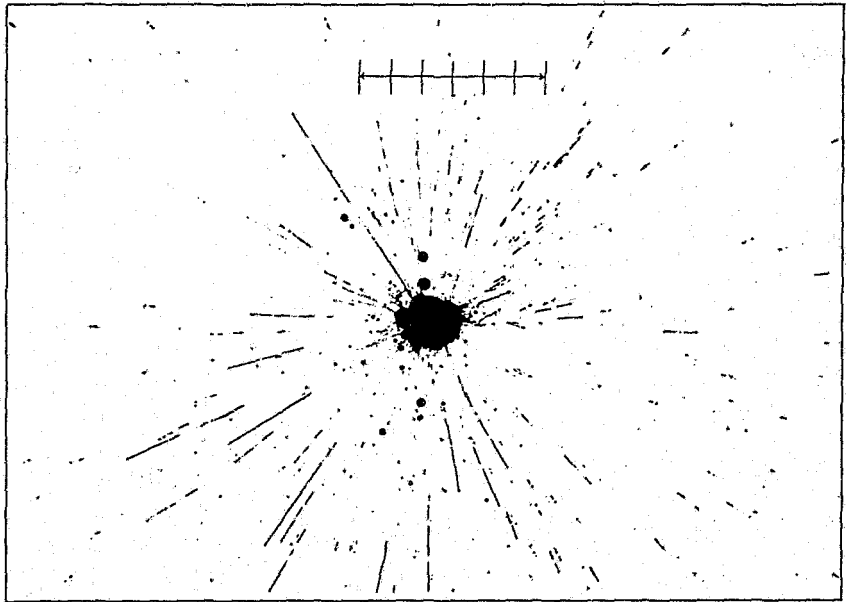


FIGURE 33.—Bloodstain pattern resulting when 1ml of human blood was projected downward forty-eight inches from an open tube to a horizontal, hard, smooth, cardboard target (6" ruler).

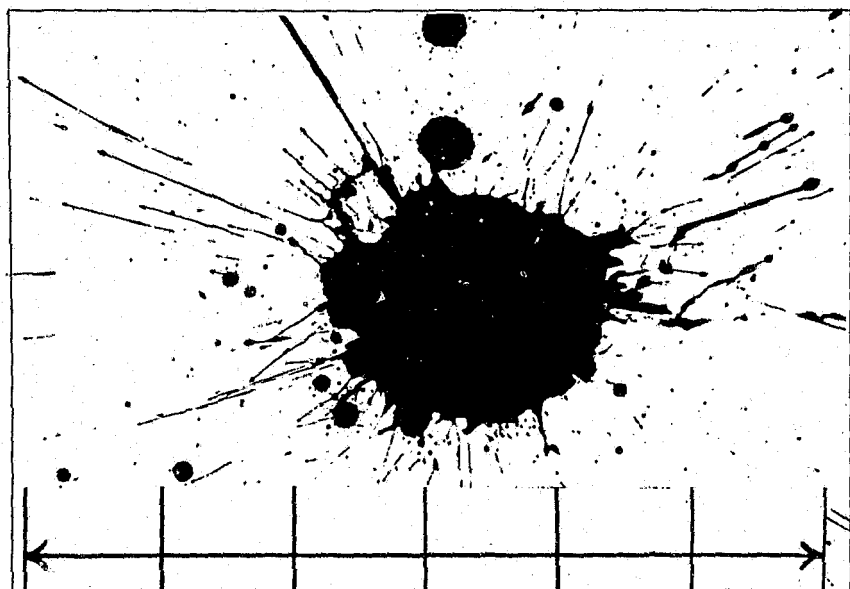


FIGURE 34.—Detail of the central area of Figure 33.

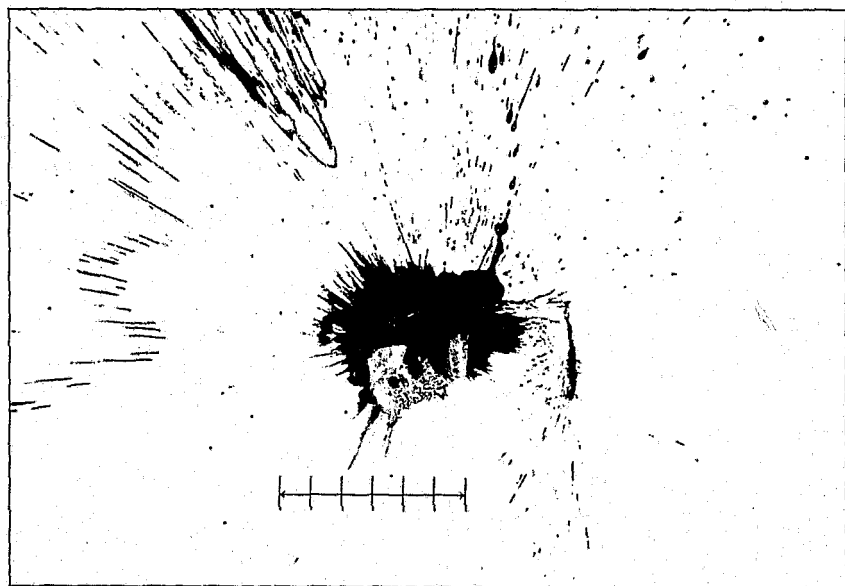


FIGURE 35.—Bloodstain pattern produced when a shod foot stamped into a pool of blood.

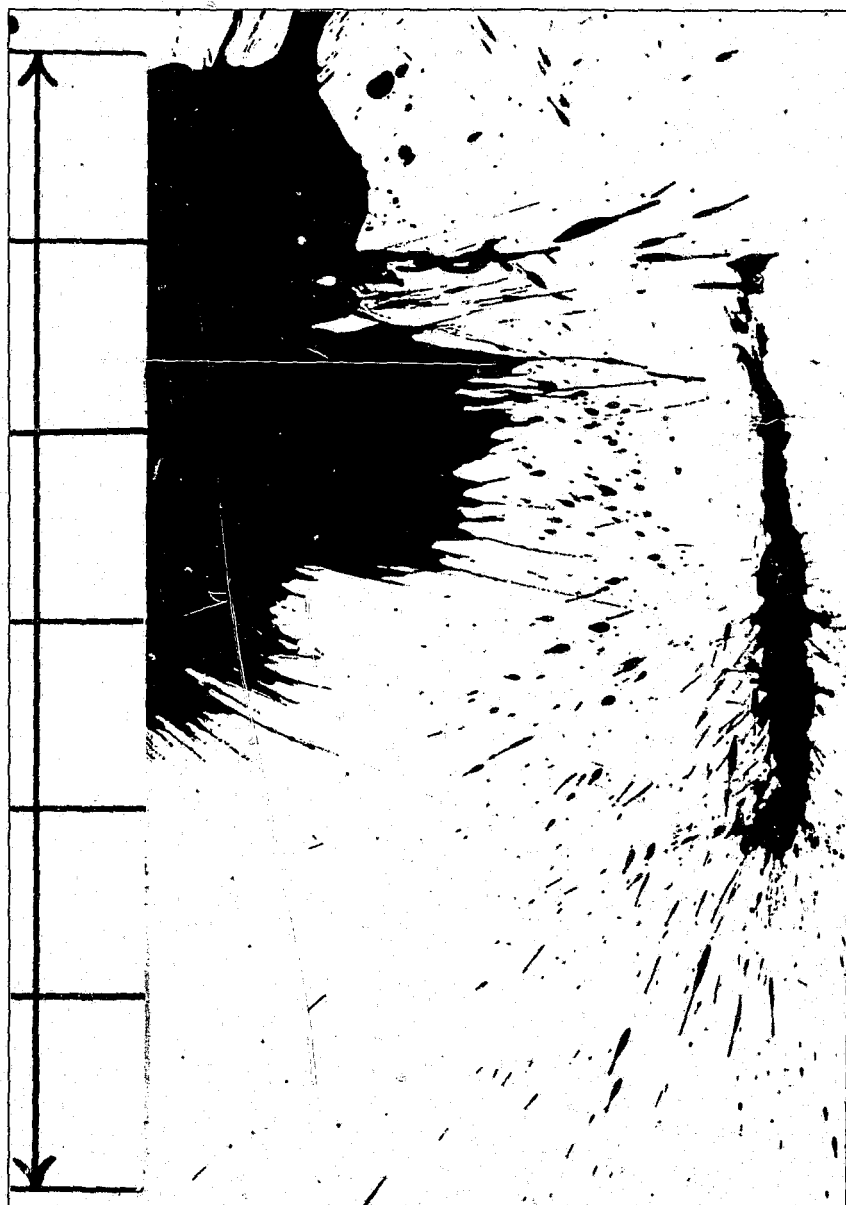


FIGURE 36.—Detail of the instep area of Figure 35 (6" ruler)

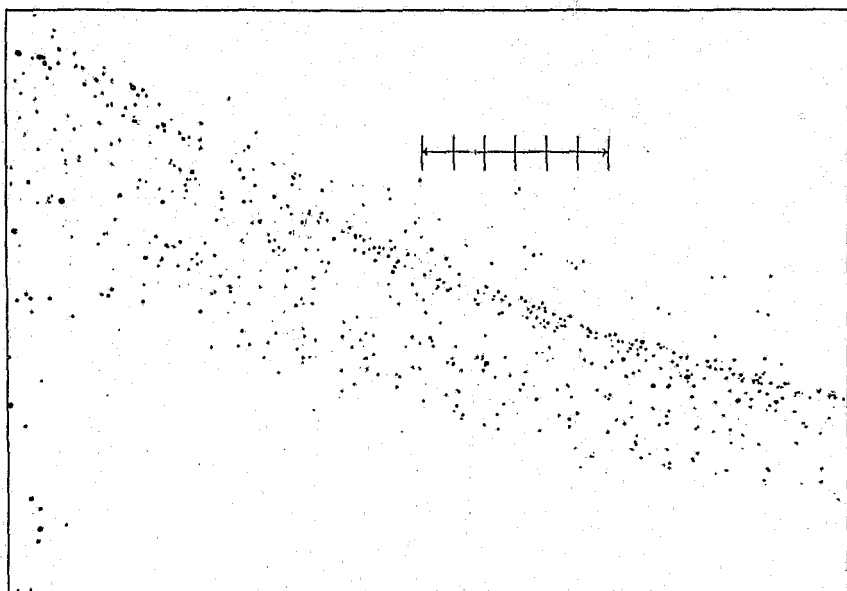


FIGURE 37.—Pattern of bloodstains produced when a hand covered with human blood was swung in front of the target (6" ruler).

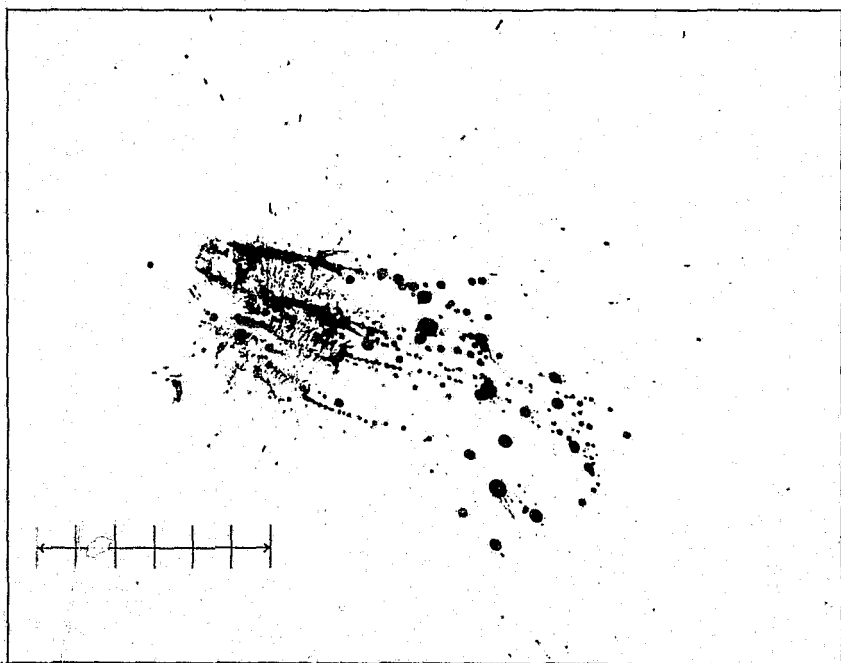


FIGURE 38.—Bloodstain pattern resulting from slapping a blood covered hand down onto a horizontal, hard cardboard. Right hand pattern, thumb on bottom, fingertips to the right (6" ruler).



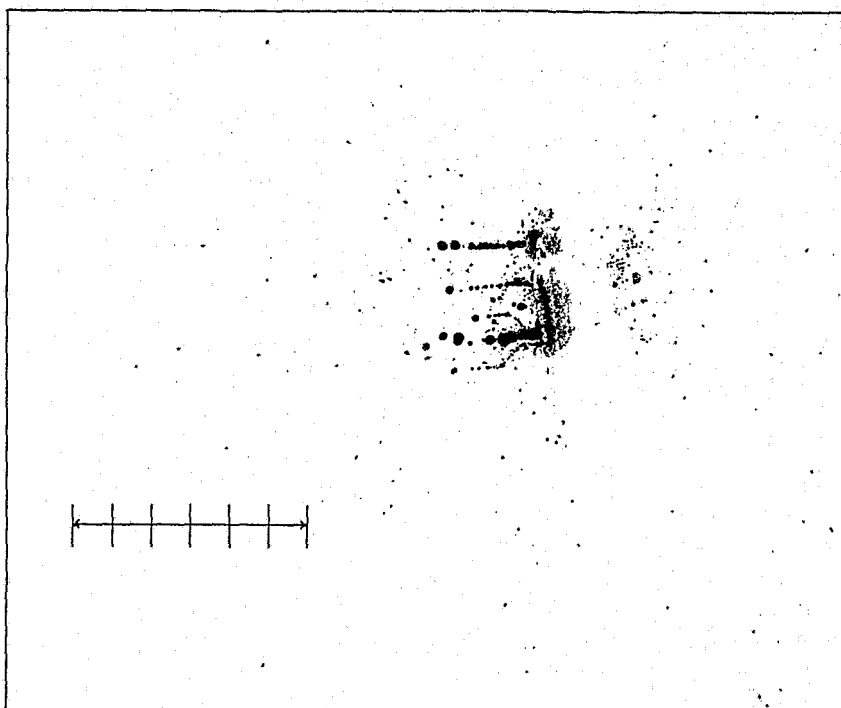


FIGURE 39.—Bloodstain pattern resulting from three sharp blows from a blood covered hatchet blade. The chopping motion was downward into a small piece of wood resting on the cardboard target (6" ruler).

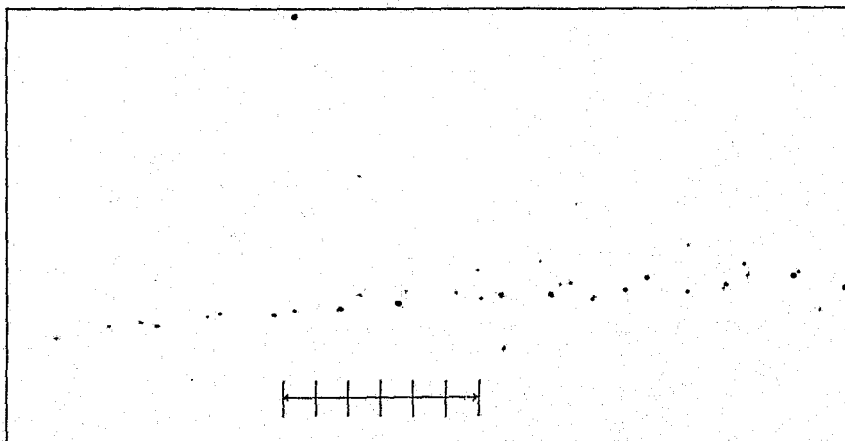


FIGURE 40.—Bloodstain pattern resulting from an overhead swing by a one-half inch diameter steel rod that was covered with human blood (6" ruler).

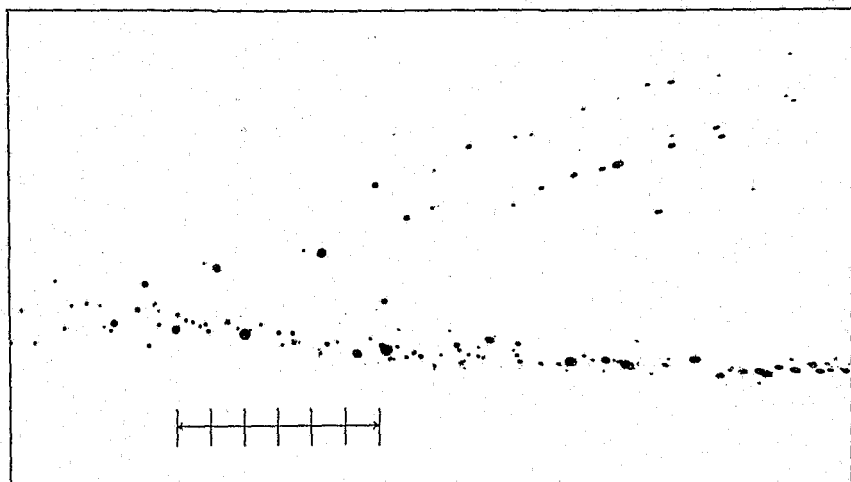


FIGURE 41.—*Bloodstain pattern resulting from an overhead swing by hatchet that was covered with human blood (6" ruler).*

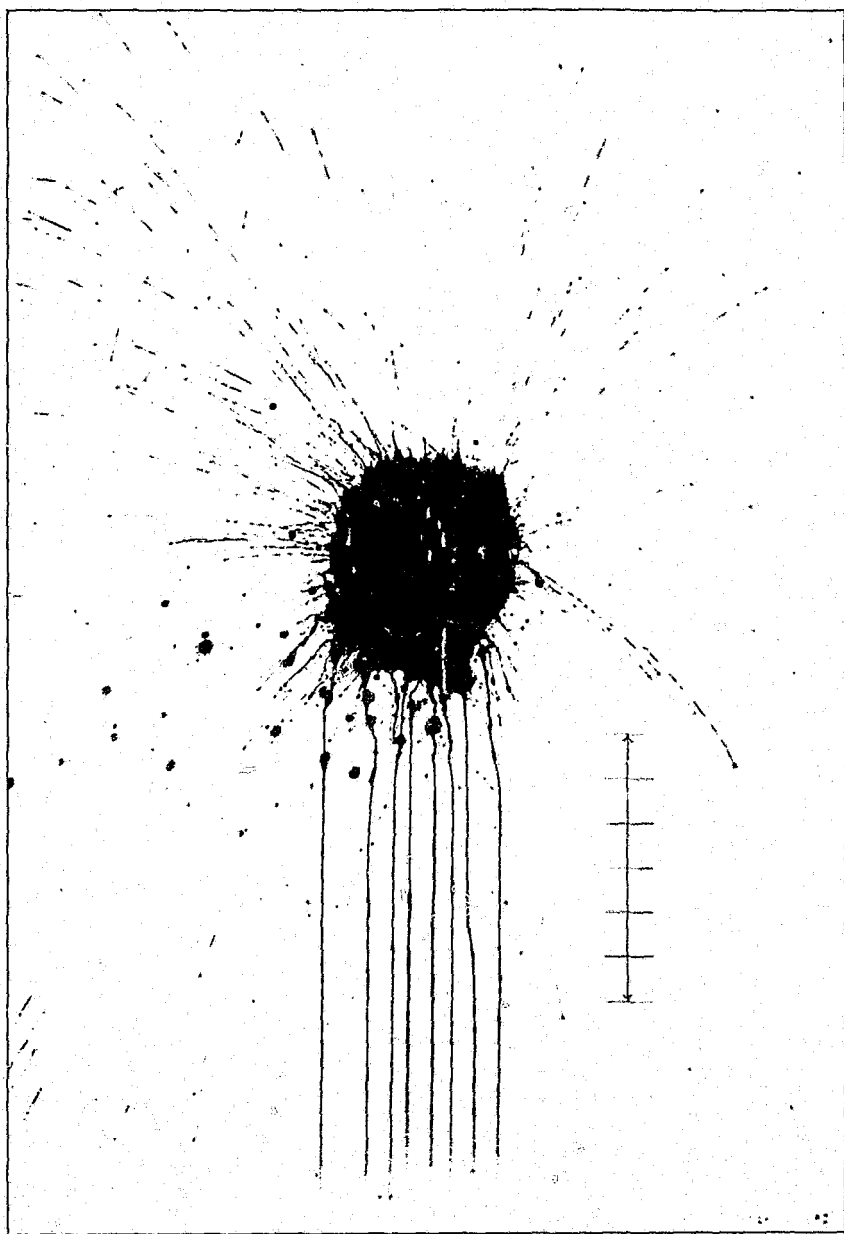


FIGURE 42.—Large bloodstain produced when 10ml of human blood were thrown three feet against a vertical hard, smooth cardboard target (6" ruler).

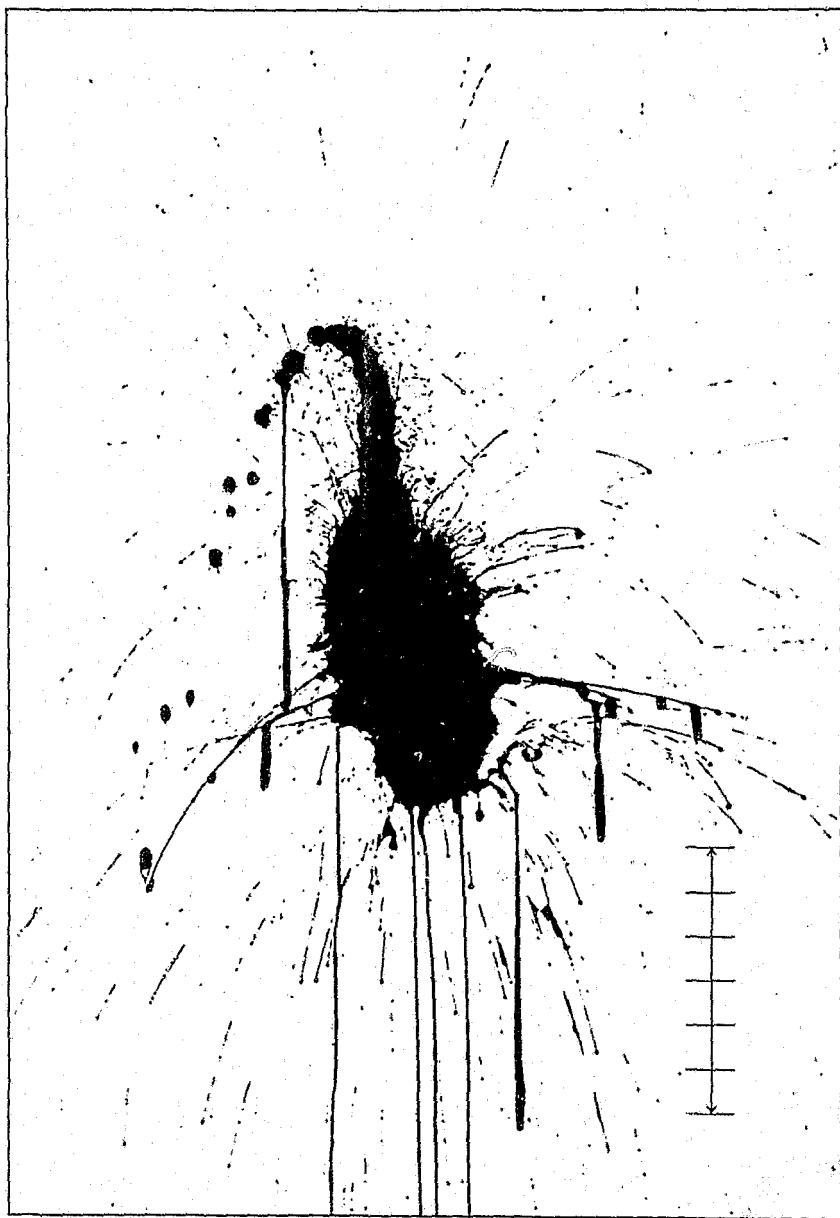


FIGURE 43.—*Large bloodstain pattern produced when 10ml of human blood were thrown slightly upward onto a verticle hard, smooth piece of cardboard (6" ruler)*

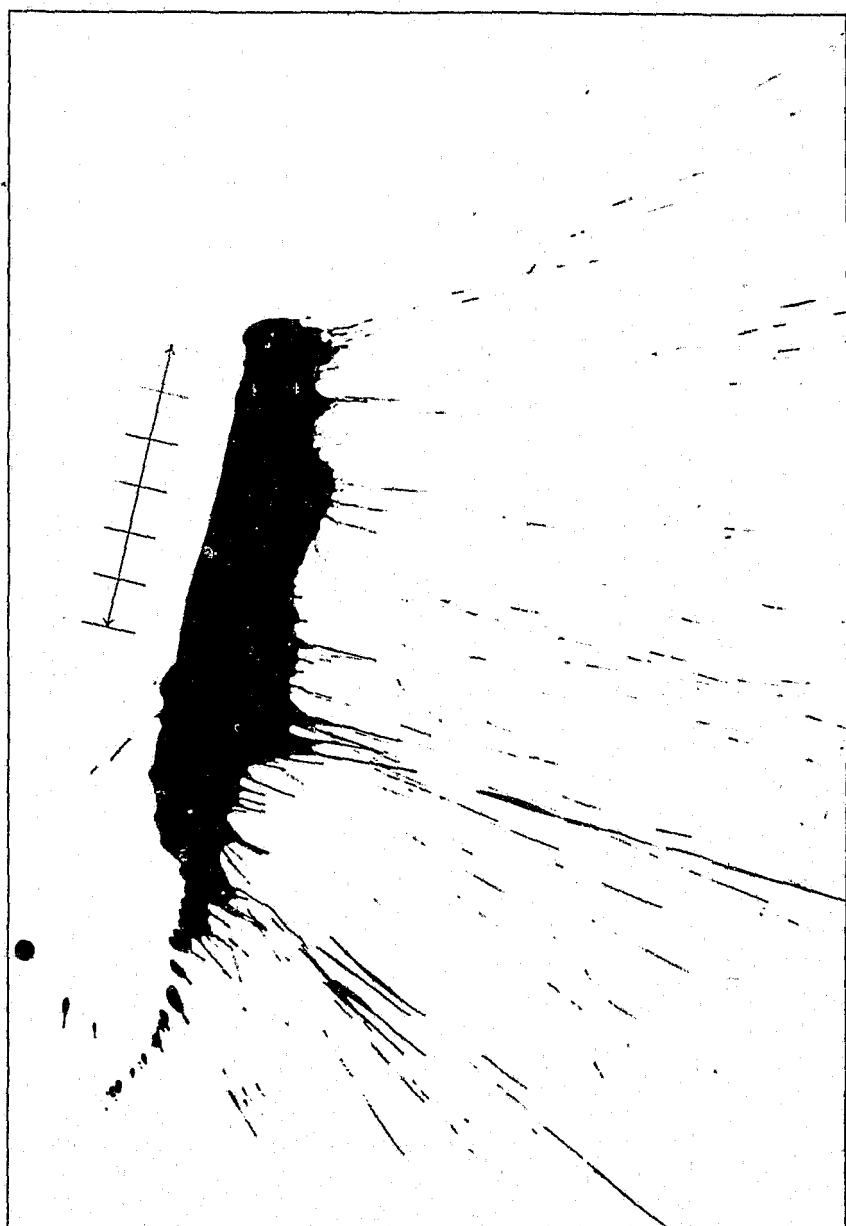


FIGURE 44.—*Large streaked bloodstain pattern produced when 10ml of blood was thrown out over a horizontal, hard, smooth cardboard target (6" ruler).*

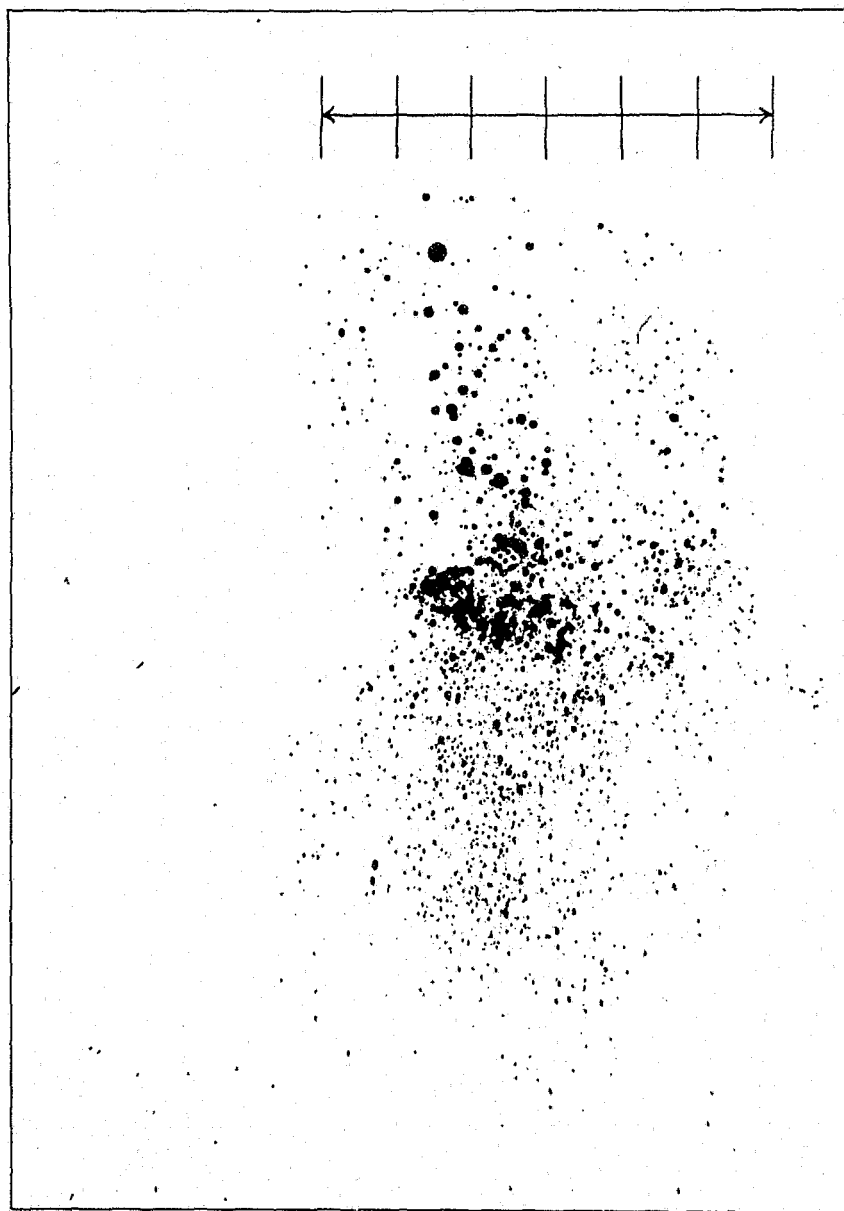


FIGURE 45.—*Medium velocity blood spatters produced by a twenty-five foot per second impact. Blood was projected sideways to a verticle target six inches from the point of impact (6" ruler)*

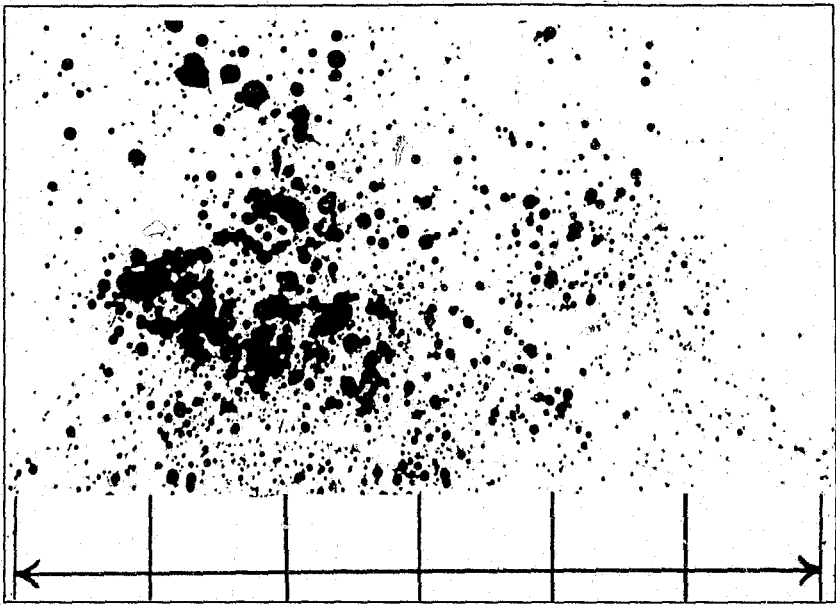


FIGURE 46.—Close-up detail of the central area of Figure 45 (6" ruler)

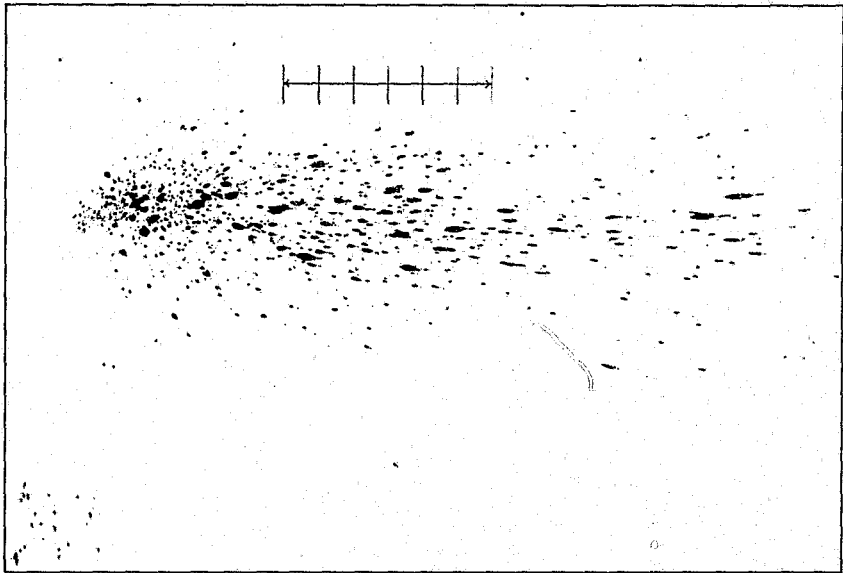


FIGURE 47.—Overall stain pattern produced by a twenty-five foot per second impact to human blood. Impact was from the left slightly above this horizontal target (6" ruler).

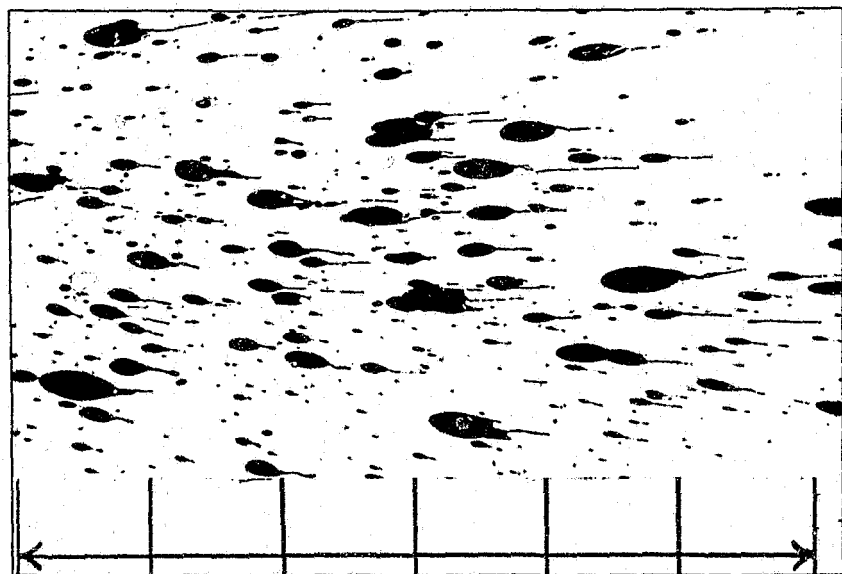


FIGURE 48.—Close-up detail of the central area of Figure 47 (6" ruler)

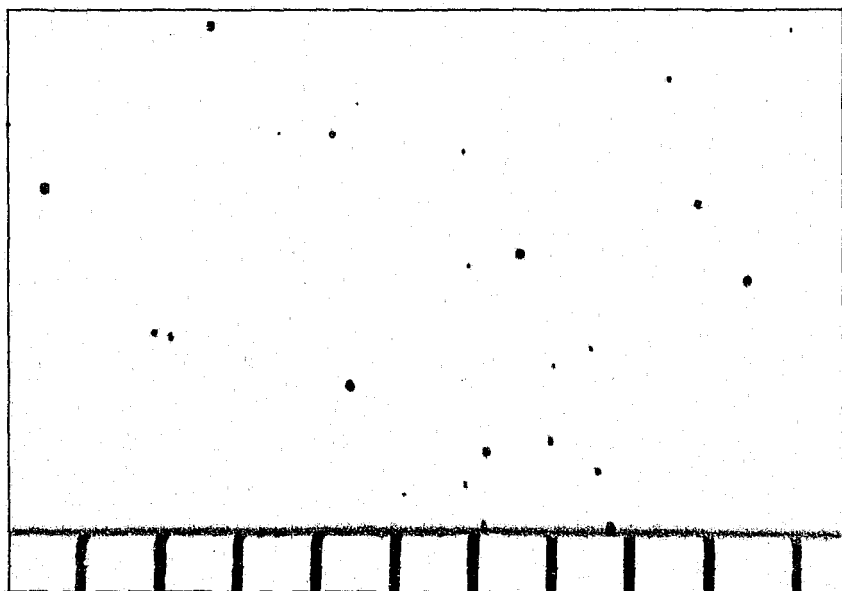


FIGURE 49.—Photomacrograph of typical bloodstains resulting from medium to high velocity impact at a distance of twenty inches from the spatter origin. The scale is in sixteenths of an inch.



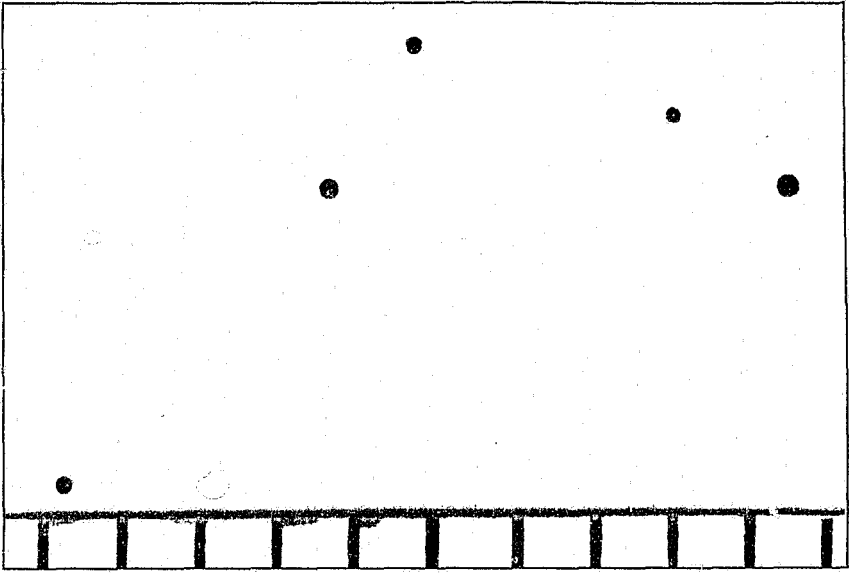


FIGURE 50.—Photomacrograph of typical bloodstains resulting from medium to high velocity impact at a distance of forty-nine inches from the spatter origin. The scale is in sixteenths of an inch.

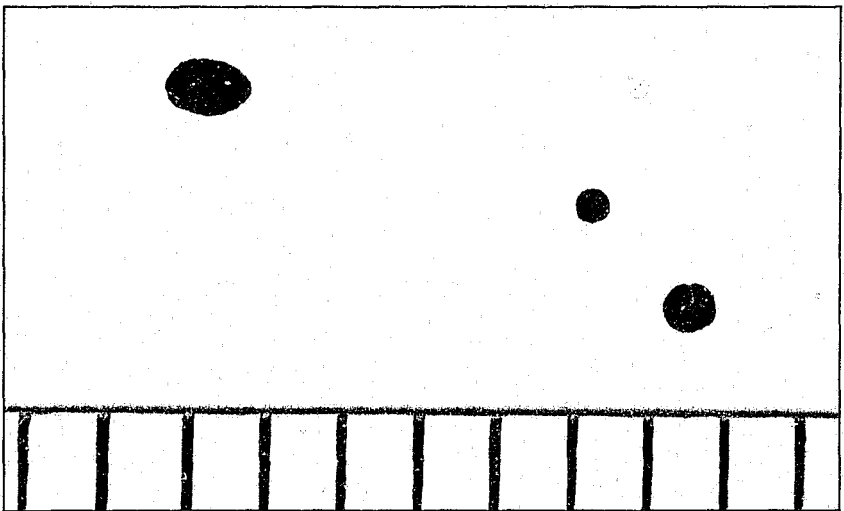


FIGURE 51.—Photomacrograph of typical bloodstains resulting from medium to high velocity impact at a distance of seventy-eight inches from the spatter origin. The scale is in sixteenths of an inch.

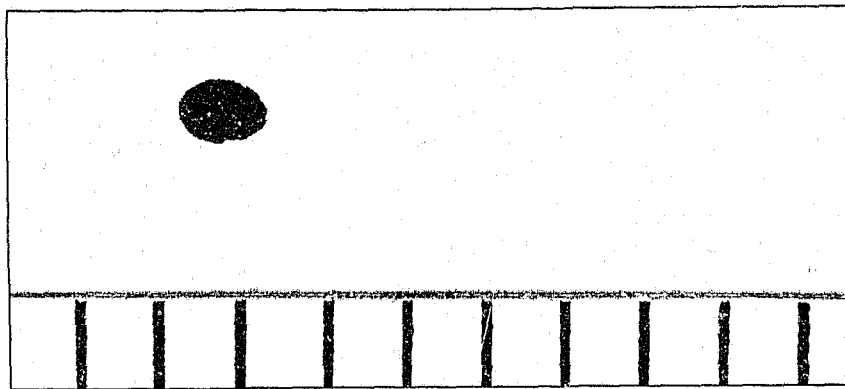


FIGURE 52.—*Photomacrograph of typical bloodstains resulting from medium to high velocity impact at a distance of one hundred-six inches from the spatter origin. The scale is in sixteenths of an inch.*



FIGURE 53.—*Photomacrograph of typical bloodstains resulting from medium to high velocity impact at a distance of one hundred-thirty three inches from the spatter origin. The scale is in sixteenths of an inch.*

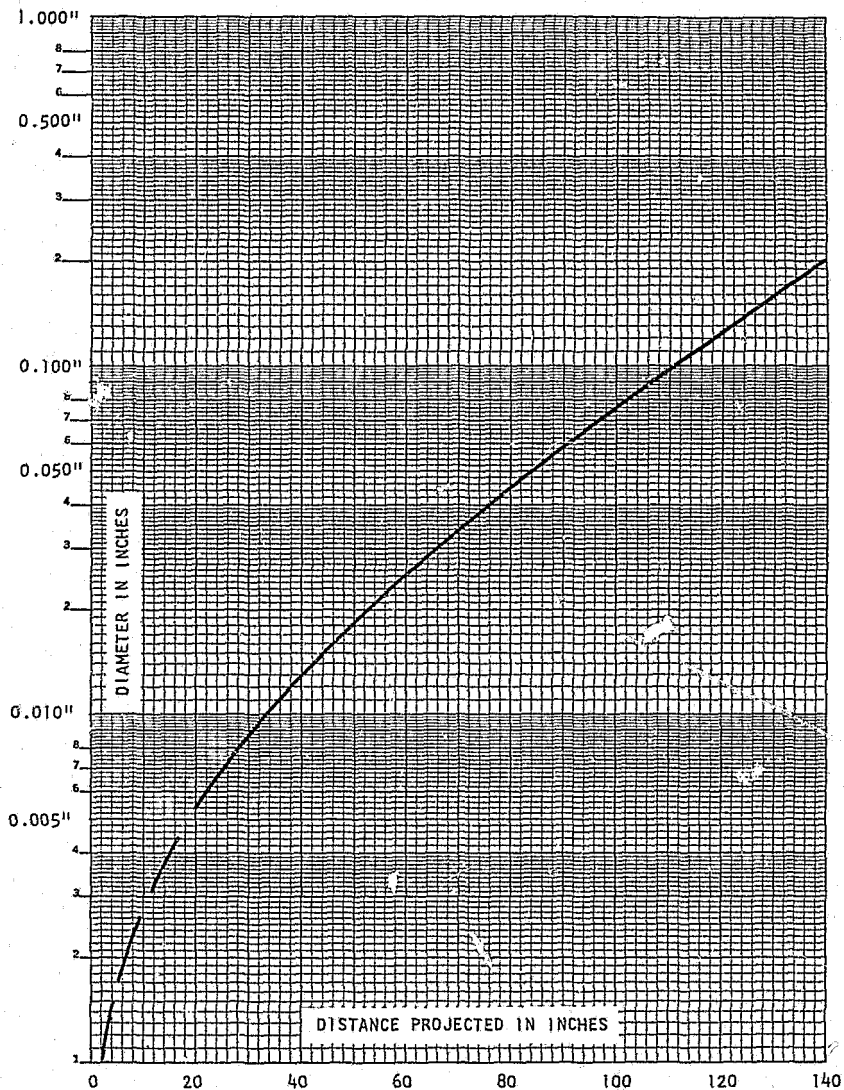


FIGURE 54.—Distance from point of impact as a function of bloodstain diameter for medium to high velocity blood spatters.



FIGURE 55.—*High speed photograph of human blood spattered by gunshot impact of one thousand feet per second five milliseconds after impact. The ruler directly beneath the spattered blood is one inch on its upper edge.*

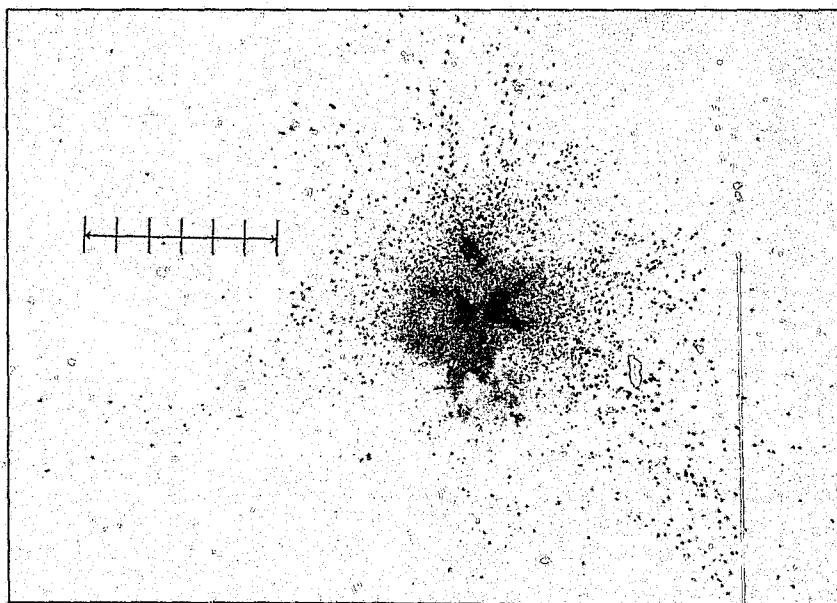


FIGURE 56.—*Bloodstain pattern formed on a verticle cardboard target placed six inches behind the point of high velocity impact. The bullet struck bloody polyurethane foam at about one thousand feet per second before striking this target (6" ruler).*

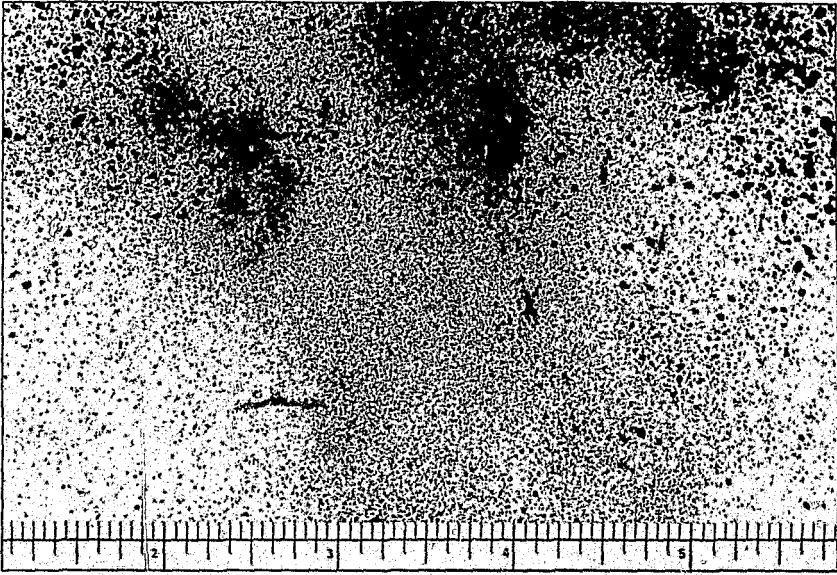


FIGURE 57.—Closer view of the central portion of Figure 56.

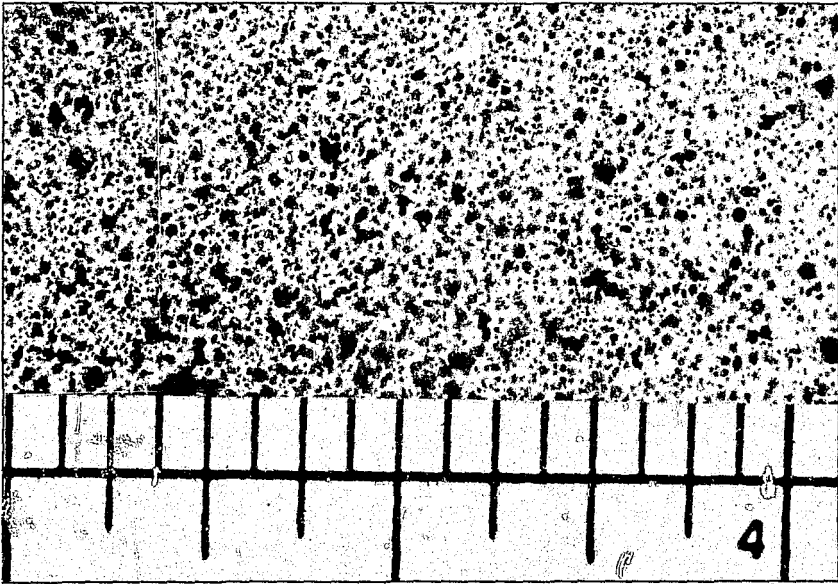


FIGURE 58.—Photomicrograph of the central portion of Figure 57.  
Each division on the ruler is one sixteenth of an inch.

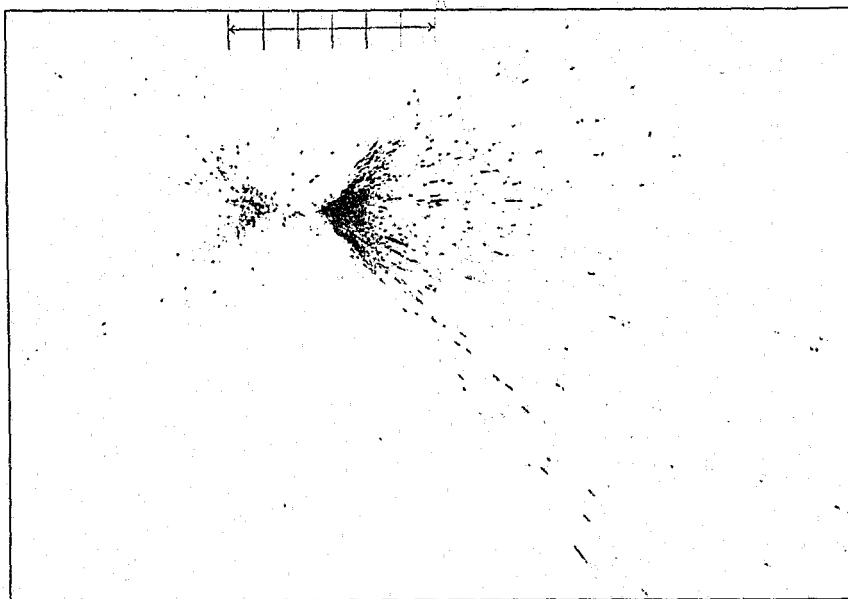


FIGURE 59.—Bloodstain pattern produced on a flat, horizontal, cardboard target when bloody polyurethane foam is struck by gunshot. The foam was held just above the target and the bullet passed parallel to the target before and after impact (6" ruler).

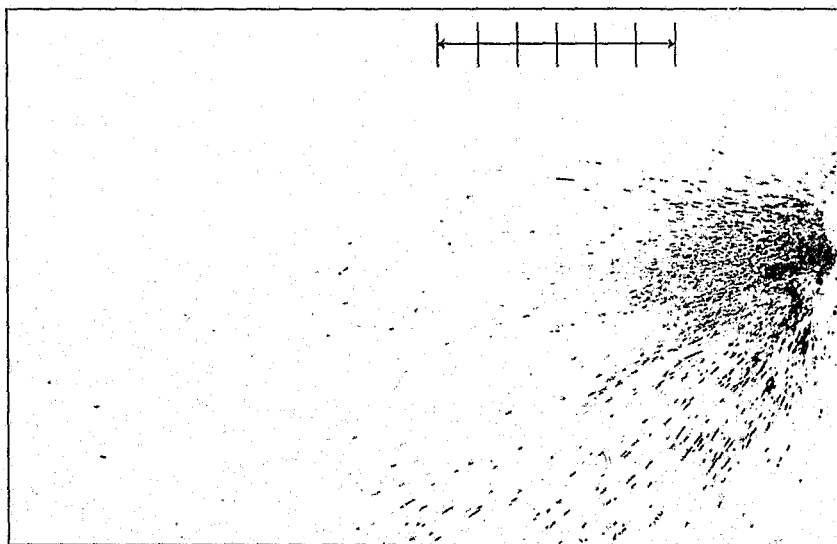


FIGURE 60.—Bloodstain pattern produced on a vertical cardboard target by gunshot through a piece of bloody polyurethane foam. The bullet struck the impact site travelling from right to left parallel to, and just one inch in front of, this target (6" ruler).

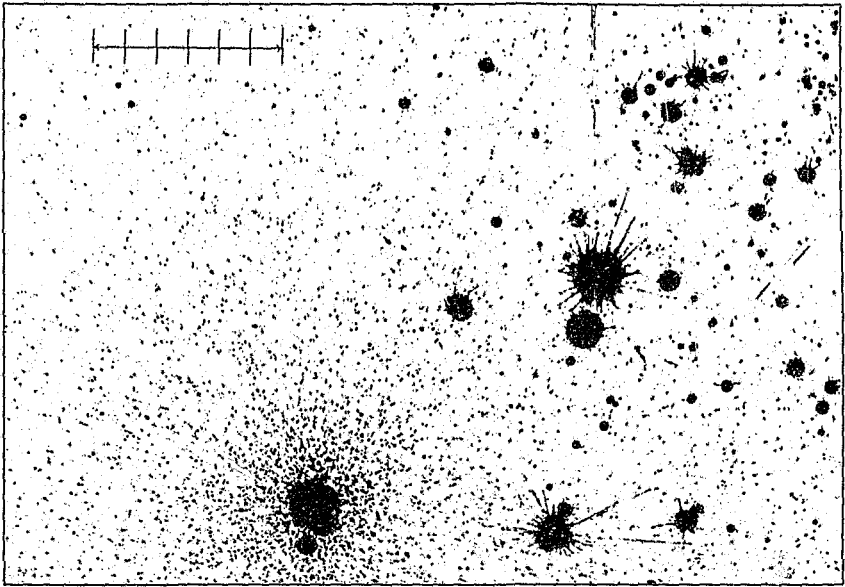


FIGURE 61.—Bloodstain pattern produced on a flat, horizontal card-board placed behind and fifty-five inches below a test animal impact site. Gunshot to the heart horizontally over the target, twelve gauge shotgun slug (6" ruler).

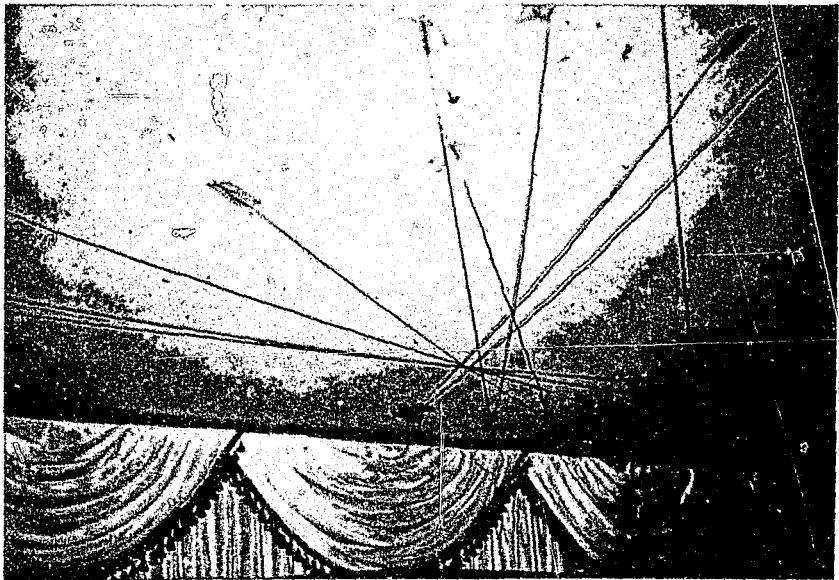


FIGURE 62.—Strings taped to a bedroom ceiling parallel to bloodstains showing their projection back to a common area of origin.

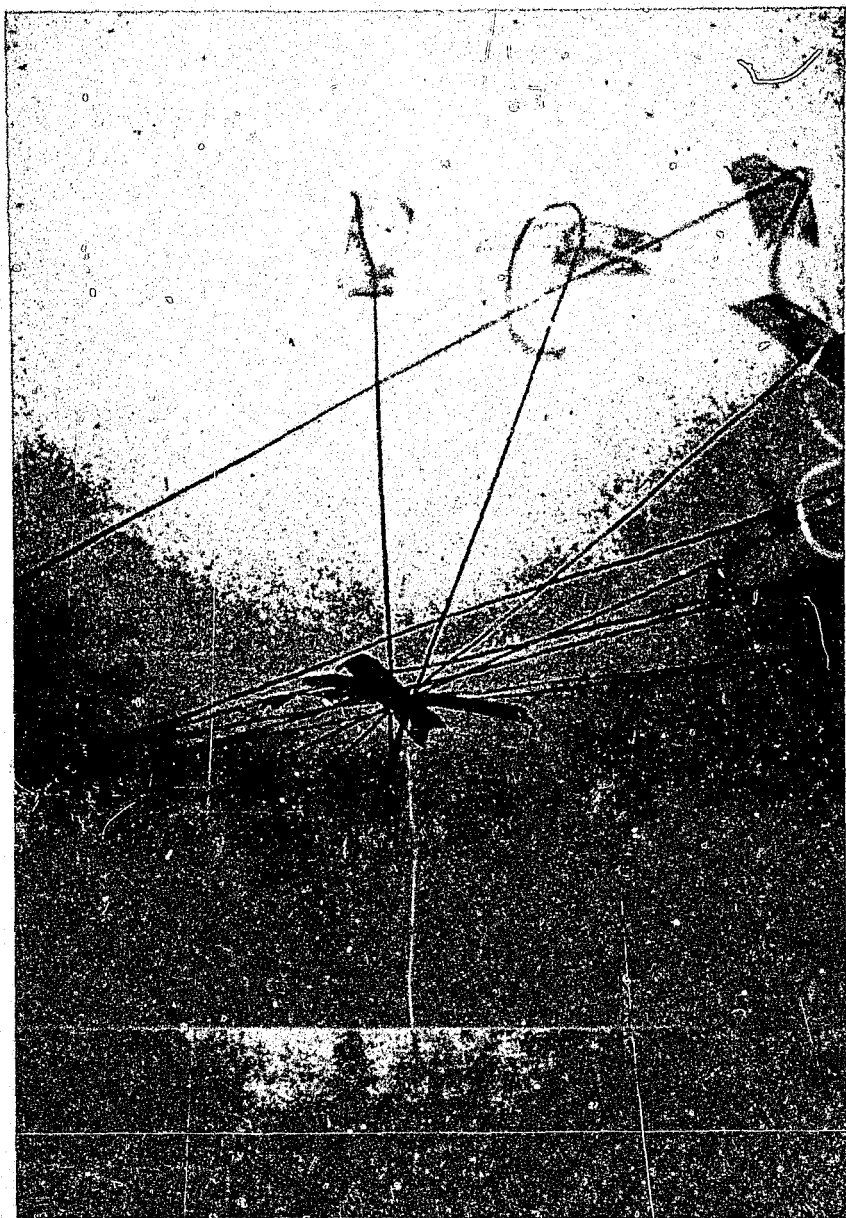


FIGURE 63.—Another view of the ceiling in Figure 62 but taken from the right side of that figure. A verticle plumb line is taped to the area of convergence of the ceiling projections.



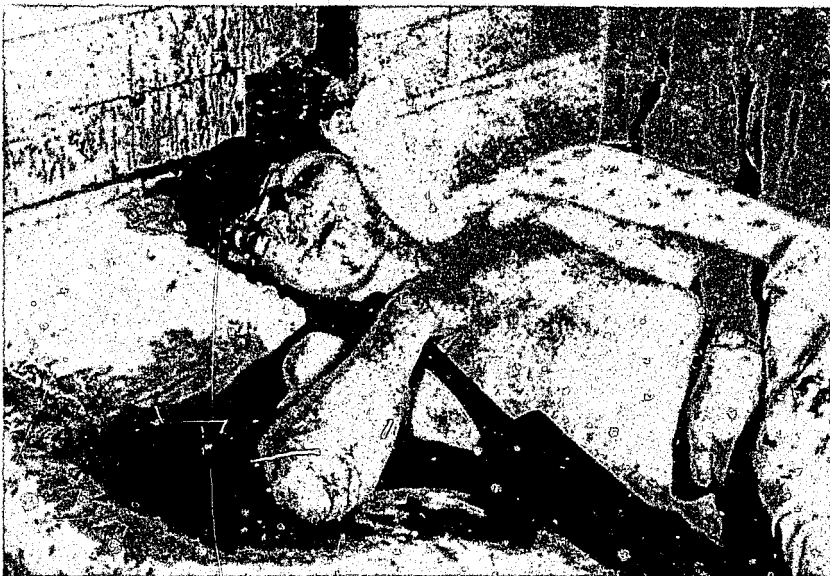


FIGURE 64.—*Suicide resulting from a shotgun blast into the roof of the mouth. Multiple high velocity bloodspatters clearly define the nature of impact.*

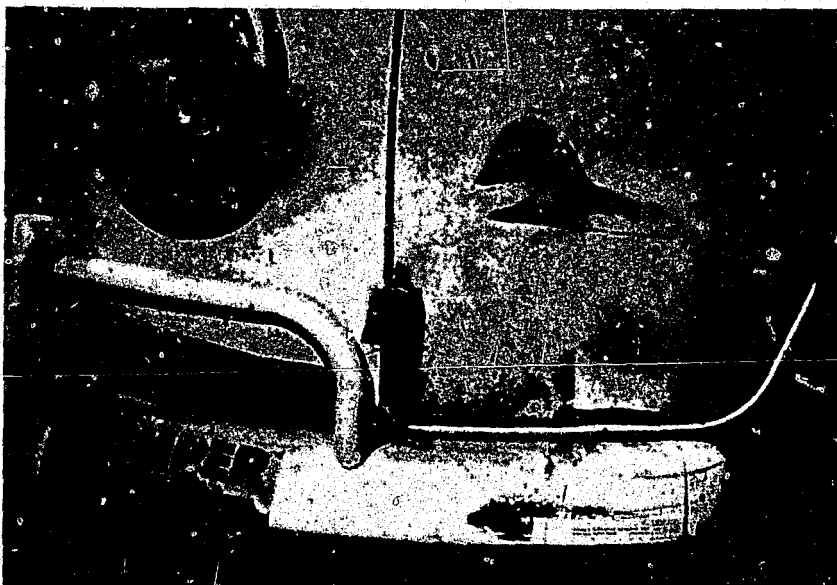


FIGURE 65.—*Overall view of the wrap-around front bumper of a 1966 Volkswagen Microbus.*

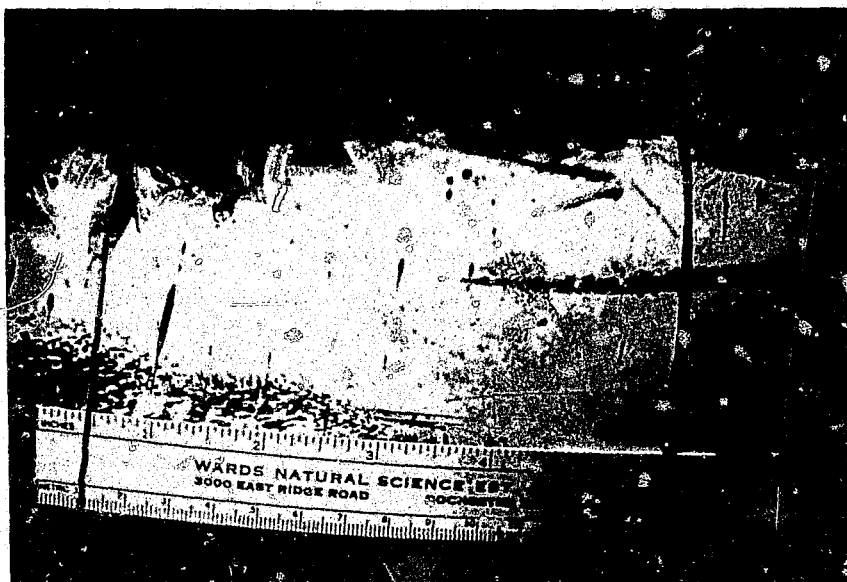


FIGURE 66.—Close-up view of the lower right portion of Figure 65 showing very small bloodspatters on the bumper.

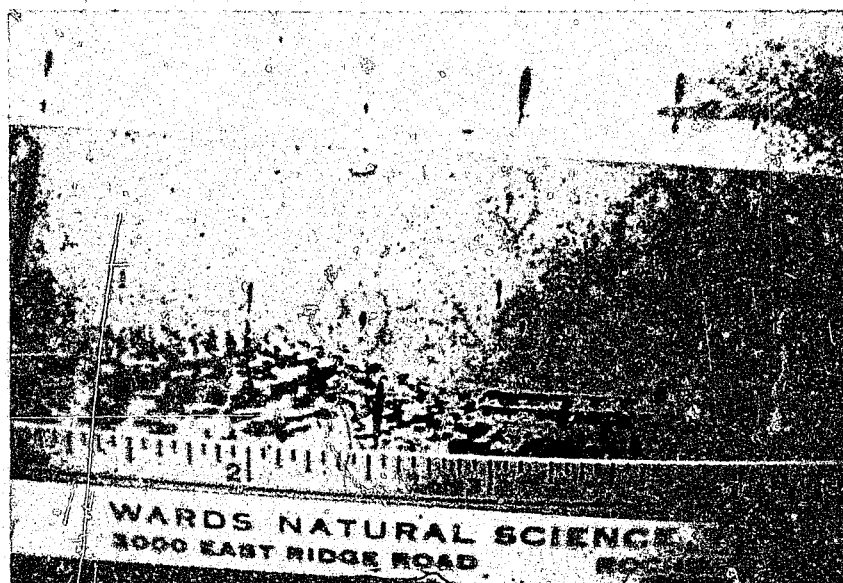


FIGURE 67.—Composite of high velocity bloodspatters produced by gunshot in the laboratory overlaid onto the evidence bloodspatters on the bumper. Laboratory, or known bloodstains, are circled for identification.



FIGURE 68.—Murder victim found lying flat on her back. The blood-stain over the left ear proves the victim must have been upright at the time this blood was shed, and further, that the body must have been moved after it had clotted.