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SUMMARY REPORT  
OF THE  
BLOODSTAIN PATTERN ANALYSIS  
RESEARCH GROUP

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## INTRODUCTION

### BACKGROUND AND SCOPE

The Bloodstain Pattern Analysis Research Group was formed in the spring of 1981 and was composed of six Crime Scene Analysts of the Florida Department of Law Enforcement. Each of the participants involved were in the final stages of a year long training program designed to create a mobile response Crime Scene Section within each of the State's five regional crime laboratories. The group's formation resulted from a need to explore subject matter related to crime scene analysis, particularly with respect to event reconstruction.

The primary objectives of the research effort were directed toward two aspects of bloodstain evidence which, heretofore, have not received the full attention of the forensic science community. These are bloodstain pattern analysis and drying rate. Crime scene investigations involving injury and death possess a high probability of containing evidence of this nature.

For years, bloodstain chemical analysis (serology) has been a mainstay of the forensic sciences. The chemically oriented background of the serologist is well suited to the nature of the analytical results produced. This same orientation, however, is not necessarily essential for bloodstain pattern analysis and drying rates. All of the physical sciences, including chemistry, provide the pattern analyst with a broad awareness of cause and effect relationships together with the need to exercise scientific caution in drawing inferences. It is the process of event inference, therefore, which differentiates pattern analysis from chemical analysis of bloodstains.

### PREVIOUS RESEARCH

In the past few authors have devoted more than a cursory statement) concerning the value of bloodstain pattern evidence. There are two notable exceptions to this, however, and each has contributed significantly to the state of the art. ←

The pioneering work of Herbert L. MacDonell, Flight Characteristics and Stain Patterns of Human Blood, published in 1971 under a grant from the Law Enforcement Assistance Administration, has remained the primary reference source of data on bloodstain pattern interpretation. By subjecting observations of the characteristics of bloodstains to very scrupulous study he has made the topic one worthy of examination, although the field is not without its critics. While the authors have detected some discrepancies in MacDonell's results, and have some doubt as to the validity of the extent to which he draws inferences, they

have, nonetheless, been able to verify much of what he accomplished.

The other noteworthy contributor to the field was the late Paul L. Kirk. His posthumously published Crime Investigation, Second Edition (1974) discusses in a concise, logical way the factors which deserve consideration when analyzing a bloodshed related crime scene. Tempered by an understanding of the laws of nature, Kirk posits that "...no other type of investigation of blood will yield so much useful information as an analysis of the blood distribution pattern" (p. 167). His assessment of the parameters within which such evidence can be related to the events of an incident may be as valid now as when first written.

#### RESEARCH APPROACH

The authors are indebted to both of these men for their contributions. The data and discussions which are presented in the following pages are the result of experiments performed along lines similar to those of MacDonell and in light of Kirk's perspectives. The research effort was not designed to retrace previous experiments exactly, nor was any attempt made to exhaust all avenues of inquiry. Rather, the topics examined were selected for their merit in contributing to the potential value of crime scene analysis.

Throughout this study an attempt was made to examine factors at their simplest level. Complex issues which involved several variables were, whenever possible, reduced to component parts. In some cases it was found that examination of individual variables proved insignificant in light of overriding, uncontrollable factors, e.g. using the diameter of a blood spot to determine the height from which it fell. In other cases test results gave rise to questions which would necessitate that more time consuming and variable controlled experiments be done in the future, e.g. the effect of factors other than impact velocity on spot size. As will be seen, topics examined began with consideration of individual drops of blood and progressed to consideration of patterns involving multiple deposits of blood.

In spite of the limited extent of the experiments conducted, primarily the result of a time availability factor, much useful information was developed. Perhaps the single most important development was the confirmation of MacDonell's admonition that actual experience is necessary to properly understand bloodstain patterns. In-depth analyses of stains produced under laboratory controlled conditions and the preservation of the results as a reference source are essential phases of this type of study. The authors have found that personal experience is imperative for discernment of the sometimes subtle differences in patterns which result from different actions.

## SECTION I - LIQUID BLOOD-DROP VOLUME

### OVERVIEW

The crime scene analyst often encounters stains resulting from bloodshed. The interpretation of dried stains is primarily based upon the observation of physical properties of the stain such as shape, size, and location. To accurately interpret these characteristics, however, requires some understanding of the physical properties of the substance producing them, liquid blood.

This first series of experiments explores the basic unit of stain formation, the single drop of liquid blood. Actual blood stains may be observed and recorded by their linear dimensions. The size of a spot, for example, can be measured for its diameter, or length and width if non-circular. Descriptive measurements of the drop of blood which produced the spot, however, are made by reference to the drop's volume. Laboratory controlled experiments designed to simulate actual stain formation are based on the major assumption that blood, as a fluid, behaves in a highly consistent manner. It is, therefore, necessary to understand just how consistent the size of a normal drop of blood is.

Bleeding generally produces a mass of blood which is fresh and at a temperature of approximately 37° C. Single drops of blood resulting from this mass may form under a variety of conditions depending on what contact the blood has with physical objects prior to drop formation, e.g. skin, clothing, hair, etc. Bleeding can also be a slow or fast action depending on the severity and location of the injury.

The analyst generally does not have access to information related to these variables when examining a crime scene. Nonetheless, it is important to understand how such variables impact on drop formation. This Section was designed to explore the reproducibility of a "normal" drop of blood, i.e. a drop forming freely due to gravity.

The use of freshly drawn whole human blood would be the most ideal medium with which to perform experiments since this is what is shed at a crime scene. The practical realities of blood's clotting tendency and the need for a constant source of donors, however, preclude the use of this medium. Since experimentation is a time consuming process the medium selected must be stable when not in use. Additionally, the medium must be available in quantities sufficient to permit repeated testing. For these reasons, whole human blood preserved with CPDA-1, Citrate Phosphate Dextrose Adenine solution, Type 1, and obtained from commercial or hospital blood banks, was used in all experiments except the first.

Experiment 1 explores what effect the use of a preservative has on the

volume of a drop of blood. Experiment 2 explores what effect the temperature of the blood, at the time of drop formation, has on the volume of the drop. Experiment 3 explores what effect various surfaces and delivery methods have on drop volume. Finally, Experiment 4 explores what effect the speed of bleeding has on drop volume.

## EXPERIMENT 1 - EFFECT OF PRESERVATIVE ON DROP VOLUME

### OBJECTIVE

The purpose of this experiment was to determine if the volume of a drop of blood is significantly affected by the presence of a preservative.

### METHODOLOGY

Throughout this experiment freshly drawn blood was used. Ten volunteers each donated ten milliliters of blood. The preservative CPDA-1 was added to one-half of the sample and no preservative was added to the balance.

Drop volume was determined by a simple volumetric technique which consisted of dividing a known volume of blood by the number of drops issued by that volume. Volume determinations of the fresh whole blood were performed within three minutes of the time of drawing. Those of the preserved blood were performed within ten minutes.

Additional data was gathered throughout these tests to calculate the weight per drop. Both volume and weight were used to monitor any change in blood density which might result.

### RESULTS

TEST #	DROP VOLUME (milliliters)		DROP WEIGHT (grams)		DROP DENSITY (gm./ml.)	
	FRESH	CPDA-1	FRESH	CPDA-1	FRESH	CPDA-1
1	.045	.043	.046	.045	1.02	1.05
2	.045	.044	.047	.046	1.04	1.05
3	.044	.039	.044	.040	1.00	1.02
4	.042	.037	.042	.038	1.00	1.03
5	.044	.037	.043	.038	.98	1.03
6	.046	.038	.046	.039	1.00	1.03
7	.045	.041	.045	.041	1.00	1.00
8	.048	.040	.047	.041	.98	1.03
9	.045	.041	.045	.040	1.00	.98
10	.045	.043	.043	.040	.96	.93
MEAN	.045	.040	.045	.041	1.00	1.03



## DISCUSSION

This experiment demonstrated that the addition of a preservative to fresh whole blood significantly affects the volume and weight of individual drops by about ten percent. This finding is important since all other experiments in this report were performed using whole human blood preserved with CPDA-1. The results indicate that the analyst performing laboratory controlled experiments must take this factor into consideration when using volume as a variable in any calculation. The slight change in blood density was not found to be statistically significant.

During some of the tests individual drops of blood were collected on 3" x 5" index cards. The drops were allowed to fall 12" in all cases. No observable differences were noted in stain shape or character between those of fresh blood and those of preserved blood. The size (diameter) of the blood spots, however, did vary slightly. Variations in diameter are examined more fully in Section II.

## EXPERIMENT 2 - EFFECT OF TEMPERATURE ON DROP VOLUME

### OBJECTIVE

The purpose of this experiment was to determine if the volume of a drop of blood is significantly affected by the temperature of the blood.

### METHODOLOGY

Drop volume was determined by a simple volumetric technique which consisted of dividing a known volume of blood by the number of drops issued by that volume. Blood was tested at three different temperatures of 4, 21, and 37 degrees centigrade. In each case the blood and delivery mechanism were brought to the same temperature prior to running the test. One delivery mechanism and blood source were used throughout this experiment.

### RESULTS

TEST #	<u>VOLUME PER DROP (milliliters)</u>		
	4°C.	22°C.	37°C.
1	.040	.038	.037
2	.040	.042	.040
3	.040	.040	.036
4	.043	.039	.038
5	.042	.040	.038
6	.042	.039	.036
7	.043	.040	.038
8	.043	.040	.040
9	.043	.040	.040
10	.043	.041	.039
MEAN	.042	.040	.038

### DISCUSSION

This experiment demonstrated that the temperature of the blood has a significant, and generally consistent, effect on the volume of individual drops of blood. That is, blood at body temperature produces drops which are slightly smaller in volume than those produced by colder blood. The results indicate that the analyst performing laboratory controlled experiments must take this factor into consideration.

Blood leaving the body does so at about thirty-seven degrees centigrade. However, if that blood is deposited on an object such as a skin surface or clothing prior to forming into individual drops its temperature quickly adjusts to that of its surroundings. Since the analyst will rarely have information sufficient to identify how the drop was formed, considerations of temperature will rarely need to be made.

During several of the runs individual drops of blood were again collected on 3" x 5" index cards. The drops were allowed to fall 12" in all cases. No observable differences were noted in stain shape or character between blood spots of refrigerated, room temperature, or body temperature blood.

The balance of the experiments performed utilized blood at room temperature whenever possible.

EXPERIMENT 3 - EFFECT OF DELIVERY METHOD ON DROP VOLUME

OBJECTIVE

The purpose of this experiment was to determine if the volume of a drop of blood is significantly affected by the method of delivery.

METHODOLOGY

Drop volume was determined by a simple volumetric technique which consisted of dividing a known volume of blood by the number of drops issued by that volume.

Twelve different mechanisms were employed in this experiment to dispense individual drops of blood. In each case, a blood-filled pipet was positioned such that its delivery end was in direct contact with a wall or side of the test mechanism at a point above the area of drop formation. When pipets were used alone, individual drops were issued directly from the pipet's delivery end.

Each mechanism was tested five times after establishing a steady-state of blood in or on the mechanism. The steady-state was achieved after excess blood was allowed to run off of or through the test mechanism to the point where it stopped dripping. When the wet fingertip and palm were tested the skin surface, at the point of drop formation, was covered with liquid blood prior to establishing the steady-state.

In all test runs drop formation proceeded one drop at a time with no perceptible rate of flow. Blood dispensed from the pipet was allowed to accumulate at the bottommost point of the mechanism until the effect of gravity caused individual drops to form and release.

RESULTS

MECHANISM TESTED	VOLUME/DROP (ml.)	MECHANISM TESTED	VOLUME/DROP (ml.)
Eye Dropper #1	.043	Medicine Dropper #1	.061
Eye Dropper #2	.044	Medicine Dropper #2	.063
Pipet #1	.051	Pipet #3	.063
Pipet #2	.052	Cotton Glove	.068
Palm of Hand Dry	.052	Fingertip Wet	.072
Fingertip Dry	.060	Palm of Hand Wet	.087

The values listed represent mean volumes. Individual experimental runs

*5mm - 50 mm drops (diameters)*

resulted in volumes as low as .042 ml. and as high as .094 ml. It was noted in performing the experiments that drop volume seemed to increase as the surface area of the mechanism increased at the point of delivery. This appeared particularly true for blood falling from the hand at either the fingertip or the palm. By wetting the entire skin surface area at the point of delivery immediately prior to the volumetric determination, larger drop volumes were obtained. This factor may be due to a relationship between the surface tension of the blood, the physical properties of the releasing surface, and the size of the surface area available for cohesion.

Another fact observed during the experiments was that when individual drop volumes approached .07 ml. there was a tendency toward satellite drop formation, for lack of a better term. This is a condition wherein a very small drop is formed from the connection between the primary drop and the surface from which it is pulling free. A momentary elongation of liquid blood occurs as the effect of gravity finally overcomes the cohesion between the surface and the blood. As this elongated neck snaps some of the blood is drawn back up to the surface, some joins the primary drop, and, as in these cases of large primary drop volumes, some forms a small drop between the two. Measurement of the satellite drop was not possible with the volumetric technique employed. The values for drop volumes listed near .07 ml. have not corrected for this factor.

#### DISCUSSION

This experiment demonstrated that the volume of a drop of blood is significantly affected by the method of delivery. The skin surfaces and cotton glove were employed in these experiments to simulate conditions which might be encountered at a crime scene. The experiments made it readily apparent that there is no universal value for the volume of a single drop of human blood. They also confirm what would seem to be common sense, that bleeding can take place under a variety of conditions. Blood deposited at a crime scene, even when limited to a consideration of single drops which fell to the floor, can be the result of dripping from skin surfaces, fabric surfaces, hair or fibrous surfaces, and even hard non-porous surfaces such as from a weapon.

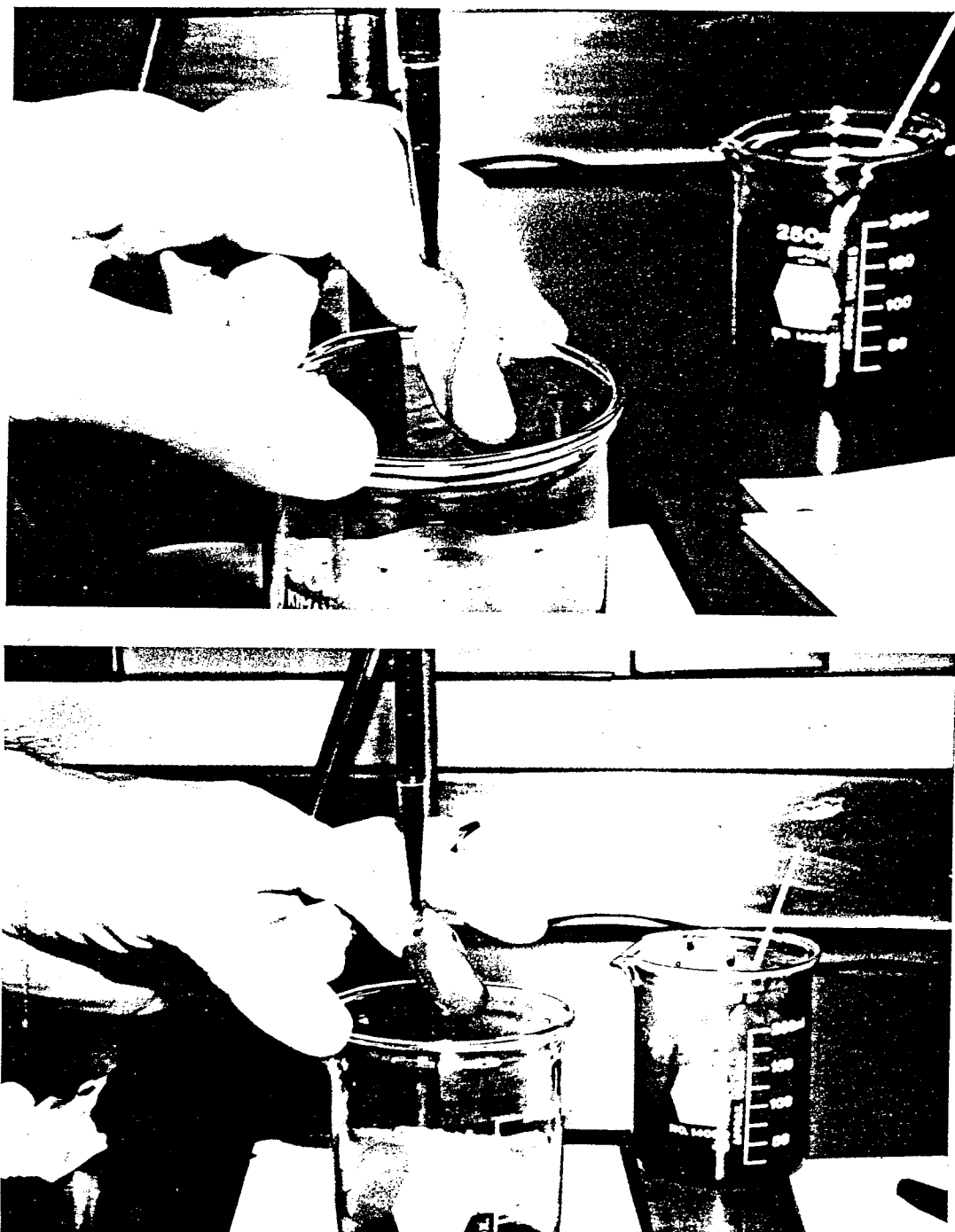


FIGURE 1 - Typical volumetric set up for determining volume per drop of dry fingertip (upper) and wet fingertip (lower).

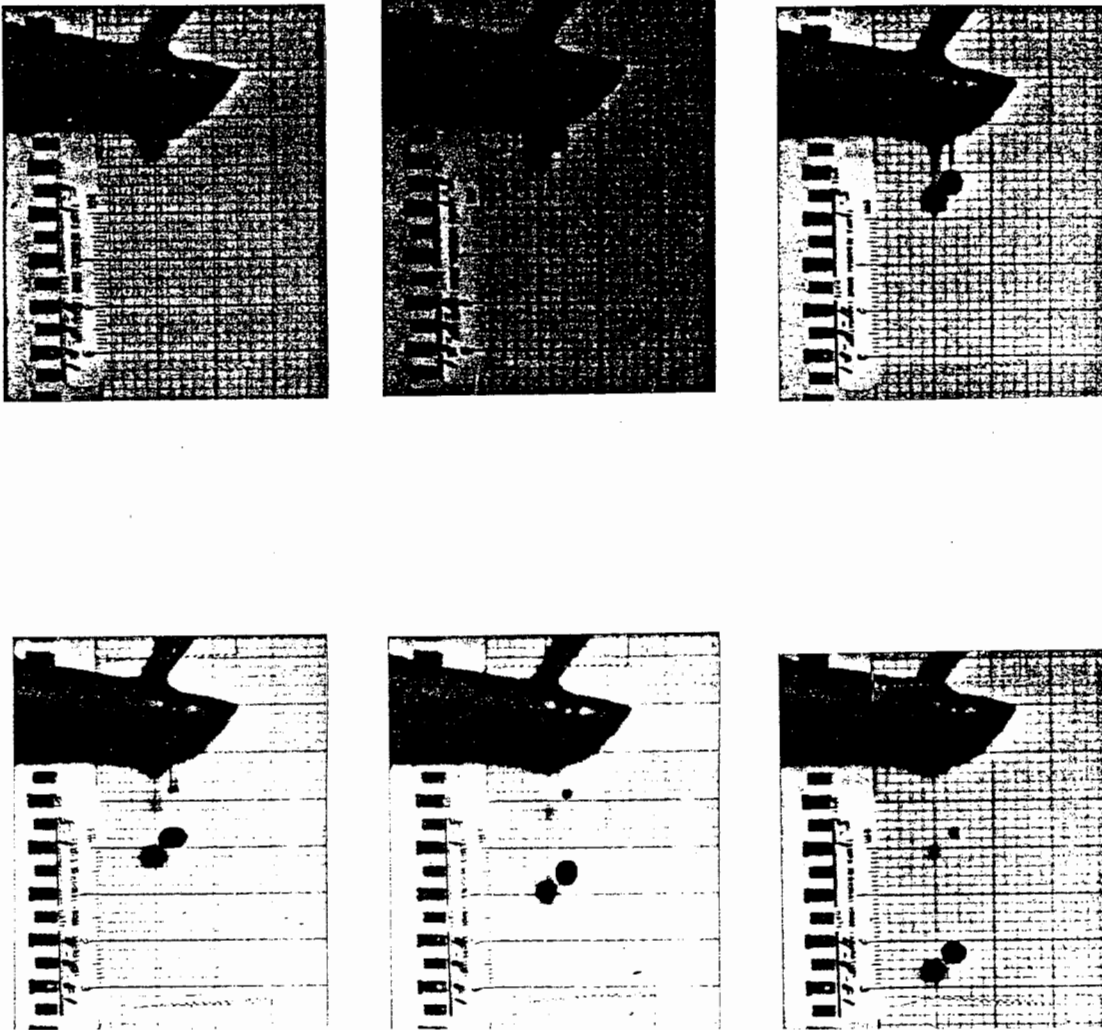


FIGURE 2 - Sattelite drop formation from a wet fingertip. Note the resonating shape of the drop as it falls.

## EXPERIMENT 4 - EFFECT OF FLOW RATE ON DROP VOLUME

### OBJECTIVE

The purpose of this experiment was to determine if the volume of a drop of blood is significantly affected by the rate of flow of the blood forming the drops.

### METHODOLOGY

Drop volume was determined by a simple volumetric technique which consisted of dividing a known volume of blood by the number of drops issued by that volume.

Flow rate was determined by using a stopwatch to time the number of seconds required for 50 drops to fall into a catch beaker. Random flow rates, held constant for each run of both tests, were used in a range from approximately 0.5 dps (drops per second) to 2.5 dps.

Test 1 utilized a 5 ml. pipet graduated in 0.1 ml. as the delivery mechanism. The volume per drop delivered by this pipet under no-flow conditions (one drop at a time and slower than 0.5 dps) was .051 ml. Test 2 utilized a different 5 ml. pipet graduated in 0.1 ml. The volume per drop delivered by this pipet under no-flow conditions was .066 ml.



## RESULTS

<u>TEST 1</u>			<u>TEST 2</u>		
RUN NUMBER	VOLUME/ DROP (ml.)	DROPS/ SECOND	RUN NUMBER	VOLUME/ DROP (ml.)	DROPS/ SECOND
1	.051	.65	1	.066	.48
2	.051	.69	2	.067	.66
3	.053	.72	3	.068	.66
4	.051	.75	4	.068	1.00
5	.052	.78	5	.068	1.02
6	.051	.80	6	.068	1.02
7	.051	.81	7	.070	1.04
8	.054	.93	8	.070	1.09
9	.053	.95	9	.070	1.16
10	.053	.97	10	.070	1.23
11	.053	.97	11	.072	1.47
12	.051	1.13	12	.072	1.47
13	.055	1.25	13	.074	1.52
14	.054	1.47	14	.074	2.00
15	.054	1.51	15	.074	2.08
16	.056	1.67	16	.074	2.13
17	.057	1.75	17	.076	2.13
18	.056	2.04	18	.075	2.16
19	.056	2.04			
20	.059	2.08			
21	.056	2.13			
22	.059	2.13			
23	.059	2.13			
24	.059	2.17			
25	.057	2.27			
26	.060	2.33			
27	.058	2.56			

## DISCUSSION

This experiment demonstrated that the volume of a drop of blood is significantly affected by the flow rate of the blood. In both tests the volume per drop increased by as much as fifteen percent with an increase in flow rate. It is reasonable to assume that drops which issue from a serious wound and profuse bleeding can be larger than those from a less serious wound.

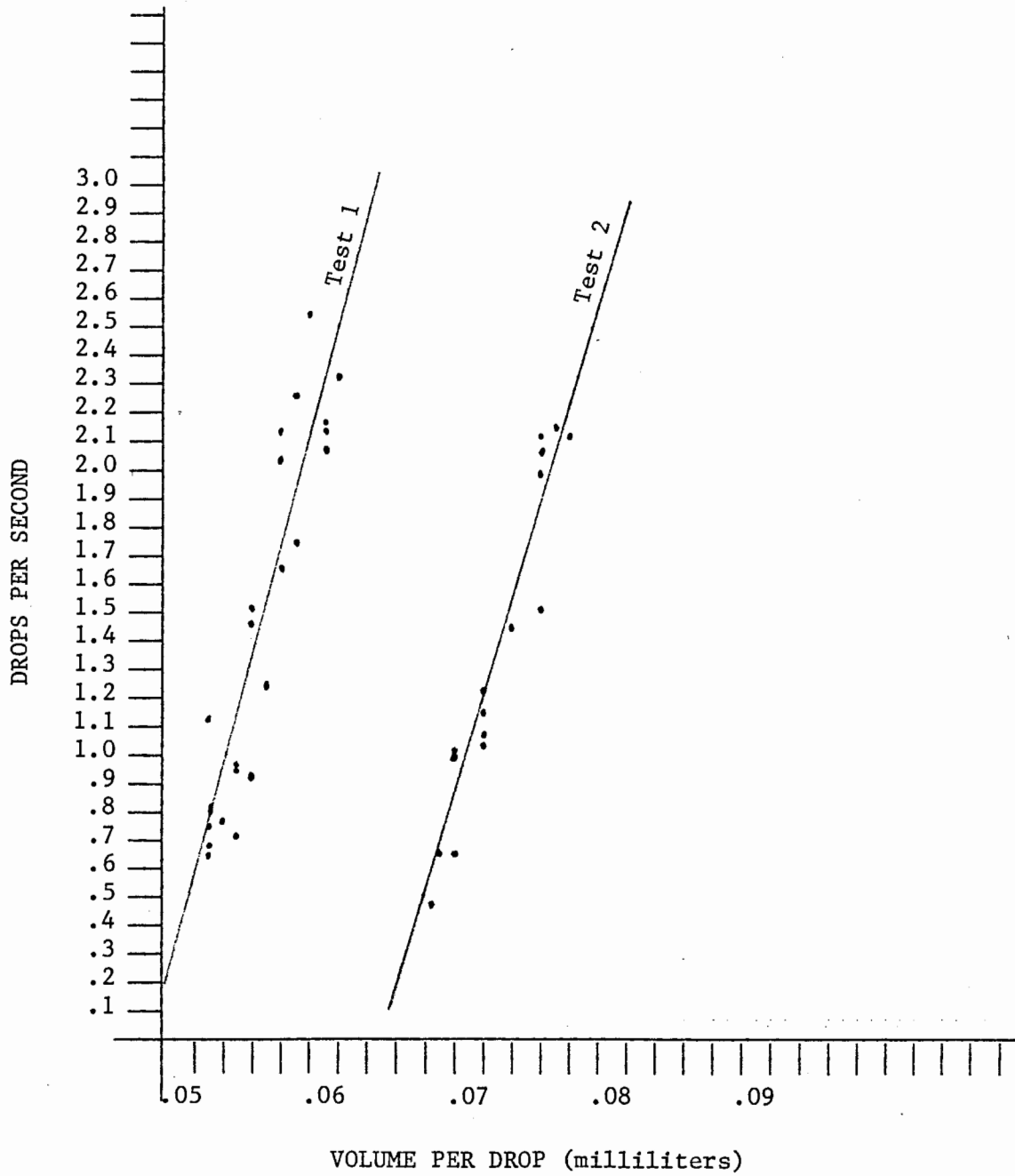


FIGURE 3 - Drop volume as a function of flow rate.

## SECTION I - LIQUID BLOOD-DROP VOLUME

### SUMMARY

This section explored some of the operant mechanisms in blood drop formation using gravity as the major influence. This was done to simulate ways in which blood drops might form during actual bleeding or dripping from a bloodied object.

The wide range of variation demonstrated by these experiments indicates that a "normal" drop of blood is only a relative term. The effect of gravity and the nature of liquids to behave in certain ways (fluidics) operate to produce drops of blood which can range from approximately .040 to .090 ml. This range represents freely forming drops not subjected to forceful stress. The laws of fluidics indicate that stress other than gravitational force will produce even smaller drops but the dynamics of this phenomenon are beyond the scope of these experiments. It is important to note, however, that once a "normal" sized drop of blood is formed it will not break up into smaller drops unless acted upon by some force.

A mass of blood dropping through air will always seek to assume the most energy conserving geometric shape, a sphere. There is, however, some upper size limit at which a mass of blood, even when spherical, must subdivide into smaller, normal sized drops when subjected to the stress of wind resistance during flight. The results of this series of experiments indicate that drops forming from typical bleeding or dripping do not achieve the upper size limit. No subdivision of individual drops, once formed and in freefall, was observed. This factor was also reported on by MacDonnell (1971, p.4).

Additional experimentation would be needed to better define the maximum volume that individual drops of blood can achieve without subdividing. Such information, however, may prove to be inconsequential in that it would probably not contribute significantly to the present understanding of the nature of liquid blood behavior.

Any examination of flight characteristics of blood must be based upon precise calculations of the properties of blood drops. This would include considerations of mass, volume, force, and velocity. These properties are all highly interrelated and, for the most part, defy precise measurement. The wide variability of blood drop volume alone, as demonstrated by this series of experiments, indicates that the analyst must allow for a wide latitude in flight characteristic considerations. A prime example of this can be seen when one attempts to determine the distance a drop of blood has flown horizontally and its exact flight path.

## SECTION II - DRIED BLOOD-SIZE OF SPOT

### OVERVIEW

At a crime scene individual spots may be the result of blood dripping from a variety of surfaces under a variety of conditions. They may also result from actions other than dripping. It is important that the analyst be able to distinguish between stains resulting from forceful and non-forceful actions. The first step in this process is to identify characteristics of blood spots which are indicative of non-forceful dripping.

The major characteristic by which individual blood spots are evaluated is size. Circular spots can be measured as to their diameter. Oval or elongated spots can be measured by their length and width. This series of experiments was designed to explore the range of variation one can expect when observing circular spots which result from single drops of blood.

Section I demonstrated that blood drop volume is affected by both the surface from which it falls and the rate at which it flows. Variation in drop volume may result in a corresponding variation in spot sizes. A need exists, therefore, to determine the normal range of spot sizes which result from freefalling drops.

Experiment 5 examines the consistency of spot size as a function of the surface from which the blood drops (variable drop volume). Experiment 6 examines the consistency of spot size as a function of the rate at which the blood is flowing (variable drop volume). Experiment 7 examines the consistency of spot size as a function of the distance the drop of blood falls (fixed drop volume).

## EXPERIMENT 5 - EFFECT OF DELIVERY METHOD ON SPOT DIAMETER

### OBJECTIVE

The purpose of this experiment was to determine if the diameter of a dried blood spot is significantly related to the volume of the drop which produced it.

### METHODOLOGY

The procedure for determining the volume per drop used in Section I was used for each mechanism tested in this experiment. During each volume per drop determination so made, five consecutive drops were collected for measurement.

The blood spot collection procedure consisted of mounting a standard 3" x 5" white index card on a flat surface 12" below the mechanism being tested. The spots which resulted were allowed to air dry before being measured.

Twelve mechanisms were employed in this experiment, most of which were the same as those used in Experiment 3.

### RESULTS

DELIVERY MECHANISM	VOLUME/ DROP (ml.)	SPOT DIAMETER (mm.)		
		LOW	MEAN	HIGH
Eye Dropper #1	.043	13.40	13.52	13.70
Fingertip Dry	.043	13.97	14.31	14.55
Eye Dropper #2	.044	14.10	14.20	14.50
Pipet #1	.047	15.47	15.83	16.28
Palm of Hand Dry	.055	13.97	14.20	14.30
Medicine Dropper	.058	16.18	16.28	16.51
Pipet #2	.060	16.64	16.97	17.40
Pipet #3	.063	16.87	17.02	17.20
Pipet #4	.065	16.74	17.04	17.15
Cotton Glove	.068	16.36	16.66	16.84
Fingertip Wet	.075	17.37	17.55	17.65
Palm of Hand Wet	.083	17.70	18.26	18.59

Sattelite drop formation was again noted as drop volumes increased in size. Since the target was perpendicular to the fall of the drop, the sattelite drop landed on top of the primary drop.

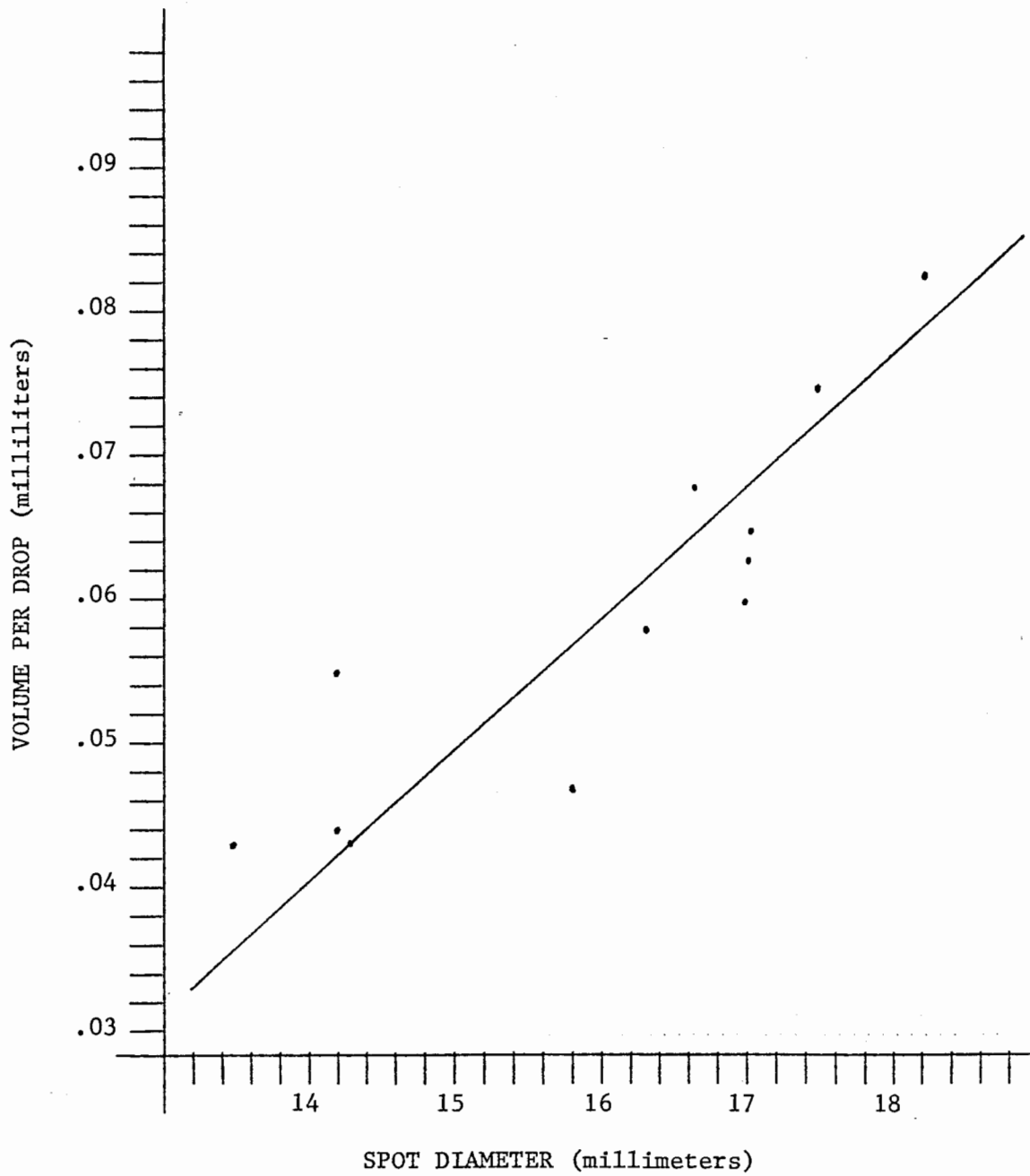


FIGURE 4 - Bloodspot diameter as a function of drop volume

## DISCUSSION

This experiment demonstrated that the diameter of a blood spot is significantly related to the volume of the drop producing the spot when all other factors are held constant. A range of drop volumes from .043 to .083 ml. produced a range of spot diameters from 13.5 to 18.3 mm. This may be considered as a normal range for drops falling 12" to a flat surface.

Variation of spot diameter within each run was limited to a measureable difference of less than three percent. Examination of the photographs of blood dripping from the finger (page 12) offers a possible explanation for this variation. The falling drop of blood appears to undergo a constant shape fluctuation. At times the drop tends to flatten slightly in the horizontal plane. At other times the drop tends to flatten in the vertical plane. This resonating shape change appears to occur during the entire time the drop is falling. The slight variation in individual spot diameters may be partly dependent upon how the drop was resonating at the time of impact.

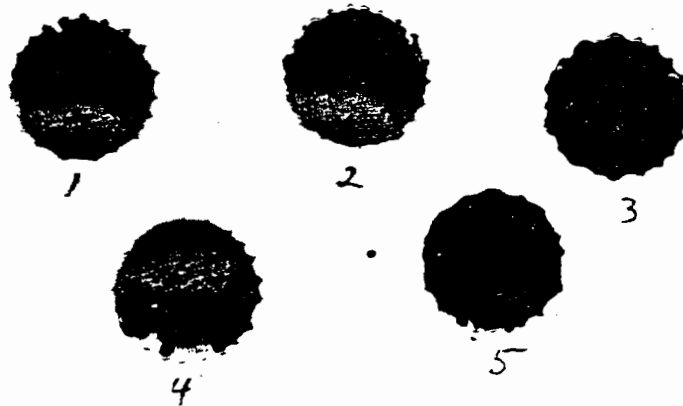
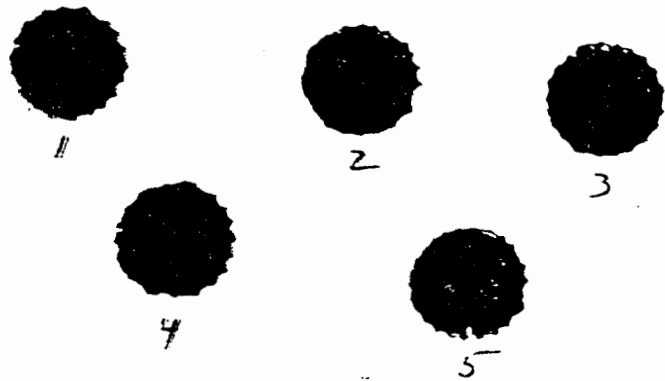


FIGURE 5 - Bloodstains created by single drops of blood falling 12" to smooth cardboard. Upper set is from a dry fingertip (.043 ml./drop). Lower set is from a wet fingertip (.075 ml./drop).



EXPERIMENT 6 - EFFECT OF FLOW RATE ON SPOT DIAMETER

OBJECTIVE

The purpose of this experiment was to determine if the diameter of a dried blood spot is significantly related to the flow rate of the blood.

METHODOLOGY

The drop delivery mechanism employed consisted of a 5 ml. pipet with its delivery end affixed 12" above a flat surface. The pipet was equipped with a standard ball type pipet filler which permitted hand controlled rates of drop flow. A stopwatch was used to time the number of seconds required for 50 drops to fall into a catch beaker.

One no-flow volumetric test run was made which found the normal drop volume to be .050 ml. Eight random flow rates, held constant for each run, were used in a range from 1.35 dps to 2.34 dps.

The collection of representative blood spots was made on standard 3"x5" white index cards. As each run was in progress, ten individual spots were collected. All blood spots were allowed to air dry prior to measurement.

RESULTS

RUN NUMBER	VOLUME/ DROP (ml.)	DROPS/ SECOND	SPOT DIAMETER (mm.)		
			LOW	MEAN	HIGH
1	.052	1.35	15.7	16.1	16.5
2	.052	1.43	15.8	16.1	16.5
3	.054	1.70	15.5	16.5	17.1
4	.053	1.82	16.4	16.8	17.3
5	.054	1.85	15.9	16.5	16.9
6	.055	1.92	16.3	16.7	17.3
7	.055	1.99	16.3	16.6	17.0
8	.057	2.34	16.5	16.8	17.1
NO- FLOW	.050	N/A	15.3	16.0	16.5

Some satellite drop formation was observable at the highest flow rate. Other flow rates were attempted in excess of 2.5 dps but the presence of the satellite drops made visual counting impractical as it was difficult to distinguish separate drops.

## DISCUSSION

This experiment demonstrated that the diameter of a blood spot is significantly related to the flow rate of the blood when all other factors are held constant. Experiment 4 demonstrated the relationship of flow rate to drop volume while Experiment 5 demonstrated the relationship of drop volume to spot diameter. Thus it is not surprising that the results of this experiment reconfirm the inference that flow rate affects spot diameter.

The degree to which spot diameter is affected by flow rate, however, appears to be insignificant in light of the diameter variation shown by Experiment 5. Changes in drop volume due to differences in delivery mechanism are far greater in degree than those due to differences in flow rate. Consequently, changes in spot diameter are more dependent upon the delivery mechanism than upon the flow rate.

## EXPERIMENT 7 - EFFECT OF DISTANCE ON SPOT DIAMETER

### OBJECTIVE

The purpose of this experiment was to determine if the diameter of a blood spot is significantly related to the height from which the blood drop fell.

### METHODOLOGY

Two delivery mechanisms were used in this experiment to dispense individual drops of blood

- 1) Glass eye dropper-standard .044 ml./drop, and
- 2) 12 cc. plastic syringe-standard .060 ml./drop.

For both mechanisms the collection procedure consisted of allowing individual drops of blood to fall vertically to standard 3" x 5" white index cards mounted on a flat surface. The delivery mechanisms were affixed at various heights ranging from 3" to 96". Several spots were collected at each height and allowed to air dry before being measured.

### RESULTS

HEIGHT OF FALL (inches)	SPOT DIAMETER (millimeters)	
	.044 ml./drop	.060 ml./drop
3	10.0	11.4
6	12.0	12.8
9	12.7	14.7
12	14.6	14.9
18	15.4	16.9
24	16.4	17.7
36	16.6	18.7
48	17.6	19.2
72	17.9	19.9
96	19.0	22.2

### DISCUSSION

This experiment demonstrated that the diameter of a blood spot was significantly related to the height from which the drop of blood fell, when all other factors are held constant.

Spot diameter, for any given drop volume, increases as the distance of

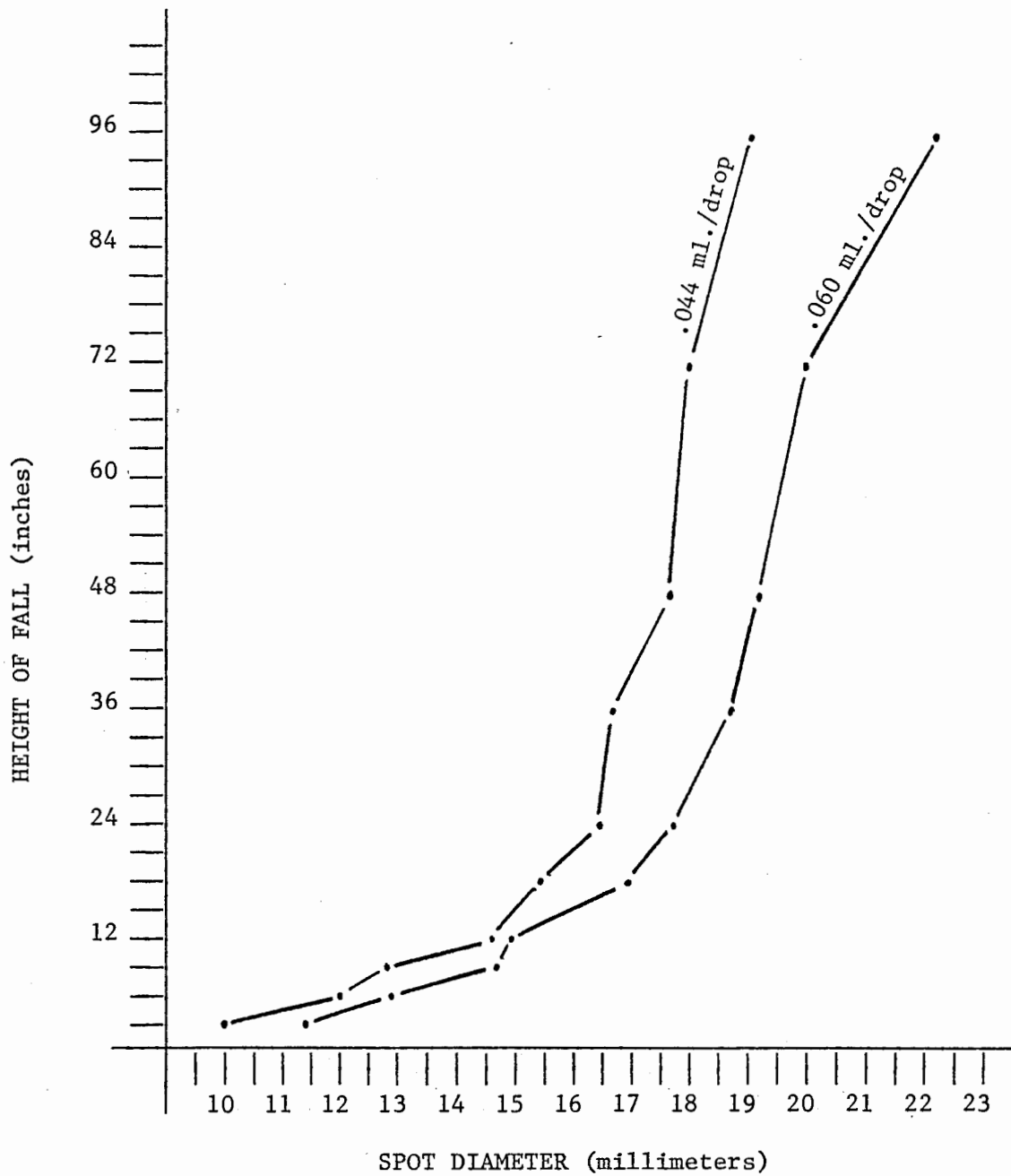


FIGURE 6 - Bloodspot diameter as a function of distance fallen.

fall increases. The graph of the data (page25) illustrates the general functional relationship between height of fall and spot diameter. It can be seen from the graph that increases in spot diameter become less pronounced as the height of fall exceeds 36". As a general statement, it can be said that the range of spot diameters one can expect from normal drop volumes will extend from 10 to 20 mm.

Since few crime scenes will involve blood which has fallen more than about six feet, this range will probably cover even the larger sized, freefalling blood drops. Diameters of less than 10 mm. are generally indicative of the fact that the drop which created the spot did not result from normal dripping. Rather, it indicates that some force was applied which produced a smaller than normal drop. Some of the actions which produce these smaller drops are examined more fully in subsequent experiments.

In addition to diameter, spots which result from freefalling drops can be observed for their edge characteristics. Drops falling only a short distance had a slight degree of spine formation or scalloping radiating outward from the edge. Drops which fell a greater distance had a greater degree of spining often resulting in a sunburst type of appearance. This edge characteristic is partly indicative of the fact that drops falling a greater distance impact at a greater velocity as a result of acceleration due to gravity.

\* For more information on velocity of freefalling blood drops see Mac Donell, 1971, p. 3-4.

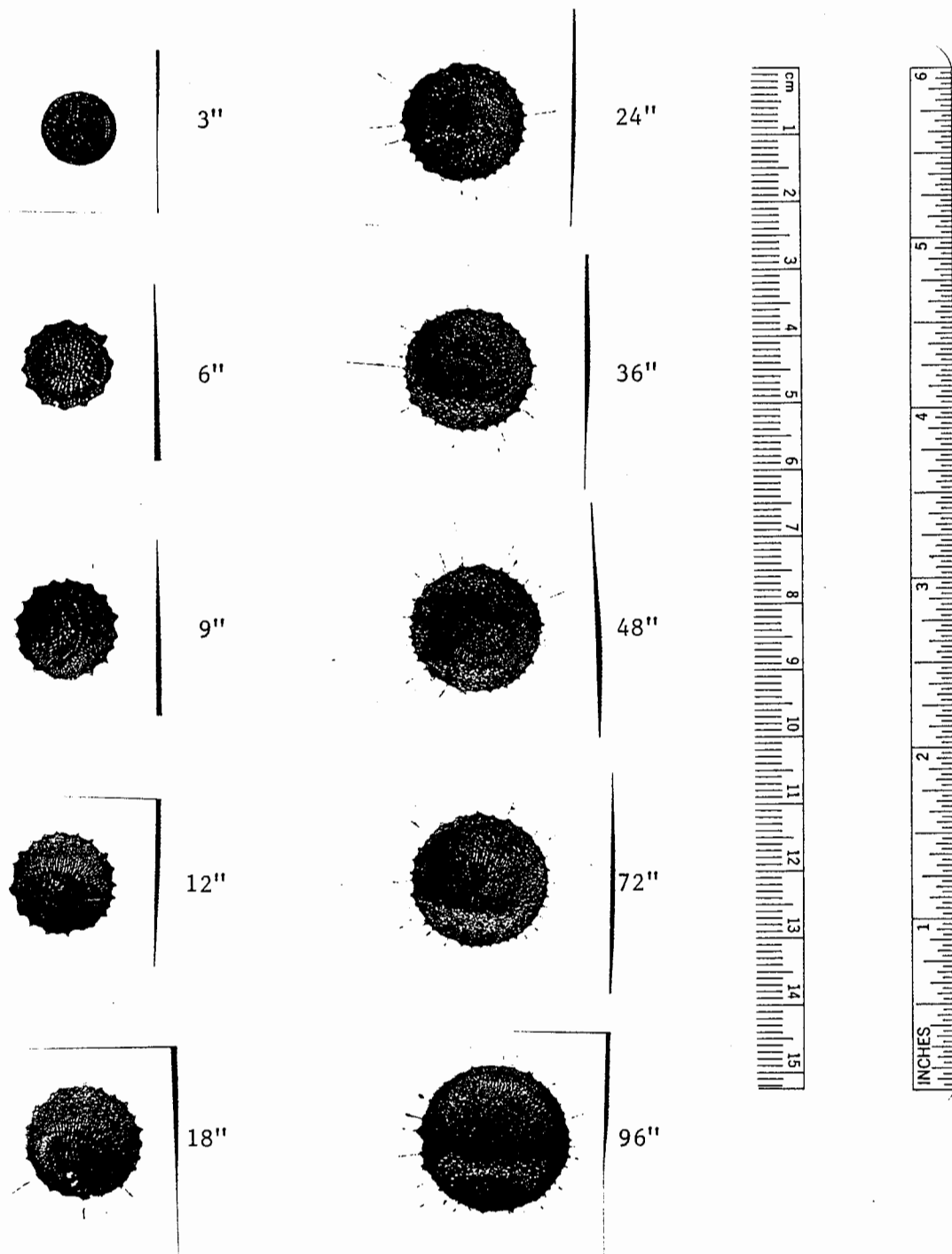


FIGURE 7 - Bloodstains created by single drops of blood falling various distances to smooth cardboard (.060 ml./drop).

## SECTION II - DRIED BLOOD-SIZE OF SPOT

### SUMMARY

Blood stains which result from individual drops of blood falling perpendicular to a target have two characteristics which can be used to categorize the spot. These are the diameter of the spot and the character of the spot edge.

Experiments 5 and 6 demonstrated that the volume of the drop is partly responsible for the diameter of the spot. Experiment 7 demonstrated that the distance the drop has fallen is also partly responsible. It is important to note, however, that it is not possible to determine the distance a drop has fallen by reference to the spot diameter unless the exact volume of the drop is already known. Likewise, it is not possible to determine the volume of a drop of blood by reference to the spot diameter unless the exact height of fall is already known.

To illustrate this point observe that in Experiment 5 several drops were allowed to fall 12". The smallest diameter produced by this experiment was 13.52 mm. while the largest was 18.26 mm. If one attempts to determine the distance of fall by comparing these diameters to the data developed in Experiment 7 it can be seen that the distance of fall could be as short as 12" or as great as 72". When these same diameters are compared to the graph developed by MacDonell (1971, p. 33) the possible range is even more evident, 12" to 108".

Another factor which may influence the diameter of a spot is the surface texture of the target. Other experiments using different types of surfaces, for reasons unrelated to examination of spot diameter, indicated that a rougher surface tends to slightly increase the diameter of the spot. The degree of increase, however, appears to be insignificant in light of the wide variation present due to changes in volume or height of fall.

The second characteristic of a blood spot which can be used to categorize its type of fall is the nature of the edge. As indicated in the discussion of Experiment 7, some relationship appears to exist between the degree of spining and the velocity of the drop at impact. Once again the surface texture of the target appears to affect the degree of spining. Other experiments using different types of surfaces, for reasons unrelated to examination of edge characteristics, indicated that a rough surface such as wood produces considerably more edge spines than a smooth surface such as glass. Since this factor has already been examined in some detail by MacDonell (1971, p. 7-8) and since the present work appears to confirm his findings, surface texture experiments are not repeated here. Nonetheless, it is worthwhile to note that examination of bloodstain spining must always take into consideration the surface texture of the target.

### SECTION III - DRIED BLOOD-SHAPE OF SPOT

#### OVERVIEW

This series of experiments was designed to examine the geometric shape of single blood spots. Blood is a rather consistent type of liquid in that it behaves in a predictable fashion as most liquids do. Section II demonstrated that blood falling perpendicular to a flat surface consistently produces circular spots. Since not all stains found at a crime scene are the result of blood dropping vertically to a flat surface, a fuller examination of the stain's geometric shape is needed.

Event reconstruction at the crime scene often requires that movement of objects be considered. This may involve not only blood dripping from a moving, injured individual but also the dripping of blood which was deposited on an assailant or weapon. A third type of movement must also be considered and involves blood put to flight by impact. This last type of action is explored more fully in Section IV. In all cases the geometric orientation of the blood's flight path and the surface it strikes must be examined.

Experiment 8 explores the characteristics of blood stains which result when a drop of blood falls vertically but strikes a surface at an angle. Experiment 9 explores the characteristics of bloodstains which result when a drop of blood falls at an angle to a flat surface, i.e. when the drop has a horizontal velocity in addition to a vertical velocity.



## EXPERIMENT 8 - EFFECT OF IMPACT ANGLE ON SPOT SHAPE

### OBJECTIVE

The purpose of this experiment was to determine if the degree of circular distortion of a bloodstain (height to width ratio) is proportional to the angle of incidence of the drop producing the stain.

### METHODOLOGY

Individual drops of blood were allowed to fall from two set heights, 18 and 36 inches, onto targets which varied in angle from 10 to 90 degrees. Two target surfaces were employed, hard smooth cardboard and blotter paper. In each case the target was mounted on a piece of wood paneling to insure a solid backing. Several drops were collected at each setting.

Three mechanisms were used in this experiment to deliver individual drops by gravity:

- 1) Eye dropper-standard .045 ml./drop,
- 2) 5 ml. pipet-standard .063 ml./drop, and
- 3) Wet index finger-standard .087 ml./drop.

In the case of the index finger .087 ml. was the total volume per drop determined immediately prior to running the test. Each drop resulted in two spots, one quite large and one quite small. This was due to satellite drop formation as discussed in Experiment 3. The volume of the larger drop was arbitrarily defined as .087-x while the volume of the smaller was defined as 0.x ml.

The blood spots created by this experiment had an elliptical shape. Each spot was measured by its height and width. A ratio was determined by dividing the height by the width (MacDonell, 1971, p. 11). The ratios were averaged for each target surface at each angle. The satellite spots were treated in the same manner as the larger spots.

## RESULTS

<u>HARD SMOOTH CARDBOARD - HEIGHT TO WIDTH RATIO</u>						
ANGLE	EYE DROPPER		PIPET	WET FINGER		MEAN
	18"	36"		.087-x	0.x	
90	1.01	1.01	1.01	1.01	1.00	1.01
80	1.03	1.01	1.03	1.03	1.05	1.03
70	1.07	1.06	1.07	1.07	1.08	1.07
60	1.14	1.13	1.17	1.14	1.14	1.14
50	1.39	1.37	1.35	1.37	1.37	1.37
40	1.77	1.73	1.83	1.72	1.73	1.75
30	2.43	2.39	2.37	2.34	2.41	2.37
20	3.66	3.96	3.66	3.51	3.62	3.68
10	5.70	6.12	5.95	7.78	7.58	6.87
(Height of fall 36" except as noted for Eye Dropper)						
<u>BLOTTER PAPER</u>						
90		1.00	1.02	1.02	1.00	1.00
80		1.05	1.03	1.04	1.05	1.04
70		1.08	1.13	1.09	1.09	1.10
60		1.18	1.22	1.23	1.19	1.20
50		1.39	1.44	1.45	1.36	1.41
40		1.80	1.77	1.93	1.99	1.85
30		2.25	2.35	2.37	2.27	2.30
20		4.68	3.45	3.77	3.49	3.96
10		7.51	6.20	6.47	6.26	6.83
(Height of fall 36")						

## DISCUSSION

This experiment demonstrated that a significant relationship exists between the degree of circular distortion (height to width ratio) of a blood spot and the angle of incidence. The data developed indicates that an angle of incidence can be inferred based upon the bloodspot's height to width ratio. The precision of this method, however, decreases at the more acute angles.

The stains produced in this experiment exhibited edge characteristics which were significant with respect to directionality of movement. In almost every case the resultant stain possessed spines radiating outward

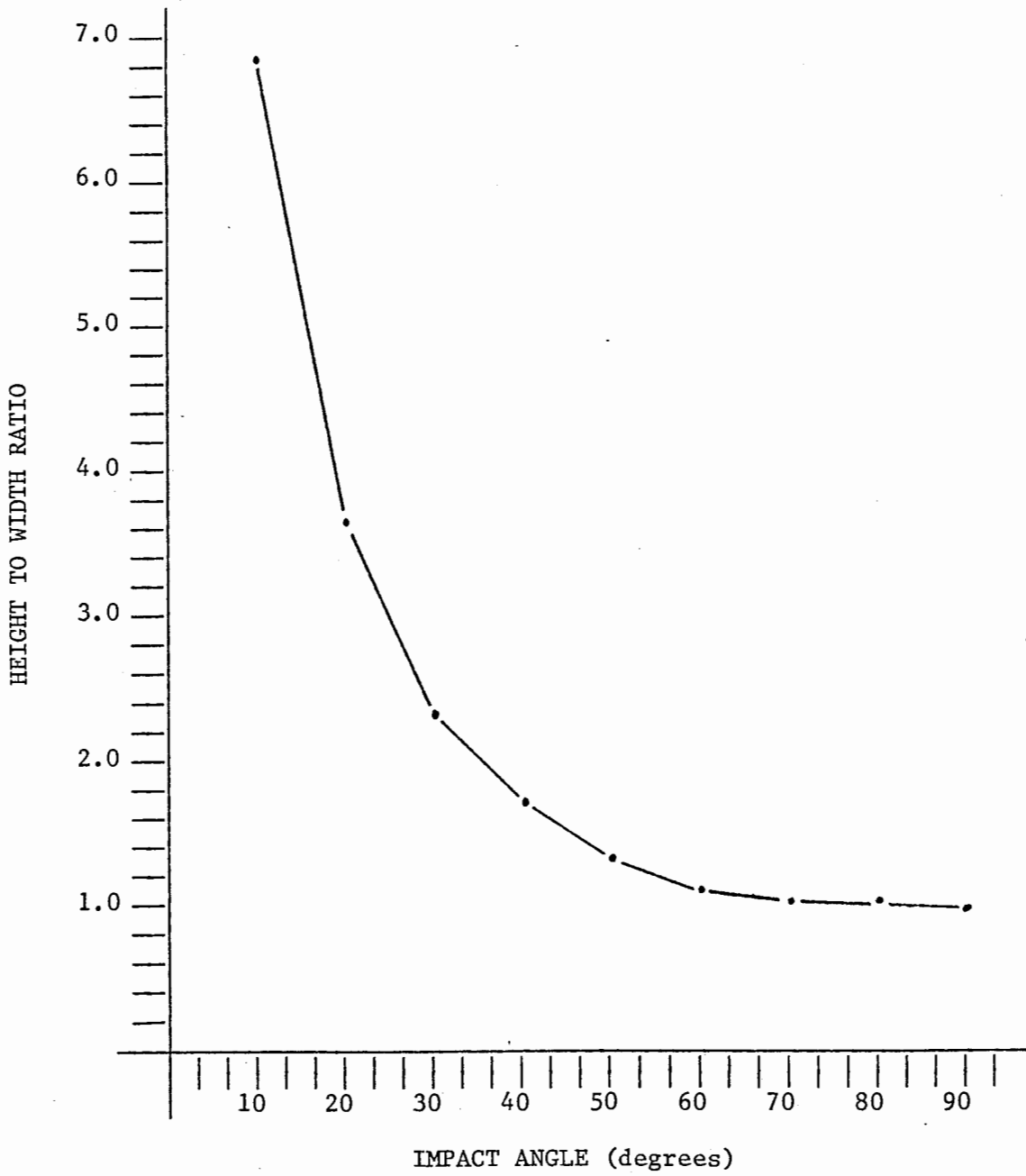


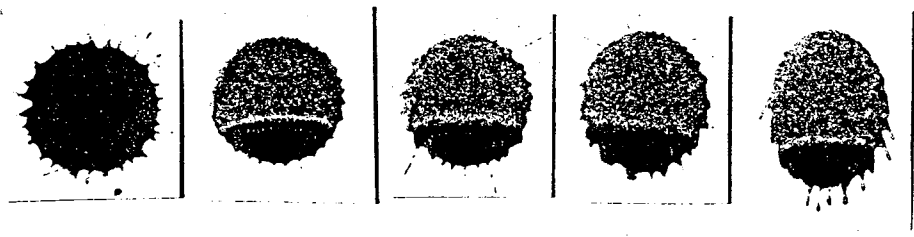
FIGURE 8 - Impact angle as a function of height to width ratio.

from the spot's leading edge. These spines appear predominantly on the edge which was formed last and generally point to the direction of travel. This is particularly evident at the more acute angles where a tail appears.

The spine-like character of the spot edges became more pronounced with drops which fell a longer distance. Drops such as these have a greater velocity at impact than drops which fall a shorter distance. The spines serve as an indication of the increased force present at impact.

The flight path of the drop can be retraced to its point of origin. This is done by taping one end of a piece of string to a questioned spot and aligning it on the determined angle of incidence with a protractor. The string must also be properly aligned with respect to the direction of travel indicated by the spot. This method of determining point of origin was highly reliable for drops which fell vertically to angular targets. This is because the flight path was actually a straight line.

Recent discussions with MacDonell (1981) indicate that a simpler and more accurate method of calculating an angle of incidence is currently being used. The method involves dividing the width of the spot by its height (inverse of the height to width ratio). The numerical value so determined theoretically equals the sine of the angle of incidence based on certain trigonometric considerations. While a complete study of this method is planned for the future, preliminary indications are that the width to height ratio is not exactly equal to the sine. A rather consistent overestimation of the actual angle of incidence occurs when the width to height ratio is treated as equal to the sine. The overestimation generally falls in the range of 5 to 10 degrees.



90                      80                      70                      60                      50



40                      30                      20                      10



FIGURE 9 - Bloodstains created by single drops of blood falling 36" to hard smooth cardboard at various degrees of impact angle (.045 ml./drop).

## EXPERIMENT 9 - EFFECT OF HORIZONTAL MOTION ON SPOT SHAPE

### OBJECTIVE

The purpose of this experiment was to determine what morphological characteristics of a blood spot can be attributed to the effect of horizontal motion.

### METHODOLOGY

Individual blood spots were created in this experiment for examination. All spots were created by releasing drops of blood while the delivery mechanism was moved parallel to a horizontal target. The delivery mechanism used was an eye dropper delivering a standard .045 ml./drop. The target surface used was white butcher block paper resting on a concrete floor.

Several runs were made while recording the horizontal velocity of the dropper and the height of fall. Individual spots which resulted were allowed to air dry before being measured for height to width ratios. These ratios were used to estimate the angle of incidence.

The horizontal velocity of the delivery mechanism was calculated by timing the operator as he traveled a ten foot distance. The speed of the walk was kept as constant as possible during each run.

### RESULTS

RUN NUMBER	VERTICAL DISTANCE (inches)	HORIZONTAL VELOCITY (ft./sec.)	MEAN HEIGHT TO WIDTH RATIO	ESTIMATED ANGLE OF INCIDENCE
1	4	3.0	1.32	50°
2	8	3.0	1.18	60°
3	12	3.1	1.16	60°
4	18	3.5	1.06	70°
5	24	3.0	1.07	70°
6	36	3.0	1.05	75°
7	4	2.8	1.31	50°
8	4	3.3	1.12	60°
9	4	5.0	2.16	35°
10	24	2.5	1.05	75°
11	24	3.3	1.07	70°
12	24	5.0	1.14	60°

## DISCUSSION

This experiment demonstrated that stains which result from drops of blood moving horizontally cannot always be distinguished from drops falling vertically onto an angular target. It should be noted that MacDonell (1971, p. 9-14) reports that this distinction can be made but only when the blood strikes a hard smooth surface. Although evidence of this was not detected in this experiment further experiments are planned utilizing such a surface.

The presence of spines and satellite spattering, in the direction of movement was again evident in the stains produced. The effect of increased velocity, resulting from either faster horizontal movement or increased distance of fall, was likewise demonstrated by the relative degree of spining and spattering.

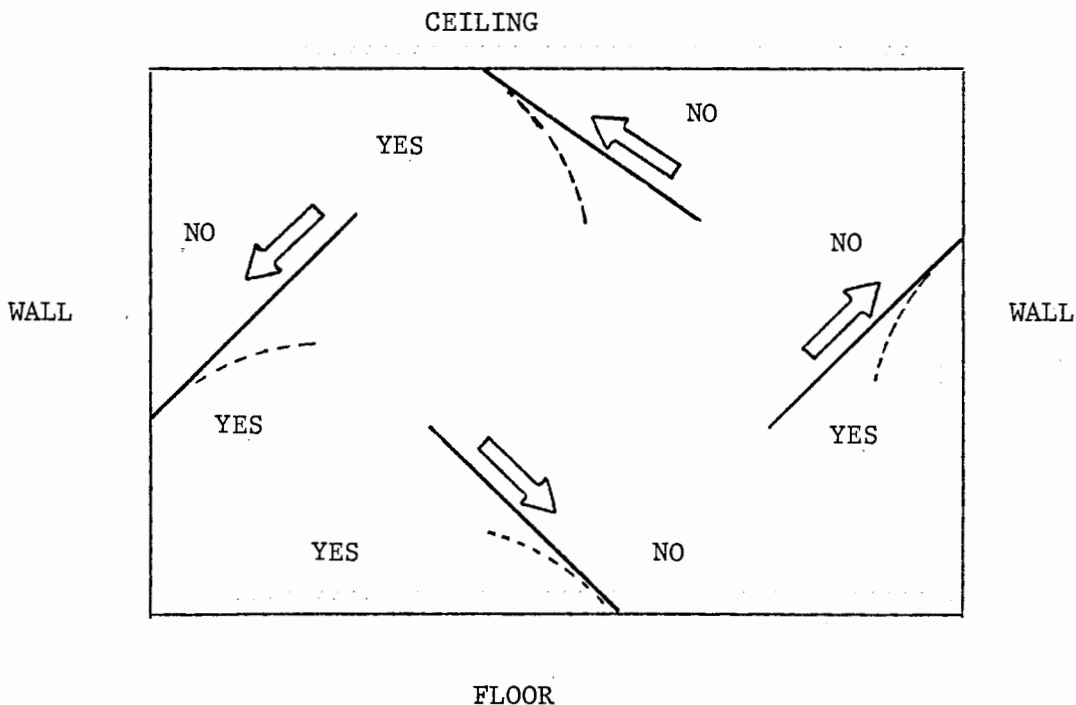
As would be expected, blood dripping from an object moving horizontally often results in a trail of blood spots. If the object was bleeding, e.g. lacerated hand, the trail would continue for as long as the object was bleeding. If the moving object was merely dripping excess blood, e.g. bloody hammer, the trail would continue only for as long as it takes the excess blood to drip off.

The angle at which blood drops strike a flat surface, when the blood is moving horizontally, is dependent upon its initial horizontal velocity, the distance fallen, and the effect of gravity. The effect of gravity on a drop moving horizontally results in a curved flight path. If the drop strikes a flat surface soon after release, i.e. a short vertical distance, the angle of incidence would be rather acute. Given the same horizontal velocity but greater vertical distance, the angle of incidence would be less acute (Runs 1-6). Likewise, an increase in horizontal velocity would result in a decrease in angle of incidence (Runs 7-12).

The string method of determining point of origin (Experiment 8) was again applied to several representative spots. While this method produced a straight line extending back toward the point of origin, it did not allow for the curved nature of the drop's flight path. The analyst must allow for this arc factor when using the string method.

While the calculation of such an arced flight path is beyond the scope of these experiments, it is possible to determine that the point of origin was at some point below the extended string. A little common sense reasoning on the nature of gravitational pull explains why this is so. Given sufficient distance, a droplet in horizontal flight will begin to fall downward. Its angle of incidence will be dependent on the spatial orientation of the surface struck and the flight path of the droplet.

The following diagram illustrates how spatial orientation affects one's considerations of possible points of origin. The arrows indicate the direction of travel of the blood drop prior to impacting at 45 degrees. All areas marked YES indicate that the point of origin could be from within that area. The areas marked NO represent impossible points of origin.



It is imperative that the directionality indicated by the questioned spot be properly interpreted. The direction of travel determines the orientation of the extended string. Practical experience is needed to fully appreciate the three dimensional nature of point of origin determination.





FIGURE 10 - Application of the string method to determine the point of origin of course and fine spatter.

### SECTION III -- DRIED BLOOD-SHAPE OF SPOT

#### SUMMARY

Stains which result from blood striking a target at an angle possess certain characteristics which can be useful in categorizing them. Section II illustrated the circular nature of spots which result from vertically dropping blood. This series of experiments demonstrated that blood drops striking a target at an angle result in stains which show a distortion of the circular shape. Experiment 8 demonstrated that the degree of circular distortion can be used to calculate the angle of incidence. Experiment 9 demonstrated that blood in motion produces stains similar to those of Experiment 8.

In both experiments the edge characteristics of the stains provided a good indication of directionality. While the basic part of the stain consisted of an oval or ellipse not all of the blood is used to form the shape. Fine satellite droplets are often created which radiate outward from the leading edge of the stain. More work is planned to investigate the possibility of using the orientation of these satellite spatters to distinguish between types of fall.

## SECTION IV - DRIED BLOOD SPOT DISPERSION

### OVERVIEW

Single independent blood spots are not the only type of stains normally found at bloodshed related crime scenes. More often the scene contains a variety of stains resulting from the dispersion of blood in quantities larger than that of single drops. These situations may involve masses of blood which form pools, smears, widely dispersed spatters, or a combination of these.

It is important at times for the analyst to be able to differentiate between dispersion stains resulting from impact and non-impact actions. Impact actions occur when an object strikes a static mass of blood thus putting blood droplets to flight. This type of dispersion will be examined in Section V. Non-impact actions involve masses of blood which are not necessarily static prior to flight. Three types of such non-impact actions are examined in this Section.

The purpose of these experiments is to determine what characteristics of the stain pattern can be used to identify the type of action involved. Experiment 10 examines stain patterns which result when masses of blood are permitted to fall freely to a flat surface. Experiment 11 examines how a mass of blood is dispersed due to movement of an object containing blood. This is commonly referred to as a cast off action and the pattern which results is called cast off staining. Experiment 12 examines the pattern produced by a mass of blood which is forcefully projected as a mass.

## EXPERIMENT 10 - SPLASHED BLOODSPOT DISPERSION

### OBJECTIVE

The purpose of this experiment was to study the degree and nature of staining which results when larger amounts of blood fall to a surface.

### METHODOLOGY

One milliliter of blood, the equivalent of about 20 drops, was placed in a separatory funnel. The funnel was mounted over a hard cardboard target at a height of 36". The valve on the funnel was opened to allow all of the blood to fall at once. The procedure was repeated at a height of 72" with a fresh target. The resultant stains were permitted to air dry.

### RESULTS

The stain patterns produced by this experiment demonstrated the following:

1. There was little break up of the falling mass of blood before impact. The central portion of the stain consisted of a nondescript pattern of slightly pooled blood. Very few spots from individual drops of blood were found around the central stain mass.
2. Some general outwardly radiating streaks of blood were present around the central stain mass. These streaks were more pronounced when the blood fell from a higher height.
3. Fine satellite spatters radiated outward from the central stained area and generally impacted at angles of ten degrees or greater.
4. The dispersion of satellite spatters, the area covered, increased as the height of fall increased. Few round spots were found in this satellite dispersion.

### DISCUSSION

This experiment demonstrated that freefalling volumes of blood, in excess of single drops, result in stain patterns which can be identified by the presence of certain characteristics. Usually these characteristics give some indication that no great force was exerted on the blood.

Individual drops of blood repeatedly falling in the same spot may produce similar characteristics particularly when they form a small pool of blood. However, there is generally less streaking present around the pool and more round satellite spots may be found close to the edge of

the central stain mass.

As one might expect, blood which falls a greater distance has a greater velocity at impact. This phenomenon is observable by examining the degree of dispersion of the satellite spots around the central stain. Additionally, as the height of fall increases the area covered by the satellite spots increases.

The observations made in this experiment reflect only general characteristics of large blood stains which result from blood falling freely. No attempt has been, nor should be, made to pinpoint the height of fall of such blood based on these characteristics alone. Future experiments performed under a variety of controlled conditions may provide more useful information regarding height of fall.

As with other types of stain patterns, it is entirely possible that splashed blood will be present at a crime scene. However, the stain characteristics may not be observable because continued bleeding has caused blood to flow over the satellite spattering.



FIGURE 11 - Bloodstain created by 1 ml. of blood dropping freely 36" to hard smooth cardboard (12 inch ruler).

## EXPERIMENT 11 - CAST OFF BLOODSPOT DISPERSION

### OBJECTIVE

The purpose of this experiment was to study the nature and characteristics of stains which result when blood is cast off or flung from bloody objects.

### METHODOLOGY

Several tests were performed which involved the projection of blood by manually swinging bloodied objects. Stain patterns were produced in this manner on paper covered walls, floors, and ceilings under a variety of conditions. Among the instruments used to cast off blood were human hands and wooden clubs. Swings were made with both the right and left arms and in upward, downward, and sideward directions.

### RESULTS

Stain patterns produced in this experiment demonstrated the following commonalities:

1. Individual spots were deposited on target surfaces in roughly linear fashion resulting in a trail or path of blood spots.
2. Individual spots in the trail, when circular, generally did not exceed  $\frac{1}{4}$  inch (6-7 mm.) in diameter. These were fairly uniform when the swing was only mildly forceful. When the swing was made forcefully the blood was broken up into smaller drops. In both cases a variety of spot sizes resulted. The dispersion of the spots (degree of spread from the midline of the trail) increased when these smaller drops were cast off.
3. The trail of spots generally exhibited an overall arc pattern which was occasionally indicative of handedness. Handedness in this case refers to the hand in which the instrument was held, not necessarily whether the person was right handed or left handed.
4. The direction in which the swing was made could be determined by the progressive elongation of individual spots. Those which were deposited first generally struck the target at or near 90 degrees. Those deposited later struck at progressively more acute angles.
5. The directionality of individual spots within the trail occasionally indicated whether the swing was made perpendicular to the target or at some oblique angle. For swings made perpendicular to the target the directionality indicated by individual spots matched the overall directionality of the trail. For swings made at some oblique angle the two directionalities did not coincide.

## DISCUSSION

This experiment demonstrated that valuable information can be obtained by examining cast off stain patterns. Practical experience in producing these patterns under known conditions, and understanding the relationship of angle and motion to impact (Experiments 8 and 9), are necessary for the proper interpretation of cast off stains.

It is possible, for example, to determine the physical location of an object casting off blood and the path it followed during the swing. This is accomplished by using the string method to determine multiple points of origin in series. If the instrument used can be identified, it may also be possible to determine the position and orientation of the person who made the swing.



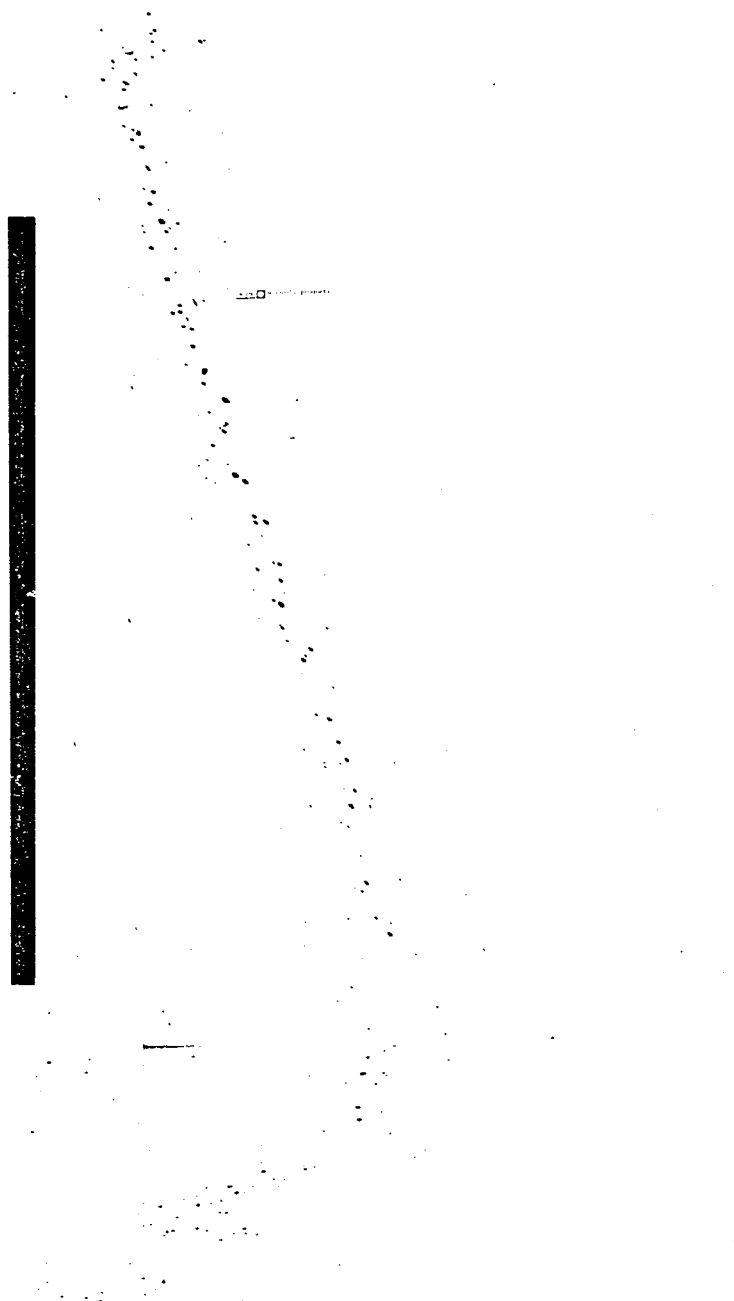


FIGURE 12 - Cast off pattern created by a downward swing of a bloody wooden club. The operator faced the wall at a 45 degree angle to the left. Note the change of direction between the wall and floor.

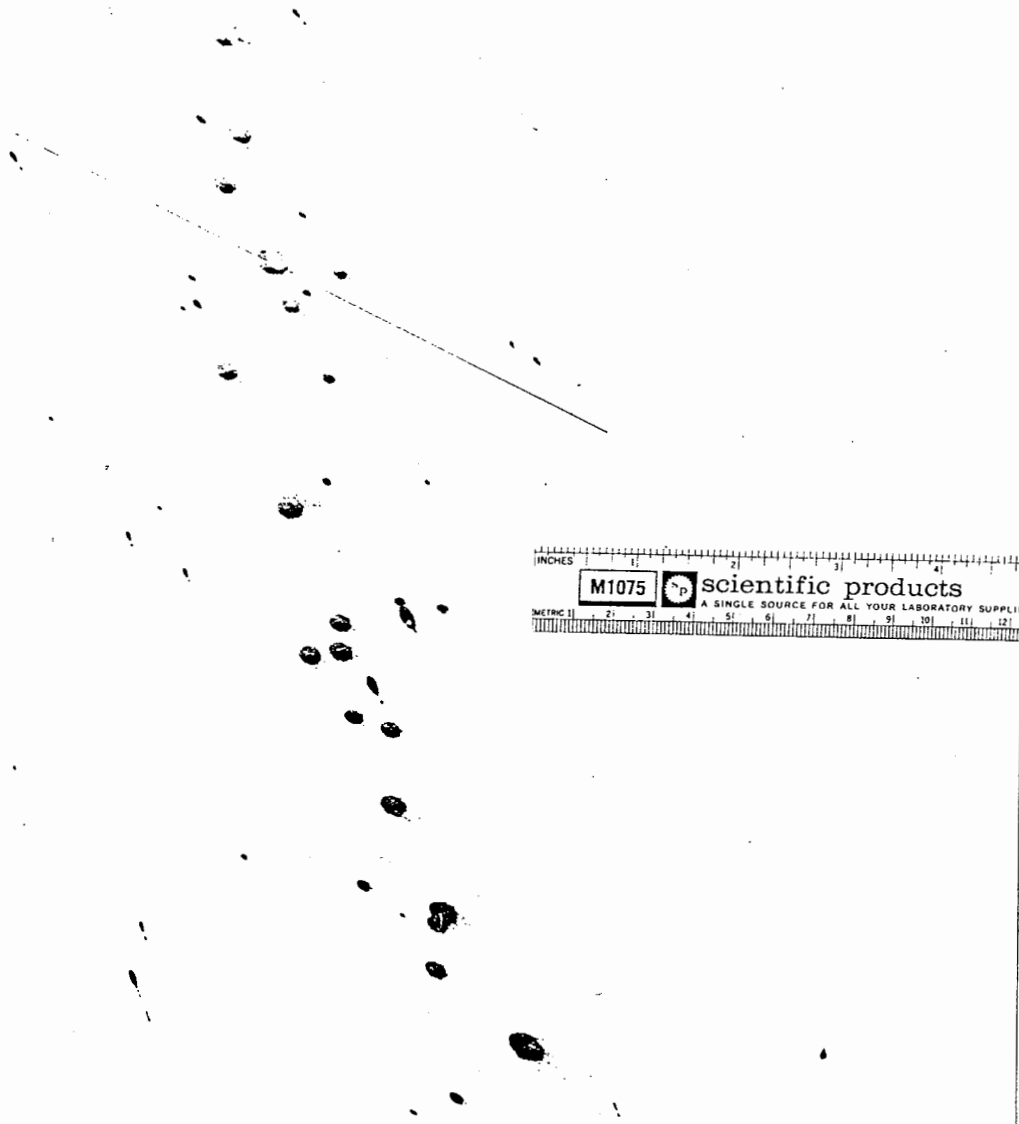


FIGURE 13 - Close up of the upper portion of Figure 12. Note that the directionality of the individual spots differs from that of the overall trail. All spots resulted from one swing of the club.

## EXPERIMENT 12 - PROJECTED BLOODSPOT DISPERSION

### OBJECTIVE

The purpose of this experiment was to study the degree and nature of staining which results when larger amounts of blood are forcefully projected onto a target.

### METHODOLOGY

One milliliter of blood, the equivalent of about 20 drops, was drawn into a needleless syringe. The syringe was mounted over a hard cardboard target at a height of 36". The syringe plunger was manually depressed to project the blood downward. The procedure was repeated at a height of 72" with a fresh target. A second test was conducted with the targets mounted vertically and the blood projected horizontally from distances of 36" and 72".

### RESULTS

The stain patterns produced by this experiment demonstrated the following commonalities:

1. There was a pronounced break up of the mass of blood projected. Smaller spots were deposited around the central stained area. These were generally smaller than spots resulting from individual drops, but larger than the fine satellite spatters resulting from impact.
2. Extensive streaking was present around the central stain. These needle-like spines generally radiate outward from the central stain.
3. Fine satellite spatters radiate outward from the central stained area and generally impact at angles of less than ten degrees. This results in a spine-like appearance with very few round spots present. On the vertically mounted targets no round satellite spots were present.
4. The dispersion of satellite spattering (the area covered) decreased as the distance traveled by the blood increased.
5. On vertically mounted targets excess blood dripped downward from the central stain mass due to gravity.

### DISCUSSION

This experiment demonstrated that volumes of blood, in excess of single drops, which are forcefully projected produce stain patterns which can be identified by certain characteristics. Usually these characteristics give an indication that the blood was subjected to a force greater than gravitational pull.

The characteristics present in projected bloodstains are not specific enough to allow for a determination of distance of flight. In certain cases, however, a point of origin may be determined by calculating the angle of incidence of some of the smaller spots around the central stain.

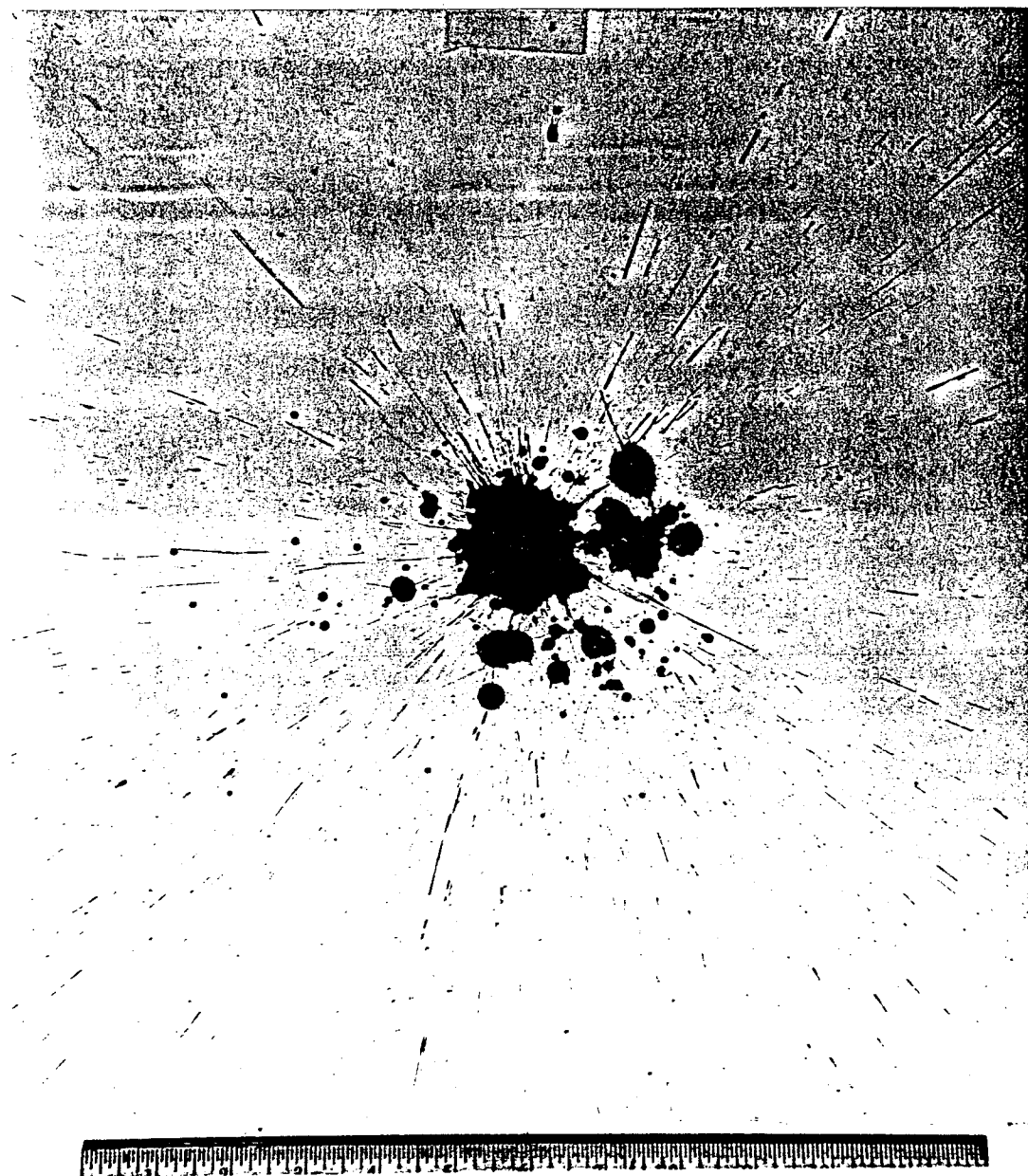


FIGURE 14 - Bloodstain created by 1 ml. of blood projected downward 36" onto hard smooth cardboard.

## SECTION IV - DRIED BLOODSPOT DISPERSION

### SUMMARY

This series of experiments provided additional evidence that significant stain characteristics result when blood strikes a surface with force. The most notable characteristic was the presence of spines or streaks of blood. A blood droplet put to flight by force will begin its flight at a certain velocity. As it travels the velocity decreases due to wind resistance until it reaches terminal velocity (MacDonell, 1971, p 3-4). If the droplet strikes a target before reaching this lower velocity a definite spining occurs around the spot formed. It is the nature and degree of this spining which permits the observer to distinguish between freefalling and forcefully projected drops.

Some cast off staining also demonstrates this phenomenon. The velocity of the individual droplets in this case is determined by the amount of centrifugal force applied before the droplet is released from the surface it is adhering to. For example, a very fast swing of a bloody weapon may result in several spots each of which show some degree of spining. It should be remembered, however, that in this case the spot sizes may be smaller than normal.

Cast off patterns can be produced under a variety of conditions. The forceful cast off described above is one such type. Less forceful movement can also produce cast off such as when a bleeding hand is swung in front of a wall. Another example is when a bloody object strikes a non-bloody surface (see Experiment 15). Some cast off is often produced just prior to impact. In all cases the amount of blood present on the moving object is the overriding factor.

Care must be exercised in the interpretation of actions resulting in cast off patterns. The analyst should remain aware of the fact that bodily movement may cause blood to travel in a direction opposite to the individual's direction of movement.

## SECTION V - DRIED BLOOD-IMPACT SPATTER PATTERNS

### OVERVIEW

This series of experiments was designed to study the effect which impact to static blood creates. Time and fiscal resources did not permit a full examination of all the dynamics involved in impact actions. Topics which still need to be addressed in future experiments revolve around considerations of energy, pressure, force, momentum, and velocity. Each of these will require a careful application of the laws of physics particularly as they apply to fluids.

At present it appears that the dominant factor responsible for the break up of blood into small droplets is the velocity of the object striking the blood. Experiment 13 explores, in rather broad terms, what happens to blood which is struck by a baseball bat. Experiment 14 explores what happens to blood when impact is due to gunshot. Experiment 15 explores what happens when a bloody object strikes a non-bloody surface.

## EXPERIMENT 13 - COURSE AND FINE SPATTER PATTERNS

### OBJECTIVE

The purpose of this experiment was to determine what characteristics are present in spatter patterns resulting from blood receiving impact.

### METHODOLOGY

In this experiment an impact point was constructed 6" above the floor and consisted of a foil covered piece of 4" x 4" wood. One milliliter of blood was placed on the impact point for each test. A baseball bat was dropped vertically onto the impact site, via a guide tube, such that the fat end of the bat, at its tip, struck the pool of blood.

Spatter resulting from impact was collected on vertically mounted white butcher block paper. The impact point was positioned at various distances from the target ranging from 3" to 36". For each test the bat was dropped from the same height and the estimated velocity of the bat at impact was 8 feet per second.

### RESULTS

The spatter patterns produced by this experiment demonstrated the following commonalities:

1. Blood is broken up into small drops when impacted with force. While occasional larger spots were present (up to 3/8" or 10 mm.) the predominant spot size ranged from 1/8" (3 mm.) to those barely visible.
2. A random dispersion of the spots occurred which was clearly observable when the target was close to the impact site. The overall shape of the dispersion was affected by several factors. The most significant of these appeared to be the geometric configuration of the surface struck and of the instrument striking the surface.
3. When the target was close to the impact site, the central portion of the spatter pattern demonstrated a predominance of spots which struck perpendicular to the target (90°). Spots located at increasing distances from the central portion demonstrated increasing angularity.
4. Many individual spots demonstrated directionality and were of sufficient size for height to width determinations. These two factors provided a relatively accurate method of estimating the three dimensional impact point of origin.
5. As the distance between target and impact site increased the spot dispersion increased, i.e. the area covered by spots increased while the concentration of spots decreased.



6. The stain created at the impact site possessed extreme streaking which radiated outward from the center.

#### DISCUSSION

This experiment demonstrated that when a volume of blood receives an impact a spatter pattern results which can be identified by certain characteristics. The most notable characteristics are spot size, concentration, and dispersion.

Reconstruction of the point of impact origin provides the analyst with an additional type of information - number of blows. When the location of the impact site was moved, without altering the location of the target, overlapping spatter patterns resulted. By applying the string method to several representative spots in the mixed pattern, both points of origin could be identified. Thus the analyst can determine that at least two impacts occurred.

When two impacts occur at the same point of origin what appears to be a single spatter pattern may result. In this case it is unlikely that the two separate actions could be differentiated. On the one hand, based upon a single spatter pattern alone, the analyst cannot state with certainty that more than one impact occurred. On the other hand, he can state with certainty that at least one impact occurred.

This inferential reasoning can be extended to situations involving multiple points of origin. For example, if five points of origin can be identified the analyst can determine that at least five impacts have occurred. While there may have been more only five can be isolated. It should be noted that the term impact, as used in this context, refers to any action which is capable of producing a similar pattern.

Other random impact tests were made in which the force delivered to a pool of blood was varied from very slight to great. There appeared to be some correlation between the size of the spots and the amount of force delivered. Generally it was observed that the spots produced by slight force were 1/8" (3 mm.) in diameter or greater while spots produced by greater force were generally smaller, 1/8" (3 mm.) and less.



FIGURE 15 - Course and fine spatter pattern created by one strike of a baseball bat to 1 ml. of blood. The target was 3" from the impact site and the ruler was parallel to the floor.

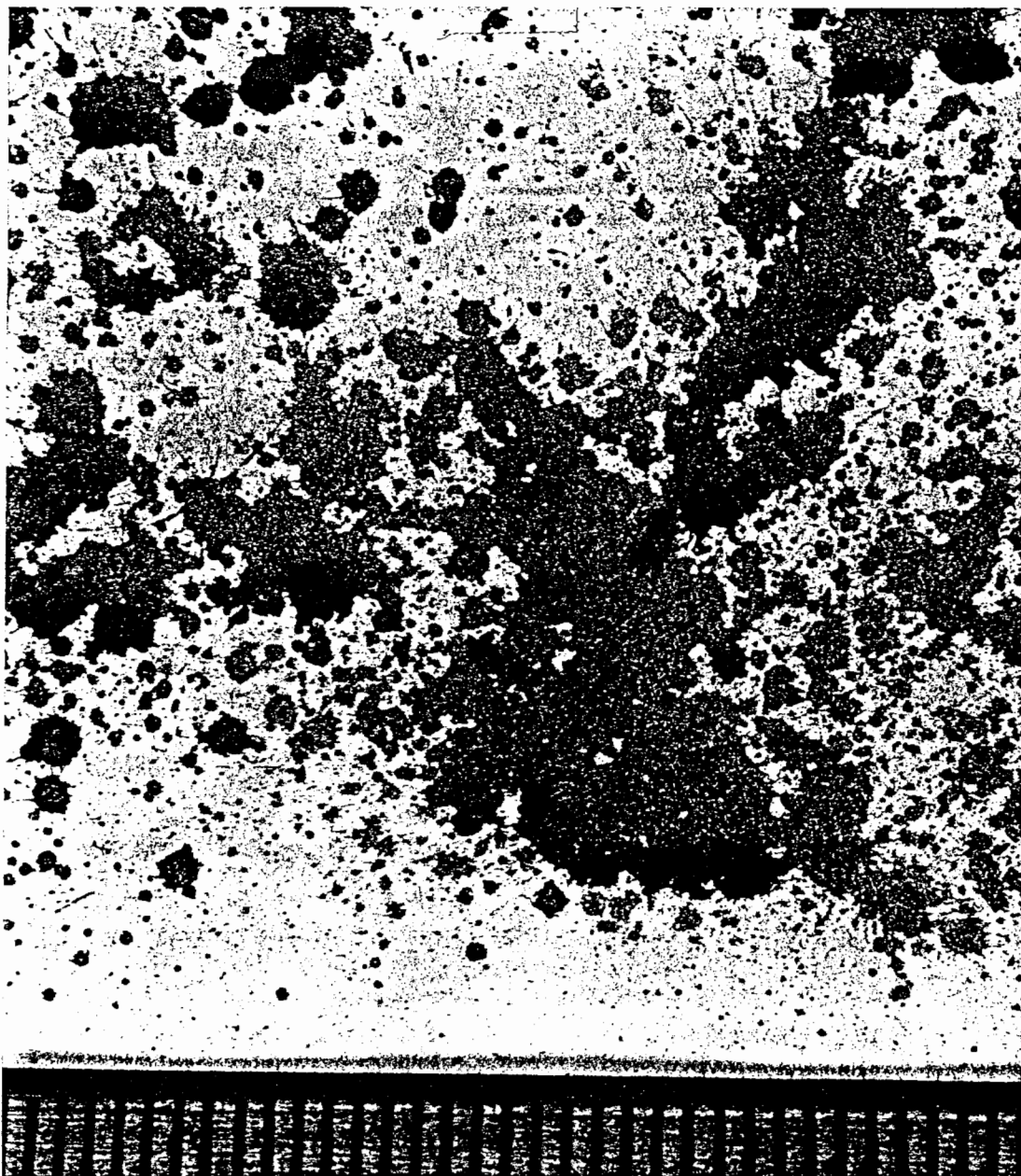


FIGURE 16 - Close up of the central stained area of Figure 15. The scale is in sixteenths of an inch.

## EXPERIMENT 14 - GUNSHOT SPATTER PATTERNS

### OBJECTIVE

The purpose of this experiment was to identify characteristics of blood spatter resulting from gunshot impact.

### METHODOLOGY

A wooden framed tunnel, 2 foot square and 7 feet long, was constructed and lined on the inside with white blotter type cardboard. Targets to collect spatter were placed on all sides of the impact site. The targets collecting forespatter and backspatter were positioned at various distances from the impact site ranging from 6" to 36".

The impact site consisted of a piece of 1/8" plywood to which blood soaked sponges were attached front and back. Two types of weapon discharge were used in this experiment. The first consisted of firing the weapon at a distance of approximately 10 feet from the impact site. In this case the bullet traveled through the backspatter target, through the impact site, and finally, through the forespatter target. The second type of discharge was a contact shot. In this case a hole was cut into the backspatter target to allow the shooter's arm to reach the impact site.

Four types of weapon were used in this experiment:

1. General Precision Corp. .22 caliber revolver, Model 20.22 L.R.
2. Smith and Wesson .38 caliber revolver, Model 10.
3. Remington Game Master 30-06 rifle, Model 760.
4. High Standard 12 gauge shotgun, Model 200.

The ammunition used consisted of:

1. Western T22, .22 caliber 40 grain long rifle.
2. Federal 38B, .38 caliber 158 grain semi wadcutter.
3. Federal Springfield 30-06B, 180 grain soft point hi-shok.
4. Western Super X, 12 gauge #1 buckshot 16 pellets.

### RESULTS

The spatter patterns produced in this experiment demonstrated the following:

1. A break up of blood into fine mist-like droplets resulted from this type of high energy impact. The resultant spots ranged in size from .01 to .001 inches (.25 to .025 mm.) and were highly concentrated in the central stained area of close forespatter targets.

2. Blood droplets were dispersed in a cone shaped fashion. Targets placed parallel to the path of the bullet demonstrated the cone shaped dispersion which resulted in the forespatter areas. Similar, but less distinct, patterns were also noted in the backspatter areas.

3. When the forespatter target was very close to the impact site a pronounced stellate dispersion pattern resulted. The stellate appearance dissipated as distance increased between forespatter target and impact site.

4. Spatter striking the back targets, while having spots in the range of .01 to .001 inches, did not possess a dense concentration of such spots as the forespatter targets did. The only exception noted was when the .38 caliber weapon was used for a contact shot.

5. With most contact shots the shooter's hand received some backspatter. Additionally, blood and debris from the impact site were found inside the weapon barrel.

6. Considerably more sidespatter was produced during the contact shot tests than during the distant shot tests. This applied only to the initial contact side of the impact site analogous to an entrance wound.

#### DISCUSSION

This experiment demonstrated that spatter resulting from gunshot impact can be identified by certain characteristics. The most notable of these was the formation and concentration of the fine mist-like blood spots. It should be noted that in most cases where spatter patterns are suspected of being gunshot related, other information from the scene will also be present. The presence of bullet holes, weapons, and the types of injury must be taken into consideration. This includes the presence or absence of exit wounds. In the absence of an exit wound gunshot spatter can result only from the entrance wound and will take the form of either sidespatter or backspatter. These situations generally produce far less staining than those involving exit wounds, particularly when clothing covers the site.

The surface texture of the targets used in this experiment was rather rough. The fine droplets which impacted rarely demonstrated sufficient directionality or uniformity of shape to allow for impact angle determinations. A smoother surface might be more conducive to such determinations but further testing is needed to verify this assumption.

No significant information was developed in this experiment with respect to type of weapon used. Laboratory controlled experiments such as these only begin to approach the conditions which might exist at an actual crime scene. The myriad of variables associated with different weapon types, ammunition, and location of injury preclude one from stating anything more specific than that the spatter could have been gunshot related.



FIGURE 17 - Gunshot spatter pattern created by one shot of a 38 caliber revolver through a blood soaked sponge. This forespatter target was 6" from the impact site (six inch ruler).

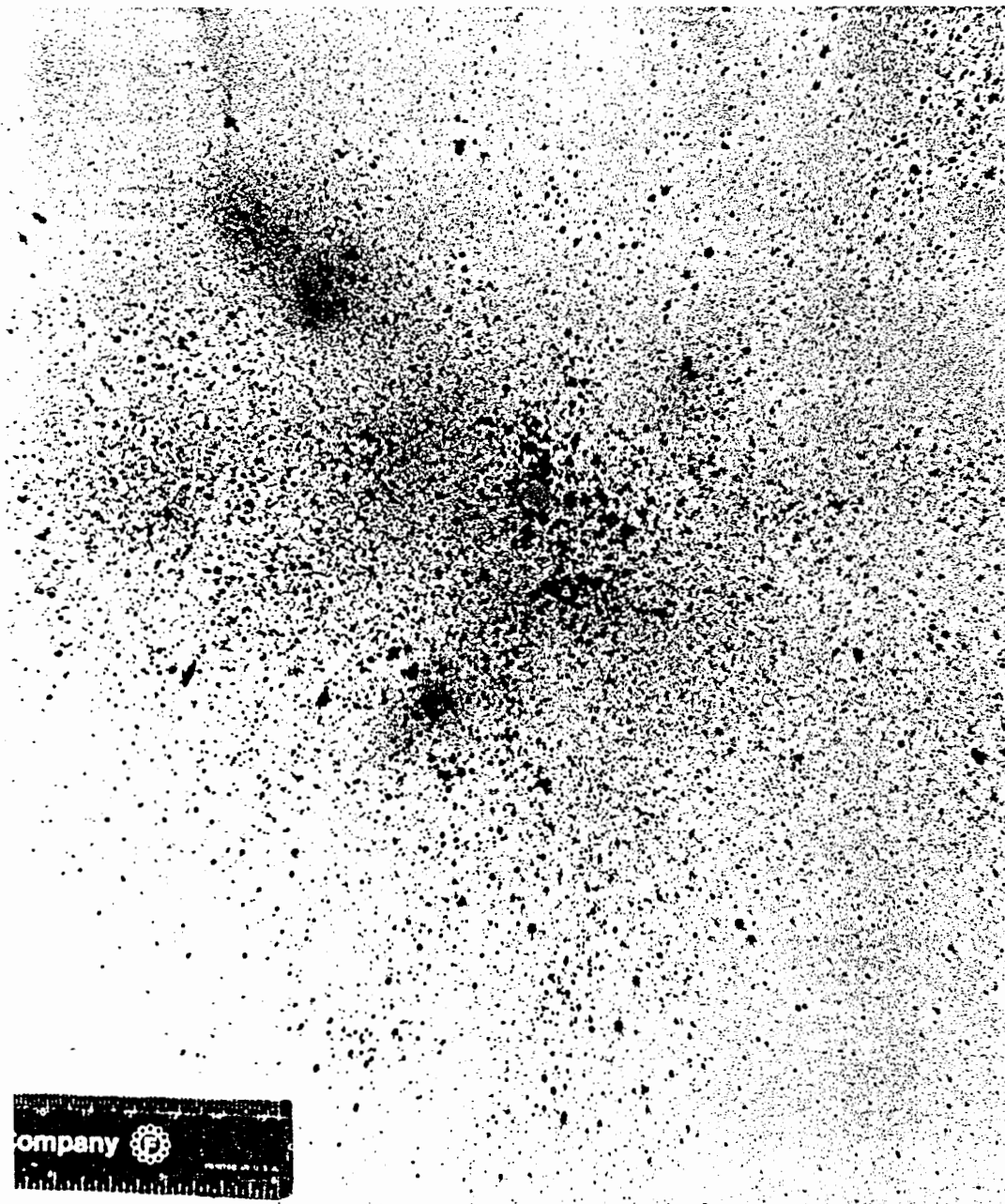


FIGURE 18 - Close up of the central stained area of Figure 17.

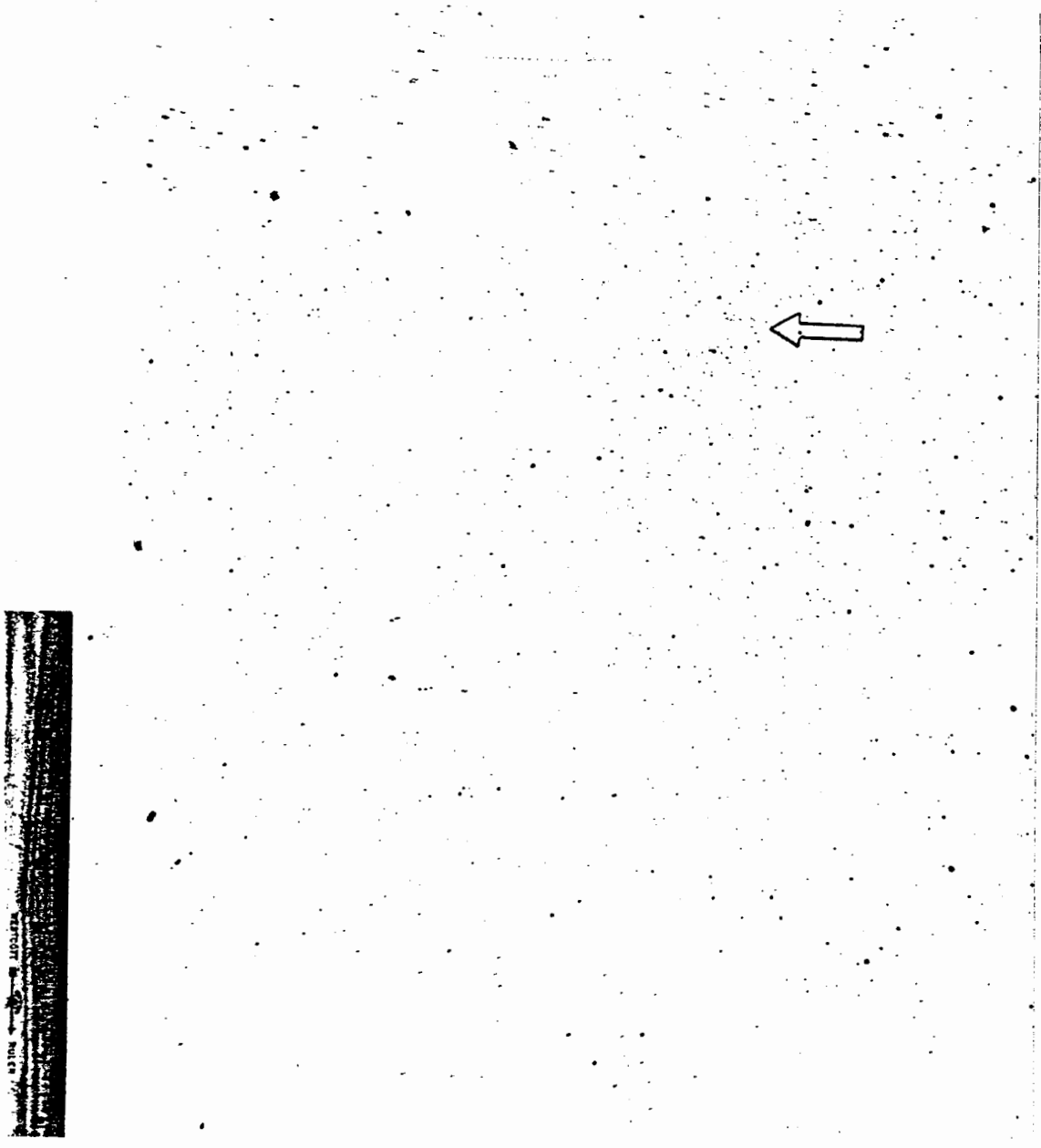


FIGURE 19 - Gunshot spatter pattern created by one shot of a 38 caliber revolver through a blood soaked sponge. This forespatter target was 24" from the impact site (arrow indicates bullet hole).



## EXPERIMENT 15 - CONTACT PATTERN RECOGNITION

### OBJECTIVE

The purpose of this experiment was to identify characteristics of stains which result from contact between two surfaces, one of which is bloodied.

### METHODOLOGY

To conduct this experiment several objects were soaked or dipped into a tray of blood and allowed to come in contact with non-bloody surfaces. Many of the contacts so made were done with varying degrees of force or pressure.

Among the objects used to produce contact stains were: palm of hand, back of hand, forearm, foot, shoulder blade, hair (wig), running shoes, fabrics, cotton, denim, polyester, terrycloth, tools, screwdriver, hammer, and tire lug wrench.

### RESULTS

The patterns produced by this experiment sometimes contained significant identifiable characteristics. Several of the patterns produced contained a combination of cast off, spattered, and contact stains.

The patterns resulting from contact of body parts often demonstrated this multiplicity. During light or medium hand and foot contacts some spining occurred around the central stain area. Many times pressure points were located which were indicative of either hand or foot. These are places where the contact between the two objects is strong enough to squeeze out excess blood leaving only a thin film of blood in the area of greatest contact. During a hard slap the degree of spining was greater and there was a greater tendency for cast off spots to form. Latent prints in blood were occasionally produced but not with regularity.

The patterns resulting from the use of the tools failed to demonstrate specific class characteristics indicative of the tool used. It is probable that reconstructive efforts would be needed for each case involving a questioned weapon.

The patterns resulting from the use of various fabrics sometimes contained identifiable class characteristics of the fabric weave. Additionally, there was a potential for fiber evidence to remain in the stain although discoloration of the fibers by the blood might result.

In most cases directionality of movement during contact could be determined. Smears produced during movement often yielded characteristics indicative of direction of movement. The tapering nature of such smears allows the observer to distinguish direction of movement.

Contact stains which resulted from the bloody wig were clearly and uniquely distinguishable from other types. The fineness of the brush-like streaks of stain were highly indicative of contact with hair. Again the potential for hairs to remain embedded in the stain was also observable.

#### DISCUSSION

This experiment demonstrated that identifiable class characteristics of the object making contact were often detectable in the resultant stain. Occasionally such stain patterns were suitable for further laboratory examination for latent prints, fabric impressions, foot/shoe tracks, hair, and fiber transfer. With stains of questionable origin the analyst will need to recreate a similar pattern under known conditions in order to render an opinion on the stain's origin.

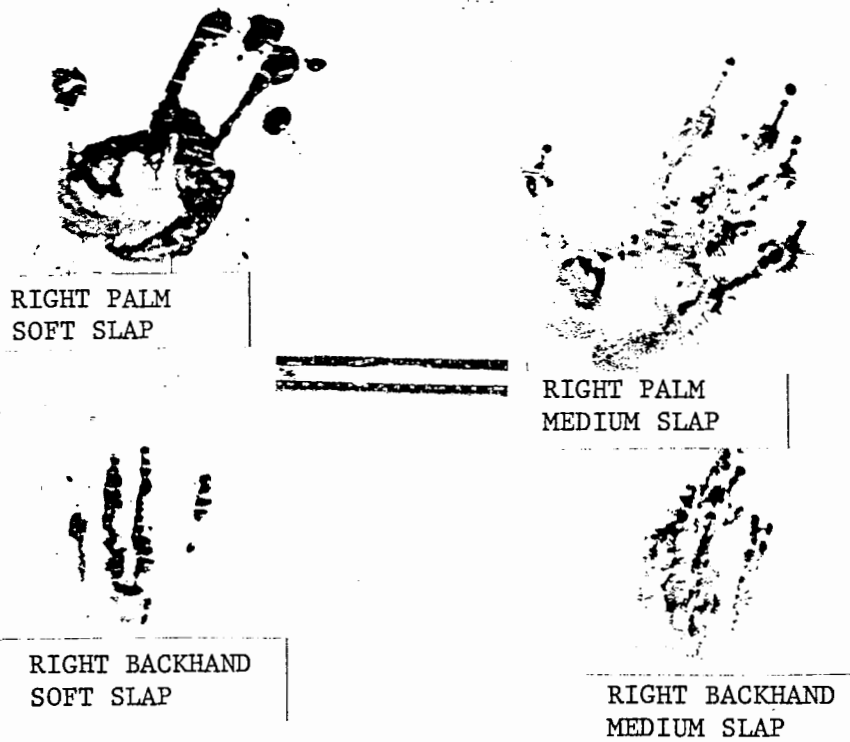


FIGURE 20 - Imprint contact bloodstains created by a bloody hand. Note the cast off stains trailing from the fingertips of the medium force slaps.

## SECTION V - DRIED BLOOD-IMPACT SPATTER PATTERNS

### SUMMARY

The stain patterns produced in this series of experiments demonstrated, among other things, that gunshot spatter can usually be distinguished from other types of forceful impact. The extreme difference in impact velocities used (Experiment 13, 8 ft/sec vs. Experiment 14, 750+ ft/sec) does not permit a precise determination of the effect of various types of impact. The results indicate that only general assumptions can be made.

MacDonell categorizes spatter by reference to the velocity of the object impacting on static blood (1971, p 16-23). Briefly summarized, he defines low velocity spatter as that resulting from an impact of less than 5 feet per second, medium velocity as that from 5-25 feet per second, and high velocity as any impact in excess of 25 feet per second. The authors have found that spot size and dispersion patterns are affected by factors other than impact velocity alone. As pointed out in Experiment 13, the physical characteristics of surfaces which make contact can affect spot size and dispersion.

Consider for the moment a case in which a hammer blow is delivered to a skull. Assuming that blood is already present on the surface from a prior blow, one must consider the possible modes of contact. If the face of the hammer head strikes flat against the skin, blood will be first compressed then projected outward to the sides under extreme pressure. If, on the other hand, the edge of the hammer head strikes the skin blood will be projected outward with less pressure. In both cases additional bleeding may occur as the skin is torn. This may further add to the overall stain pattern produced.

Certain questions arise from this scenario such as how to categorize the patterns so produced. Should both swings of the hammer be classified as medium velocity impact? What is the normal velocity of a hammer swing by a person? Do the patterns produced significantly differ from that which would have been produced if a fly swatter were used in place of the hammer?

Clearly the factors at work during the instantaneous spattering of blood involve more than velocity alone. Energy, force, momentum, pressure all play some part in the dispersion of blood. For these reasons the authors refer to spatter patterns by their descriptive nature rather than solely by the impact velocity used.

Much more experimentation is needed to better define spatter in terms of impact velocity and other operant factors. This is particularly true for non-gunshot impacts which are often involved in crimes of violence. Stain patterns which result from this type of lower energy impact often

contain a variety of different sized spots which can be placed in two general categories.

Larger spatter spots range in size from 1/8" (3 mm.) to approximately 1/2" (13 mm.). These are referred to as COURSE spatter and can be distinguished from spots caused by dripping. The dispersion of some smaller spatters mixed in with these course spots is indicative of the fact that some sort of impact occurred although not very forcefully.

Smaller spatter spots range in size from 1/8" (3 mm.) to those barely visible. These are referred to as FINE spatter. Generally, fine spatter occurs when static blood receives a more forceful impact. While a few course spatters may be present a predominance of spots are fine spatter.

The identification of spatter resulting from gunshot impact requires a subclassification of fine spatter called MIST-LIKE spatter. These spots generally measure only a few thousandths of an inch (hundredths of a millimeter). What is important here is the concentration of such spots. If the mist-like spatter is deposited on an object in close proximity a dense concentration of these spots can be observed. Very rarely will larger spots be found in the pattern. When present they may be the result of a puddling of several small droplets. Pieces of flesh and bone may also be present in the pattern which can be quite large at times.

Blood droplets put to flight by impact will continue to travel until one of two conditions has been met. The first condition occurs when the droplet's energy of motion is exhausted and it falls to the ground. The mist-like droplets produced by gunshot impact have very little mass and, therefore, generally do not travel very far. This was quite evident in Experiment 14 when the targets were placed at increased distances from the impact site.

The second condition occurs when the droplet strikes an object before its energy is exhausted. Since impact disperses droplets in a rather random fashion any object in the flight path of the droplets will collect some staining. If the object is then moved one can expect to find a void of staining in the target area shielded by the object. This shadow effect of dispersed spatter may occasionally aid the analyst in determining whether or not an object has been moved since bloodshed occurred.

Determining the point of origin of course and fine spatter by using the extended string method (Experiment 8) proved to be highly reliable. It was noted in making such a determination that several strings need to be erected. These extend from random, but representative, spots located within the dispersion pattern. The point at which the extended strings converge represents the highest possible point of origin.

The selection of representative spots in the pattern must, once again,

incorporate a consideration of the effect of gravity. As a general statement, spots which demonstrate some upward directionality yield more valuable information than those which demonstrate downward motion. Spots indicating downward motion may be caused by droplets which are no longer flying in a straight line from the impact site. Rather, they may have already begun to arc downward due to exhaustion of their forward energy. A string projected from these spots would serve only to expand the possible point of origin upward (review the diagram in Experiment 9).

The contact stains produced in Experiment 15 often produced spattering which extended outward from the impact site. While determining point of origin from these spatters was not always necessary due to the presence of the contact stain, the exercise proved to reconfirm the accuracy of the method.

The interpretation of contact stains requires a great deal of practical experience. Much like a doctor who must identify symptoms in order to determine the cause of an illness, the analyst must learn to recognize certain class characteristics of contact stains before determining their cause. Actual case work may require that the analyst try to recreate a questioned pattern under known conditions. This involves many factors such as surface texture, weapon used, angle of incidence, amount of blood present and others.

## SECTION VI - BLOODSPOT DRYING TIME

### OVERVIEW

While the bulk of this research effort was directed to an examination of morphological characteristics of bloodstains, another avenue of inquiry was also examined. This examination dealt with some of the basic factors related to the time required for blood to dry.

Occasionally a crime scene analyst may arrive at a scene in which liquid blood is still present. It would be beneficial to the analyst to have some understanding of how long it takes blood to dry. Information on this topic may contribute to factors such as determining the sequence and time frame of events surrounding bloodshed.

Indirectly this information may provide investigative leads to the case investigator which can be used to confirm or refute statements of the principals in the case. A suspect's claim, for example, that he arrived at the scene several hours after the victim's death might be illogical if bloodstains are found on his clothing or shoes.

This series of experiments was designed to examine some of the basic considerations involved in planning a fullscale research effort. It is important to note that the main purpose of these experiments was not to develop empirical data on the drying time of blood. Rather the intent was to determine whether or not certain factors affecting drying time are worthy of more indepth examination. Time did not permit inquiry into several theoretically important factors such as room temperature, humidity, and barometric pressure. The topics examined here represent only the most basic, preliminary steps needed to plan further work.

Experiment 16 examines the reliability of a standard method by which dryness can be determined. Experiment 17 examines what effect the use of a preservative has on drying time. Experiment 18 examines what effect the temperature of blood, at the time of drop formation, has on drying time. Experiment 19 examines how drying time is affected by the size of the spot. Experiment 20 examines how drying time is affected by air flow over the spot.

## EXPERIMENT 16 - METHOD OF DRYNESS MEASUREMENT

### OBJECTIVE

The purpose of this experiment was to determine the precision of the method selected for detecting dryness.

### METHODOLOGY

Five drops of blood were allowed to fall from an eye dropper a distance of 12" onto a 3" x 5" white index card. The volume of the drops was determined by a simple volumetric technique to be .044 ml./drop. The blood was observed during drying and the time was recorded. For the purpose of this study "dry" was defined as the lack of tackiness. Near the point of dryness the blood loses its shiny appearance and takes on a dull sheen. The blood was tested near this point for tackiness by pressing a one inch square of facial tissue to the stain with about five pounds of pressure. A gentle blow was applied to the tissue. If the tissue was blown away the stain was considered dry.

Each run consisted of five cards with five drops each. Four total runs were made under different environmental conditions in order to vary the times required for drying.

### RESULTS

RUN NUMBER	MEAN TIME	95% CONFIDENCE LIMITS	MEDIAN TIME	MODE TIME
1	56	61.78 - 50.22	55	55
2	58	62.24 - 53.76	58	57
3	79	87.04 - 70.96	78	78
4	64	70.98 - 57.02	63	63

All times in minutes.

### DISCUSSION

Prior to conducting this experiment several techniques for detecting dryness were examined. The intent was to develop a method of measurement which was field applicable and could be performed by patrol and other



investigative personnel. Therefore, the use of sophisticated instrumentation was avoided. The facial tissue procedure appears to be well suited to field use.

The results of this experiment are limited to consideration of single drops of blood only. In addition to the dry time the point at which the blood lost its shiney appearance was recorded as the "dull time". This visual method yielded a slightly greater precision than the dry time method. The dull time was not used as the primary measurement because it was not an indication of the true end point. The end point occurs when the blood can no longer be transferred during light contact with a non-blody object.

The results indicate that the tissue method for determining dryness was relatively accurate. The end point of dryness was detectable within 10% of the mean 95% of the time. This degree of precision is acceptable for the purposes of the present research. Therefore, the tissue method for determining dryness will be utilized throughout the balance of these experiments.

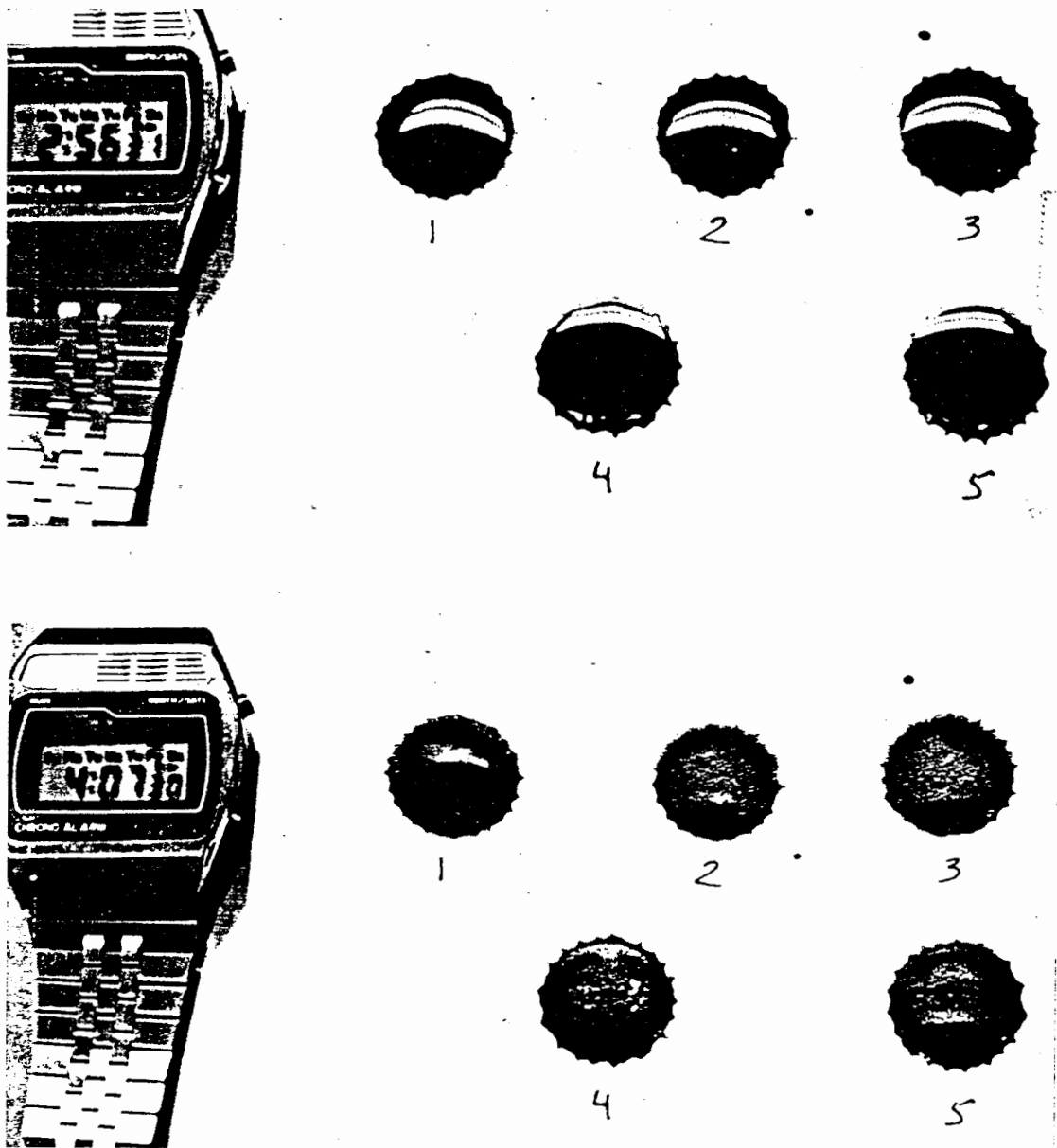


FIGURE 21 - Bloodspots created for drying time determination. Upper set is at time of dropping, note the shiney appearance. Lower set is when the spots were visibly dry but still tacky to the touch.

EXPERIMENT 17 - EFFECT OF PRESERVATIVE ON DRYING TIME

OBJECTIVE

The purpose of this experiment was to determine if preserved blood could be used as a substitute for fresh blood throughout future drying time experiments.

METHODOLOGY

Throughout this experiment freshly drawn blood was used. Five volunteers each donated 10 milliliters of blood. The preservative CPDA-1 was added to one half of the sample and no preservative was added to the balance. Tests using fresh blood were begun within 3 minutes of drawing. Those of the preserved blood were begun within 10 minutes of drawing.

Individual drops of blood were issued by an eye dropper delivering a standard .045 ml./drop. Individual spots of blood were collected on 3" x 5" white index cards placed 12" below the delivery mechanism. During drying each donor's set of cards were kept inside a cardboard box to minimize air flow. The total time required for each spot to dry was recorded.

RESULTS

DONOR	FRESH BLOOD MEAN DRY TIME	PRESERVED BLOOD MEAN DRY TIME	PERCENT CHANGE
1	96.0	82.6	13.0
2	89.6	79.4	11.4
3	77.4	63.6	17.8
4	70.2	61.0	13.1
5	67.0	57.8	13.7
All times in minutes			

DISCUSSION

Research on the drying time of blood requires the testing of many drops of blood. Furthermore, it requires that each experiment utilize blood from one individual so as not to introduce additional variables. Since

fresh blood begins to coagulate within a few minutes after it is taken from the body it is difficult to work with. The use of fresh blood requires a fresh draw prior to each run of the experiment.

The purpose of this experiment was to determine if preserved blood could be used as a substitute for fresh blood. The results of this experiment show that there is a change in the drying time due to the addition of a preservative, i.e. blood dries faster when a preservative is used. The relative degree of consistency of the preservative factor (preserved blood dried about 14% faster) indicates that the analyst can be reasonably sure of predicting the behavior of fresh blood based on preserved blood results. Further testing of the preservative effect appears to be warranted if fullscale research is to be carried out. Throughout the balance of these experiments preserved blood will be utilized for control purposes.

EXPERIMENT 18 - EFFECT OF TEMPERATURE ON DRYING TIME

OBJECTIVE

The purpose of this experiment was to determine if the temperature of the blood affects the drying time.

METHODOLOGY

Blood was tested at three different temperatures 6°C, 22°C., and 37°C. In each case the blood and delivery mechanism were brought to the same temperature prior to running the test.

Individual bloodspots were collected on 3" x 5" white index cards placed 12" below the delivery mechanism. The same delivery mechanism (pipet) and environmental conditions were used throughout. Five cards with five drops each were collected at each temperature.

RESULTS

BLOOD TEMPERATURE	MEAN DRYING TIME
6 <sup>0</sup> C.	93.3 minutes
22 <sup>0</sup> C.	87.7 minutes
37 <sup>0</sup> C.	91.4 minutes

DISCUSSION

The results of this experiment indicate what one might expect. The drop of blood, regardless of its initial temperature, adjusts quickly to the temperature of the surface it strikes and the drying time is not significantly affected. Therefore, further testing of the effect of blood temperature is not warranted. Throughout the balance of these experiments blood will be used at room temperature.

EXPERIMENT 19 - EFFECT OF SPOT DIAMETER ON DRYING TIME

OBJECTIVE

The purpose of this experiment was to determine if the drying time of a bloodspot is significantly related to the diameter of the spot.

METHODOLOGY

An eye dropper, delivering a standard .044 ml./drop, was used to issue individual drops of blood. The collection procedure consisted of placing a 3" x 5" white index card on a flat surface. The delivery mechanism was placed at various heights ranging from 3" to 96". Five drops of blood were collected at each height and allowed to air dry while the time was recorded. Environmental conditions were kept constant throughout.

RESULTS

DISTANCE FALLEN	MEAN DRYING TIME (minutes)	MEAN SPOT DIAMETER (mm.)
3"	52.5	10.0
6"	47.0	12.0
9"	40.0	12.7
12"	40.5	14.6
18"	39.0	15.4
24"	33.8	16.4
36"	28.8	16.6
48"	35.5	17.6
72"	24.5	17.9
96"	24.0	19.0

DISCUSSION

This experiment demonstrated that the drying time of a bloodspot is significantly related to the diameter of the spot when all other factors are held constant, i.e. the drying time decreases as the spot diameter increases. The implication of this finding is that spot size is a factor worthy of further testing.

The drop diameter is actually an indirect measurement of the factor producing the change in drying time. That factor is the ratio of volume to surface area. As surface area increases, with respect to a constant volume, the drying time is accelerated just as an ounce of water dries

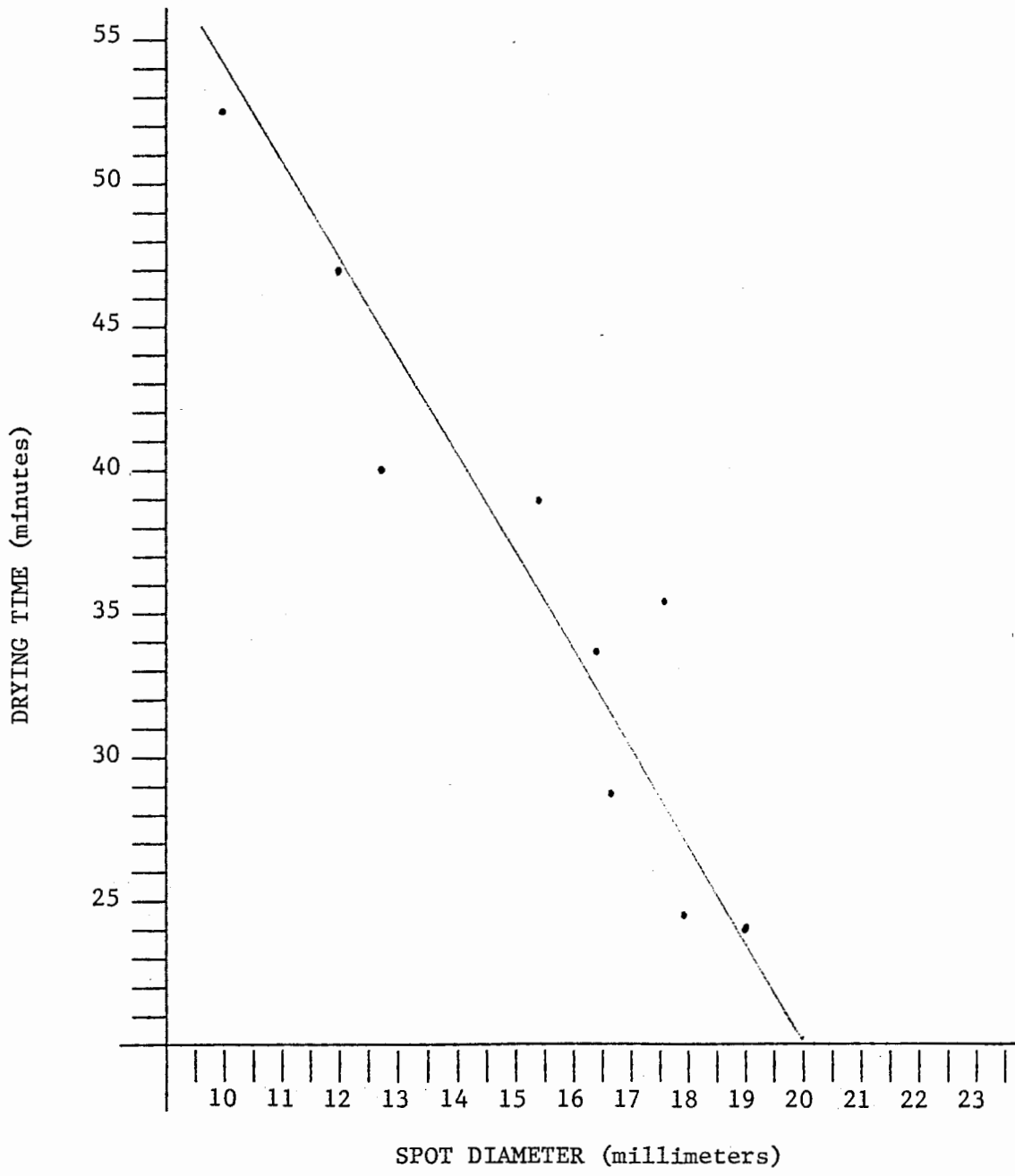


FIGURE 22 - Drying time as a function of bloodspot diameter.

more quickly when it is spread over a larger area.

Experiment 5 demonstrated the linear functional relationship between drop volume and spot diameter. Since diameter is used to calculate surface area it can be inferred that a linear relationship also exists between drop volume and surface area. Thus if two different sized drops are allowed to fall 12" to identical surfaces, the surface area to volume ratios will be practically the same. Further experimentation would be needed to determine if the drying times of two such drops would differ significantly and if it is the surface area to volume ratio which is the dominant factor.

Clearly, this experiment while demonstrating a significant relationship between drying time and diameter cannot be construed as definitive data. At best the results are parametric, i.e. they indicate only upper and lower parameters for one highly controlled test. In order to utilize this information it would be necessary to know the volume of the drop producing the questioned spot and the height from which it fell. Since the analyst would not have access to such information at a crime scene the results of this experiment are of limited value. Further testing of the effect of spot size on drying time appears to be warranted and indeed necessary for fullscale research.



EXPERIMENT 20 - EFFECT OF AIR FLOW ON DRYING TIME

OBJECTIVE

The purpose of this experiment was to determine if the drying time of a bloodspot is significantly related to the rate of air flow over the spot.

METHODOLOGY

Five drops of blood were allowed to fall 12" from an eye dropper onto a piece of formica board. The board was placed inside a box with one side removed for observation. The box reduced air currents to the point where they could not deflect a freely suspended thread. The drying time of the spots was recorded.

This procedure was repeated without the box allowing the spots to dry exposed to room currents which could be detected by the suspended thread. It should be noted that the spots were not placed in the path of any air ducts in the room.

The procedure was again repeated but utilized a fan-induced air flow over the spots. The spots were placed in front of the fan which had a transformer attached. The transformer had eight settings which ranged from very slow to very fast. At the lowest setting the blades of the fan could still be seen individually as they rotated. While actual air flow rate could not be measured, the lowest transformer setting could be equated with a slight breeze.

RESULTS

RUN NUMBER	AIR FLOW UNITS (transformer setting)	MEAN DRYING TIME (minutes)
1	.54	90.0
2	.85	57.8
3	1	49.0
4	2	30.8
5	3	25.2
6	4	20.6
7	5	21.2
8	6	19.0
9	7	17.2
10	8	21.4

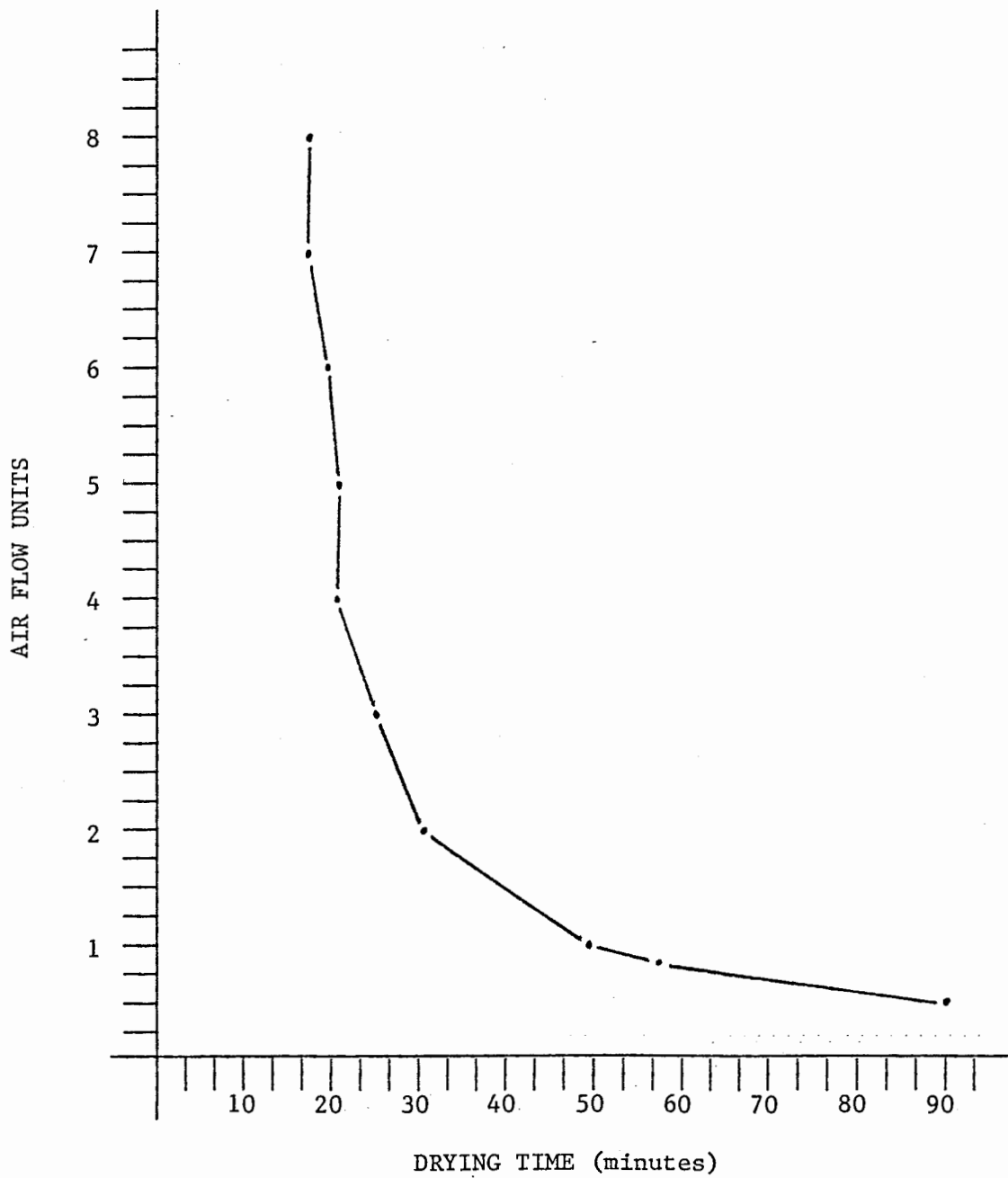


FIGURE 23 - Drying time as a function of the rate of air flow.

The values for the arbitrary air flow units of Runs 1 and 2 were calculated from the ratios of the drying times of Runs 3 and 4.

#### DISCUSSION

This experiment demonstrated that the drying time of a bloodspot is significantly related to the rate of air flow over the spot. The area of most prominent effect, however, is not between the air flow units of 1 to 4, which would equate with a slight breeze which one could feel, but in the range of air flow below Unit One. In this range the air flow could not be felt on the skin. The area below Unit One would equate to the kind of conditions one could expect to find in an air conditioned building. If there were absolutely no air flow, no molecular movement around the drop, there would be no evaporation and the drying time would extend indefinitely. Practically speaking, this condition could not occur.

In this experiment the air flow in the box was not detectable with the suspended thread. It is not likely that one would encounter a situation at a crime scene where the air flow would be equal to or less than the box situation. Therefore, it would be acceptable, for the purposes of these experiments, to refer to the level of air flow in the box as the lower limit.

As the air flow increased an approximate upper limit of effect was noted around 4 air flow units. Air flows above this rate did not exert an appreciable effect on drying time. One would expect to find a point such as this where the flow of air across the spot permits a maximum evaporation rate. Any increase in flow beyond that point would have a negligible effect. Further testing of the effect of air flow on drying time appears to be warranted for fullscale research.

## SECTION VI - BLOODSPOT DRYING TIME

### SUMMARY

This series of experiments dealt only with single drops of blood. Factors involved in the time required for blood to dry must be studied at their simplest level before attempts are made to examine larger masses of blood. These experiments only scratched the surface of such basic factors. A vast amount of additional experimentation would be needed to fully explore the topic particularly with respect to pools of blood.

In spite of the limited nature of the work accomplished, some worthwhile information was developed. For example, the dramatic effect of air flow on drying time appears to overshadow the lesser effect of the other factors examined. Future testing on the effect of air flow, temperature, humidity, barometric pressure, and surface medium may reveal other, more important elements which impact on drying time.

However, such testing may also illustrate additional problems. It may be discovered that the lack of reproducibility of certain experiments, or the extreme variation in drying times in multivariable experiments, precludes the formation of scientifically based inferences other than in the most general of terms.

The longest time required for blood to dry in any of these experiments was 96 minutes (Experiment 17). It is conceivable that longer times should be expected under conditions which impede the evaporation process such as high humidity. Future researchers may need to direct attention to developing a system of classification by which environmental conditions can be categorized. Testing would then be needed to define upper and lower time limits of drying for blood within each such category.

The authors hope that these experiments can in some small way contribute to such an effort. The results have at least provided some insight to the difficulties associated with blood drying time research.

## CONCLUDING REMARKS

### ANALYTICAL METHOD

The area of bloodstain pattern analysis is a relatively infrequent part of most crime scene examinations. The reason for this is rather simple, it is a difficult assignment. Examining bloodstains and rendering valid opinions as to their cause is a complicated process involving measurement skills as well as an ability to apply the laws of science and logic.

The crime scene investigator, be he analyst or technician, must rely upon the static aftermath of an incident, the physical evidence present, to draw his conclusions about a sequence of events. Bloodstain patterns fall into this category and can often contribute to an understanding of the activity which transpired.

Some investigators who lack a background in scientific orientation view bloodstain patterns and offer what they feel are "reasonable" opinions as to cause. In many such cases these reasonable opinions are unknowingly supported by the laws of physics. Even when the investigator is unable to fully articulate the reasons for his belief, he may be correct in ruling out certain explanations which would have been impossible.

On the other hand the investigator may also offer what amounts to nothing more than a hunch without consideration of other possibilities. The inherent potential for erroneous conclusions in this method is at least disquieting. The focus of an investigation can be misguided if it relies too heavily upon conclusions of this quality.

There is an obligation incumbent upon all crime scene analysts performing bloodstain pattern analysis to remain above the level of the unscientifically trained technician. In any discussion of this topic the need for the application of scientific principles, particularly those involving the laws of physics, should be self-evident. The very process of analysis involves studying the component parts of a problem and the manner in which they interrelate with each other.

### DECISION MAKING PROCESS

In analyzing the static aftermath of an incident involving bloodshed certain hypotheses are developed concerning the sequence of events. These hypotheses must be based upon phenomena which are consistent with known scientific principles. The laws of physics governing the actions of projectiles in motion (ballistics), the actions of fluids receiving stress (fluidics), and the actions of objects in contact loosely define the parameters within which hypotheses must fit.

The decision making process operant in bloodstain pattern analysis can

be broken down into a four step process. The first step involves a complete examination of the scene and the detection of all bloodstain related evidence present. This may involve not only those stains and patterns which are visibly present but also those which are conspicuously absent due to shielding.

The second and third steps, while inseparable in actual practice, are delineated here for the sake of discussion. After the bloodstain patterns are located each must be examined for those aspects which can reveal significant information. This involves the recognition of those morphological characteristics present in the stain patterns which are indicative of the occurrence of specific events. In many patterns of dispersed bloodspatter not all spots are significant for determining point of origin or directionality. Appropriate representative spots must be selected and utilized. The analyst's ability to select spots which are representative can only be developed through study and experience.

The third step in this process is for the analyst to use the facts developed during the examination to interpret certain stain characteristics. In essence the analyst must make a decision on whether the observed stain pattern is uniquely related to a singular event or could be explained by a multiplicity of probable causes. In some cases this may resemble the approach one takes to a jig saw puzzle. If fact A is consistent with fact B but not with fact C, another explanation must be sought. At times two or more scenarios can be developed utilizing the same facts at hand.

Several factors impact on the development of inferred events based on analysis of bloodstains. Bloodspots must be studied both individually and as part of an overall pattern. A suitable analogy is the use of a single word. Taken alone a word has a given meaning. However, when it is used in a sentence its meaning may be altered. So too with certain types of staining. The directionality demonstrated by individual spots may indicate the direction from which the blood drop came or the direction in which a bloody object was moving. Cast off patterns are capable of providing such dual information.

Another interpretive factor is the spatial and geometric orientation of stains with respect to their points of origin. This involves an appreciation of the mechanics of plane geometry. Since the analyst must deal with a three dimensional reality on-site examination is imperative.

Likewise, kinesiology plays a role in bloodstain deposition. Particularly applicable to cast off patterns, the analyst must possess an understanding of bodily movement limitations relative to appendage swing, i.e. natural vs. unnatural. The nature, location, and extent of injuries sustained by a victim often contribute to an understanding of the spatial orientation of the victim at the time of infliction.

When multiple explanations are possible the analyst's decision making process advances to its final stage. It is here that opinions are formed and conclusions drawn as to a most probable sequence of events. Not every case will contain evidence sufficient to support a firm conclusion. The analyst must be prepared to accept this situation and render opinions only to the extent they are supported by the immediate circumstances.

#### VALUE OF PATTERN ANALYSIS

Each type of stain pattern possesses potential information which can be uniquely characteristic of certain actions. The proper interpretation of stain characteristics is essential if the field of bloodstain pattern analysis is to achieve a respectable position in the scientific community. Since the ultimate value of this analysis lies in its courtroom application, it is important that such analysis be founded on sound scientific principles.

The scientific community is often called upon to contribute to a jury's understanding of the elements of a crime. Appreciation of the significance of certain evidence, and its potential to prove or disprove a fact in the case, may well lie beyond the capabilities of a layman. It falls to the expert witness then to provide the layman with an understanding of evidentiary relationships.

Bloodstain pattern analysis focuses directly upon such relationships. Examining an end result of bloodshed, rather than the action which produced the result, demands an understanding of these relationships. It is through the practical experience of studying a specific action and its result under controlled experimental conditions that the analyst gains an ability to interpret bloodstain patterns.

#### APPLICATION OF RESULTS

Potentially valuable investigative information can be developed through bloodstain pattern analysis. Specific events can sometimes be logically inferred and sequenced when all information from the crime scene investigation is brought together. Pattern analysis can, depending on the nature of the incident, lead to a determination of:

- the point(s) of origin of bloodshed;
- the relative degree of force used to disperse blood;
- the number of blows or actions;
- the location and orientation of persons and objects during bloodshed; or
- the movement of persons and objects during or following bloodshed.

There are two major ways in which determinations such as these can be utilized. The first is to confirm or refute assumptions concerning

events and their sequence. These assumptions may impact upon the direction and scope of the case investigation. Indications of handedness may contribute to a narrowing of suspect search. Other information may also alert the investigator to be observant for sources of additional evidence should a suspect be located.

The second major use of information developed is for confirming or refuting statements of principals involved in the incident. A suspect's version of the events can be examined as to whether it "fits" the circumstances of the scene. Likewise, a witness's account can be verified in the same manner.

#### FUTURE EXPECTATIONS

Since such potential value exists in the process of bloodstain pattern analysis, and since law enforcement agencies look to crime laboratories for scientific assistance, it is reasonable to assume that the crime laboratory will be called upon to render bloodstain pattern analysis. This condition has already begun to occur with greater frequency than in the past.

The information developed by this research project has already proven to be beneficial. Certain crime scene investigations, performed by the various Crime Scene Sections of the laboratory system, have involved only the analysis of bloodstain patterns.

Throughout this report certain topics were identified which will require additional experimentation. The results of the present research effort can be used as building blocks for future studies. Additional knowledge can be developed in this manner and can prove to be an asset to the laboratory system. It is the intention of the authors to continue to pursue, independently if necessary, several of these research topics.



## GLOSSARY

- BLOOD - The fluid circulating through the vascular system, carrying oxygen and nutrients throughout the body and waste materials to excretory channels.
- CAST OFF - Blood which is flung from a moving object as a result of a change in speed and/or direction.
- PROJECTED - Propelled blood, in excess of one drop, which strikes a target.
- SPATTERED - A volume of static blood which receives an impact.
- SPLASHED - Freefalling blood, in excess of one drop, which falls upon itself.
- DRIPPED - Freefalling drops of blood which produce individual spots.
- BLOODSPATTER - A stain pattern which results from a force impacting on static blood.
- FORESPATTER - Blood which strikes a target in the same direction as the force which produced the spatter
- BACKSPATTER - Blood which strikes a target in the opposite direction of the force which produced the spatter.
- SIDESPATTER - Blood which strikes a target relatively perpendicular to the force which produced the spatter.
- COURSE SPATTER - A bloodstain pattern consisting of individual spots which are predominantly 1/8" (3 mm.) and larger in diameter.
- FINE SPATTER - A bloodstain pattern consisting of individual spots which are predominantly 1/8" (3 mm.) and smaller in diameter.
- MIST SPATTER - A bloodstain pattern consisting of individual spots which are predominantly .01 to .001" (.25 to .025 mm.) in diameter. These spots usually appear in a mist-like concentration and are normally accompanied by larger spots.

CONTACT STAIN - A bloodstain which results from the touching of a bloody object and a non-bloody object.

IMPRINT STAIN - A bloodstain impression or partial impression, containing identifiable characteristics, which results from contact with a bloody object.

SMEAR STAIN - A bloodstain resulting from movement during contact with a bloody object.

DIRECTIONALITY - A determination of the direction in which blood was moving.

HEIGHT TO WIDTH RATIO - A numerical value determined by dividing the height (length) of a bloodspot by its width.

IMPACT SITE - That location on a bloody object which receives a contact blow, often the point of origin of a bloodstain.

POINT OF ORIGIN - That location from which blood is discharged from an object.

TARGET - The surface on which blood is deposited.

REFERENCES

- MacDonell, Herbert Leon, and Bialousz, Lorraine Fiske. Flight Characteristics and Stain Patterns of Human Blood. National Institute of Law Enforcement and Criminal Justice, U.S. Government Printing Office, Washington, D.C., 1971.
- MacDonell, Herbert Leon. Personal communication with Larry R. Bedore, December 1981.
- Kirk, Paul Leland. Crime Investigation Second Edition. John I. Thornton Ed., John Wiley and Sons, New York, 1974.