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The experiments included in this research were conducted in order to compare expired human blood and two commercially available synthetic blood spatter products (Arrowhead Forensics Spatter Blood and Evident® Crime Scene Products Spatter Training Blood) in appearance and fluid dynamics in order to compare similarities and differences between the three substances. For training purposes, synthetic blood substitutes are preferred due to increased safety and reduced costs. Experiments conducted included point of origin calculations at three distances and overall appearance of spatter on wood, tile, denim, and concrete at three distances. It was determined that point of origin calculations at one of three distances was significantly different, but all other distances and experiments were comparable among the three substances.

HUMAN BLOOD VERSUS TWO COMMERCIALLY AVAILABLE BLOOD SUBSTITUTES: A COMPARATIVE ANALYSIS

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HUMAN BLOOD VERSUS TWO COMMERCIALLY AVAILABLE BLOOD SUBSTITUTES: A COMPARATIVE ANALYSIS

THESIS

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CHAPTER 1

INTRODUCTION AND BACKGROUND

Blood is a frequently encountered form of forensic evidence at a crime scene[1]. Analysis of patterns left by bloodshed events is an important component to the reconstruction of such scenes, especially when combined with DNA analysis and wound interpretation[2,3]. The discipline most responsible for blood analysis at crime scenes goes by many names: bloodstain pattern interpretation, blood spatter analysis, bloodstain pattern analysis, and blood splatter analysis/interpretation[2]. The discipline performs analysis of the size, shape, and distribution of bloodstains to determine the order in which they were created and the mechanisms which produced them[3]. Blood spatter analysis can, in simple terms, be described as a forensic tool able to be used to aid crime solving by determining scenarios based on bloodshed events[3].

Rooted in physics, biology, and math, blood spatter analysis can determine origins of bloodstains, type and direction of impact, mechanisms by which spatter would be produced, and potential positioning of victims[3]. Proper training in blood spatter analysis is essential for crime scene analysts. A minimum of forty hours of training from a recognized provider is expected to become a member of the International Association of Bloodstain Pattern Analysts. Certification in bloodstain pattern analysis is also available at the completion of forty-hour blood spatter courses.

Understanding the biological properties of blood and knowledge of common bloodstain patterns are crucial for accurate crime scene reconstructions. These elements can aid in understanding sequences of events at a particular crime scene. An analyst should have background information about the crime, be able to examine the scene, obtain physical evidence or photographs, as well as reviewing autopsy, serology, and DNA reports and crime scene diagrams and notes in order to reconstruct a crime scene in the most accurate manner. A component of the evaluation of scenes in question is conducting experiments in controlled settings to mimic characteristics of observed stains to include or exclude certain scenarios. Due to the subjective nature of blood spatter analysis, limitations do arise and alternate scenarios are always possible.

The earliest study of blood spatter analysis was conducted by Dr. Eduard Piotrowski in 1895 at the Institute for Forensic Medicine in Poland[3]. In 1968, Dr. Paul Kirk introduced the term "reconstruction" in a presentation to the California Trial Lawyers Association[3]. Today, the Scientific Working Group on Bloodstain Pattern Analysis (SWGSTAIN) is a part of the Federal Bureau of Investigation (FBI) and serves a function similar to that of the Scientific Working Group for DNA Analysis Methods.

The identification of human blood has evolved over time, originally classified through ABO and Rh blood group typing and characterization of red cell isoenzymes (isozymes), leading into the current method of DNA typing via short tandem repeat (STR) analysis[1]. Blood is a colloid made of erythrocytes (red blood cells), leukocytes (white blood cells), platelets, and plasma[2]. Considered a complex fluid, blood makes up approximately eight percent of a person's total body weight[2]. The two components of blood that have the

largest effect on blood spatter analysis are liquid plasma and red blood cells[4]. These two components combined are termed hematocrit. Hematocrit is a percentage of packed red cell volume[4] and varies between individuals and also by location within the body[4]. In healthy individuals, hematocrit can range from 30-48% of total blood volume[4]. Less healthy individuals (for example, alcoholics and drug abusers) exhibit hematocrit levels ranging from 15-29%[4].

Most blood cells have no nuclei. Without nuclei, these cells are not useful for obtaining genetic information from a crime scene. When considering the total volume of blood, approximately one percent is useful for genetic analysis[2]. However, crime scene analysts knowledgeable about blood spatter patterns can give an indication as to which stains may be most likely to yield a genetic profile.

Blood viscosity is not constant, being dependent on hematocrit, plasma phase viscosity, time, temperature, and shear rate[4]. A concept known as shear stress variance indicates changes in blood viscosity that vary based on specific situations[4]. In these terms, shear is considered to be the flow of blood and viscosity as a function of pressure gradients (shear stress), vessel diameter, and hematocrit levels[5].

The lack of consistency in blood viscosity is correlated to blood's physical properties. Most liquids follow Newton's law of fluid friction, resulting in a linear relationship between shear stress and shear rate[5]. Plasma and erythrocytes contribute to blood's non-Newtonian properties because of the violation of the fluid friction law[5]. Fluids that are considered non-Newtonian exhibit differences in the relationship between shear stress and shear rate, creating an inability to define a constant coefficient of viscosity. Blood is also classified as

shear thinning, a class of non-Newtonian fluids in which viscosity decreases with increased shear[6]. In addition, red blood cells will migrate toward the axis of vessels, a concept known as axial drift[5]. This is an additional cause for some of blood's unusual properties. Blood is also sticky (due to its viscosity), resulting in a variety of pattern transfers at crime scenes[2].

Bloodstains can be defined as patterns of blood deposited on a surface via an impact to a blood source as a result of a passive action. Bloodstains at crime scenes can be categorized in a variety of different ways. In general, they can be grouped in three major categories. These are: impact stains, passive stains such as clots, drops, flows, and pools, transfer stains such as wipes, swipes, and pattern transfers[2]. There are also two types of spatter, forward and back[2]. Forward spatter is blood that moves in the same direction and away from the force causing the spatter. Back spatter is blood moving backwards towards the source of the spatter. Once blood is deposited in a location, it will begin drying from the outer edges toward the center of the stain[2]. This location, the impact site, generally denotes the location receiving the force of a blow that results in a bloodstain[2]. A point of origin may occasionally differ from the location site, and is the general area from which a drop originates in regard to its flight path[2]. Most methods for point of origin determination have limitations in that these methods will assume that droplets travel in a straight line[2]. However, due to gravity and air resistance, distinct arched parabolas are formed in flight rather than straight lines[2,7].

When there is a break in the circulatory system, there are several bodily reactions. These reactions include: vascular spasm, platelet plugs, and coagulation/ clotting[2]. These reactions occur because when force is applied to fluid mass, the fluid must be displaced in

response to the force[2]. This displacement results in splatter, and can be difficult to accurately predict[2]. Certain displacement forms can, however, be predicted based on the mechanism causing a break in the circulatory system. For example, arterial gushes are large volume patterns that follow the rise and fall of arterial pressure, but are otherwise relatively indistinct[3]. Certain levels of force or energy typically associated with gunshots cause bloodstains to be exhibited as a mist[3]. Cast off spatter stains are generally a result of blood being 'flung' from a secondary object[3].

Physiologically altered bloodstains (PABS) occur in scenarios when blood may be biologically altered prior to landing on a target surface[4]. Alterations include cells settling, drying or coagulating, as well as mixing with other fluids[4]. These bloodstains are important to blood spatter analysis due to their predictable patterns[4]. These predictable patterns can aid in determining time sequences, the possibility of contamination, impression record, and the degree of force needed to disperse clot material[4].

Low velocity stains are usually relatively large; being greater or equal to four millimeters (mm) in diameter and moving at a velocity of up to five feet per second[3]. Medium velocity impact spatter is a pattern with stains that are one to four mm in diameter with the force creating the stain moving at a velocity between five and 100 feet per second[3]. High velocity impact spatter is a pattern in which the majority of the stains are one mm or smaller, with drops moving at 100 feet or more per second[3].

Impact patterns are critical to understanding crime scene events. An impact pattern is a bloodstain pattern that results from an object striking liquid blood, and appears as a radiating pattern of small drops[5]. Impact angle and directionality analysis are important to

consider in crime scene reconstruction in addition to these impact patterns. Most mathematical applications at crime scenes come from determining the impact angle and point of origin for the stain[2]. The impact angle of a blood drop can range from one degree to 90 degrees[2]. Impact angles can be affected by the shape of blood drops, with an assumption that drops impact surfaces while spherically shaped[2]. Directionality describes the path a droplet followed at the time of impact with the target, evidenced by a tail created from the impact of the droplet with the target[2]. The direction of impact and vertical flight path can be determined using the angle of impact and the directionality of the bloodstain[7].

The flight distance of blood drops depends on starting velocity and cross section stress[7]. Cross section stress is the relation of mass to the cross section plane[7]. Blood drops moving on a parabolic trajectory tend to have a lower velocity. In the immediate vicinity of the source, high velocity bursts of blood drops will occur[7]. Over larger distances, a difference in the vertical component (height) and expected center of origin arises due to the curved trajectory of the drop[7].

Bloodstain pattern areas of origin are the three-dimensional locations of a specific blood source, and are important in reconstructing crime scenes[8]. Estimation of the location by directional analysis involves retracing trajectories of selected bloodstains originating from the area[8]. The trajectories are determined through trigonometry relating the ellipse to the impact angle of the droplet and glancing angle of the bloodstain[8]. A glancing angle, or directionality, is the angle between bloodstain travel and a reference angle (say, 90 degrees).

One method to determine point of origin is graphically combining the impact angle and convergence point information[2]. Computer software programs also exist to analyze spatter patterns for point of origin and angle of impact information[1]. These computer programs incorporate aspects of string-based methodology in order to determine the direction of motion of blood droplets[9]. Computer use to analyze spatter patterns is beneficial in the elimination of errors and reduction in set up time at crime scenes[9]. In addition, virtual strings can be mathematically defined[9]. Combining laws of projectile motion with three- dimensional geometry, computer programs can analyze patterns appearing at crime scenes. Advantages of three-dimensional methods include short on-site preps, non-contact measurements of bloodstains, and high accuracy of bloodstain analysis[7]. In particular, vertical components of spatter can be calculated more precisely[7]. In addition to this, computer programs aid in statistical analysis of bloodstain patterns. In events where clusters of spatter occur, such programs can follow initial analysis to conduct hierarchical cluster analysis and other relevant tests.

Determining an area of impact (AOI) of blood spatter at a crime scene can be critical to an investigation. Given that blood is frequently encountered at a scene, the understanding of how it behaves can be significant to understanding the sequence of events and their three dimensional location in space relative to a criminal event. The reconstruction of blood at the scene can strengthen results from biological testing as well as eyewitness accounts of criminal events. The behavior of blood at a crime scene is not limited to the vertical travel of blood at these scenes, but also how blood travels horizontally. Horizontal travel of blood aids in the determination of point of origin and angle of impact from the initial blood letting event, adding to information determined from

vertical calculations. In understanding how blood travels horizontally, it is also important to understand how blood appears on different substrates when moving horizontally.

In blood spatter training, there is a desire to reduce reliance on expired blood products from hospitals and blood banks. This is primarily desired for several reasons. First, although blood banks do test for blood borne pathogens, they are unable to test for every pathogen in existence. In addition, in times where there is a shortage of blood products for transfusions, blood products may not be available for blood spatter training programs. If training settings for blood spatter are unable to obtain free donations of blood products, there is a $50 cost associated with obtaining expired blood products. In addition, human blood needs to be refrigerated, and requires a more hands on clean up method.

Studies have been previously conducted comparing the properties of human blood and animal blood. One of the advantages of using animal blood in experiments is the ease with which animal blood can be obtained in large quantities. However, a disadvantage to animal blood is the potential for infectious diseases to be present in the blood. This is due to the quality control for animal blood not being as stringent as that for human blood, which can therefore present a health risk to the general public.

The Snohomish County Medical Examiner's Office in Everett, Washington has conducted comparison studies using bovine, equine, swine and sheep blood as compared to post-mortem human blood from the peripheral vascular system and the properties of ink[10]. The testing focused on bloodstain shape versus impact angle, medium velocity impact spatter comparisons, and high velocity impact spatter comparisons. The study authors

concluded that there were negligible differences between the animal blood, human blood, and ink in the tests conducted[10].

The London Metropolitan University has also conducted research in the area of blood substitutes to determine if theatrical blood or synthetic medical blood substitutes have similar flow characteristics as equine blood[11]. The sterile oxalated equine blood (from TCS Biosciences) served as the control[11]. Tests conducted include drop height, impact angle, and reconstruction of composite bloodstain patterns[11]. Because synthetic medical substitutes are created for medical purposes, they are expensive. In addition they do not accurately reflect the fluid dynamics of human blood[11].

The objective of this research is to determine similarities and differences between human blood and commercially available blood substitutes over horizontal distances and on several substrates. One aim for this project is to determine if human blood and commercial blood substitutes behave similarly in experimental tests.

The null hypothesis to be examined by this project is that commercially available synthetic blood substitutes will behave in a similar fashion to human blood during fluid dynamics experiments. The alternative hypothesis is that the commercially available synthetic blood substitutes will behave differently than human blood over the course of the experiments.

CHAPTER II

METHODS

Project Outline

Two experiments were performed on aliquots of expired human blood from the Fort Worth Carter Blood Center as well as two synthetic blood substitutes, Evident® Crime Scene Products Spatter Training Blood (Evident®) and Arrowhead Forensics Spatter Blood. The first experiment sought to determine impact angle and point of origin from the three substances (human blood and two synthetic blood substitutes) at three known distances on poster board. The second experiment involved comparing overall appearance of spatter patterns from the three substances at the three known distances on four substrate types often encountered at crime scenes: denim, concrete, tile, and wood. The same measuring devices (yardstick and ruler) were used for all measurements. All measurements were taken in a consistent manner using the Common English Measurement of feet and inches. All blood droplets from experiment one were measured in millimeters using the same photographer's loupe. The denim and poster board were purchased at Target, and the other substrates were purchased at Home Depot. The porcelain tile is Traffic Master 18" X 18". The wood composite had one side that had been pressure treated that resulted in a varnished surface. Experiments were conducted on the side of wood composite that had not been pressure treated. The concrete was 17.75" X 17.5" blocks. The poster board,

concrete block, and denim materials were not reused. The tile was cleaned with ethanol, water, and bleach between experiments. The wood composite was sufficiently large to conduct multiple experiments on the same wood piece without affecting other results. The ambient temperature and humidity were taken immediately prior to the conduction of each experiment to ensure consistency during testing. Sponge weights were also taken to ensure that the sponges within an experiment (or portion of an experiment) were of similar weight. There was one rat trap used for each product (for a total of three rat traps) used consistently across all experiments. The blood drops and spatter from both experiments were photographed for visualization, and were measured in experiment one with a photographer's loupe for statistical analysis.

Sample 1: Human Blood

The human blood was received from Carter Blood Center on ice and stored in a 1000 mL beaker covered with Parafilm after being opened (see Figure 1). Once in the beaker, the blood was stored in a refrigerator when not in use. The blood was type AB and Rh positive. It included red blood cells with adenine saline (AS-1) added. Leukocytes were reduced. The blood was taken from 500mL citrate-phosphate-dextrose (CPD) whole blood. This type of blood product is typical when human blood products are used for blood spatter training purposes. There was some separation of the components of the human blood after sitting for some time (see Figure 2). The blood was mixed when removed from the refrigerator and small aliquots were brought to room temperature prior to each experiment.

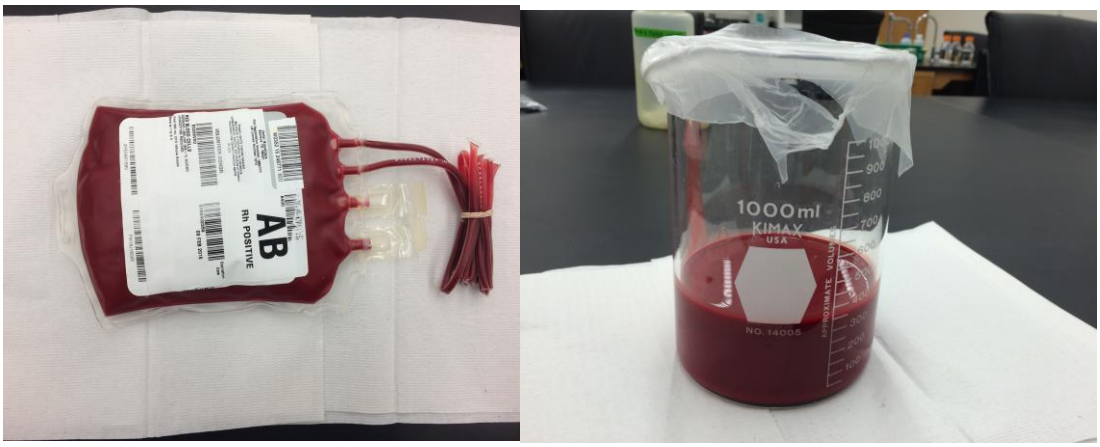

Figure 1. A. Human blood in the original package from the Fort Worth Carter Blood Center. B. Human blood after the original package was opened and the contents were in a storage beaker covered with Parafilm.

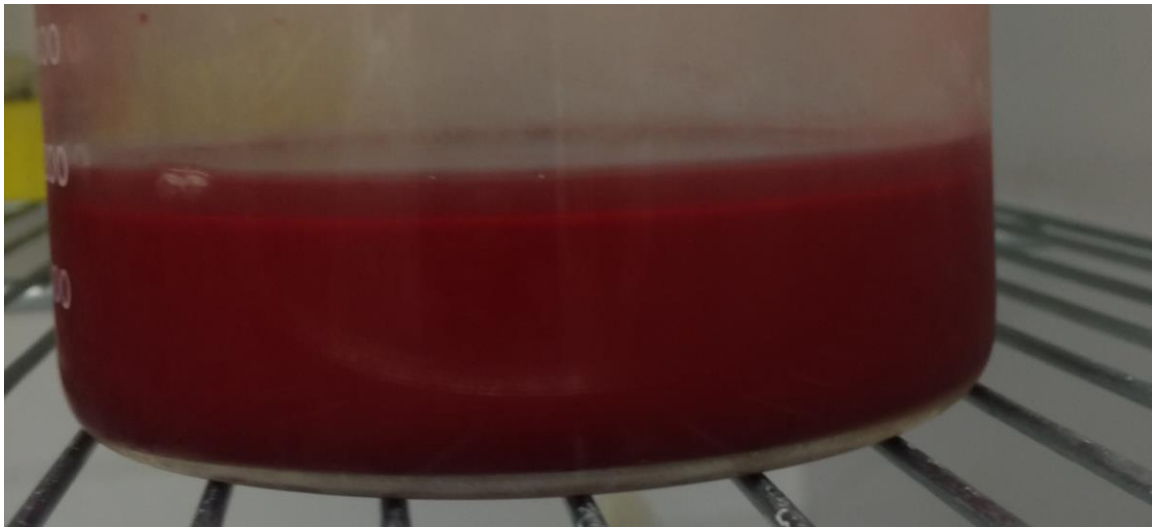
Figure 2. Separation of human blood in storage beaker when not in use.

Sample 2: Evident® Spatter Training Blood

Evident® spatter training blood is described as exhibiting similar properties to fresh human blood. It was developed to eliminate the possibility of pathogens that could originate from human blood and is produced for training purposes[12]. It is described as being, "excellent for demonstrating the properties of fresh blood spatter when dripped,

poured, or splashed onto any surface."[12] A material safety data sheet (MSDS) was available for the spatter blood. The MSDS described the spatter blood as a, "proprietary dilute aqueous mixture containing nonhazardous components."[13] The box that the Evident® spatter blood bottle is stored in notes that the spatter blood will not react with chemical tests for blood and is made of food grade reagents. The Evident® spatter training blood was stored at room temperature and shaken thoroughly prior to aliquots being made (See Figure 3).

Figure 3. Evident® Crime Scene spatter training blood box, bottle, and aliquot in 10 mL beaker

Sample 3: Arrowhead Forensics Spatter Blood

Arrowhead Forensics Spatter Blood is produced for teaching purposes to reduce potential biohazards present in human or animal blood. It is intended to mimic the viscosity, surface tension, and color of human blood[14]. A material safety data sheet (MSDS) was available for the blood product. The MSDS describes the spatter blood from Arrowhead

as, “a proprietary dilute aqueous mixture containing Hemoglobin, amino acids, protein, and other nonhazardous components.”[14] The Arrowhead forensic spatter blood was stored at room temperature and shaken thoroughly prior to aliquots being taken (see Figure 4). This spatter blood is described as not eliciting a positive reaction to presumptive and confirmatory tests for blood[15].

Figure 4. Arrowhead Forensics Spatter Blood box and bottle with an aliquot in a 10 mL beaker

Experiment 1

For this experiment, a rat trap was placed on a lab bench near a whiteboard. White butcher paper was placed on the table, and white poster board was taped to the whiteboard with duct tape. Pieces of Scotch-Brite sponge of similar weight were placed on the rat trap, and saturated with 10 mL of each substance. The height of the rat trap from the floor was maintained at a consistent 37 inches. Spatter patterns were produced in triplicate at each of three distances from the wall, 18 inches, 24 inches, and 36 inches. Distances from the wall were measured from the wall to the edge of the rat trap on which the sponge was placed. Once the spatter dried, three blood drops were identified on the

poster board and circled. Following this, the photographer's loupe was used to determine the width and length of the identified drops to determine the impact angle. The impact angle is calculated via $\sin(\theta)$= width/length. Once the angles were determined, a string was taped to each blood drop, a protractor was held at a 90 degree angle to the wall, and the string was lined up to the calculated angle and secured to the table. It was noted that attaching the string to objects on the table impacted the calculated height from the floor in a negative manner, and attaching the string to the table allowed for more accurate results. These calculations were conducted for each blood drop to give a point of convergence that can be measured (from the wall and from the floor). The measured distances can then be compared to the known distances. This process was repeated for each of the three distances from the wall. ANOVA and Tukey-Kramer post hoc statistical testing were then conducted to determine if statistically significant differences existed between the expired human blood, Evident® spatter training blood, and Arrowhead spatter training blood.

Experiment 2

The objective of the second experiment was to visually compare the spatter patterns produced by the three substances on several substrates potentially found at crime scenes. These substrates are denim, wood composite, tile, and concrete slab. This experiment was conducted to observe and compare spatter patterns of the three blood products at 18 inches, 24 inches (two feet), and 36 inches (three feet). Each substrate was either taped to a whiteboard or rested on the metal edge of the whiteboard. The rat trap was set up in the same fashion as for experiment one, but with only one replicate for each distance with each substrate due to substrate constraints. After the pattern was produced, photographs (with

a camera on a smartphone) and notes of the spatter on each substrate were taken and compared with the results of the other spatter products on that substrate at that distance. Visual comparisons of the blood types on the substrates from this experiment occurred to note differences in blood drop diameter, color, and overall appearance at each distances tested.

Chapter III

RESULTS AND DISCUSSION

Room Temperature and Humidity

The mean room temperature was 70.8 degrees Fahrenheit with a standard deviation of 0.64 and a relative standard deviation of 0.91 percent (see Table 1). The mean ambient humidity was 40.22 percent with a standard deviation of 9.94 and a relative standard deviation of 25 percent (noted in Table 1).

	Temp (°F)	Humidity (%)
	70.5	32
	70	48
	70.9	33
	70.9	32
	71.2	32
	71.3	32
	70.5	48
	70.5	47
	70.3	59
	70	60
	71.1	58
	70.2	57
	69.1	41
	70.9	35
	70.5	37
	70.9	34
	71.2	33
	70.9	32
	71.1	33

	71.2	34
	71.4	35
	71.8	36
	72.1	37
Average	70.80	40.22
SD	0.64	9.94
RSD	0.0091	0.25

Table 1. Recorded Ambient Temperatures, Humidity, Standard Deviation (SD) and Relative Standard Deviation (RSD).

Weight of Sponges

The average weight in grams of the sponges used for each of the experiments was separated by substrate type and blood/synthetic type (see Table 2). The average weight of sponges used for human blood on all substrates was 5.75 grams. The average weight of sponges used for Evident® was 6.05 grams, and the average weight for sponges used for Arrowhead was 6.06 grams.

Table 2. Average weight in grams of sponges used for each substrate separated by blood type.

	Human Blood	Evident	Arrowhead
Poster board	5.61	5.78	5.71
Denim	6.31	7.57	7.57
Tile	5.73	5.6	5.9
Concrete	5.73	6.03	5.62
Wood	5.37	5.26	5.52
Average	5.75	6.05	6.06

Experiment One: Point of Origin Calculations

Point of Origin calculations were separated into groups based on the known distances from the substrate (18, 24, and 36 inches) from which the spatter originated. The

distance from the floor at each distance was a consistent 37 inches with all three substances. Known distances from the floor and substrate as well as the average calculated distances from the floor and wall can be found in Table 3 for 18 inches from the substrate, Table 4 for 24 inches from the substrate, and Table 5 for 36 inches from the substrate. Figure 5 illustrates a point of convergence with strings from which the distance from the wall and distance from the floor can be determined. One-way ANOVA testing was performed to determine whether significant differences exist between the substances at each of the three distances. There was a significant difference ($p=0.003$) between the calculated distances from the substrate for the three substances in the 18 inches from the substrate group, as well as a significant difference between the substances at that distance for the height from the floor ($p=0.03$). After post-hoc Tukey-Kramer testing, it was determined that statistical differences existed in the 18 inches from the wall group between human blood and Evident®, as well as between Evident® and Arrowhead. For the difference seen in the distance from the floor, the difference was between Evident® and Arrowhead. For the 24 inch group, the results of the distance from the substrate calculations indicate that the three blood products are comparable ($p=0.38$). The results from the height from the floor calculations for this group also indicate comparable results between the blood products ($p=0.23$). With the 36 inches from substrate data, the results are comparable for the three blood products from the substrate ($p=0.91$) as well as from the floor ($p=0.91$).

Table 3. Known and calculated distances (in inches) with ANOVA p-value for all three products at 18 inches. *and ^ indicate locations of difference in each row.

	Known Human	Calculated (Average)	Known Evident®	Calculated (Average)	Known Arrowhead	Calculated (Average)	P-value

Distance from substrate	18	16.67*	18	20.67*^	18	10.17^	0.003
Distance from floor	37	40.17	37	36.33*	37	42.67*	.03

Table 4. Known and calculated distances (in inches) with ANOVA p-value for all three products at 24 inches

	Known Human	Calculated (Average)	Known Evident®	Calculated (Average)	Known Arrowhead	Calculated (Average)	P-value
Distance from substrate	24	19	24	24.08	24	21	0.38
Distance from floor	37	37.33	37	36.33	37	40	0.23

Table 5. Known and calculated distances (in inches) with ANOVA p-value for all three products at 36 inches

	Known Human	Calculated (Average)	Known Evident®	Calculated (Average)	Known Arrowhead	Calculated (Average)	P-value
Distance from substrate	36	31.67	36	27.5	36	29	0.91
Distance from floor	37	37.33	37	37	37	37.33	0.91

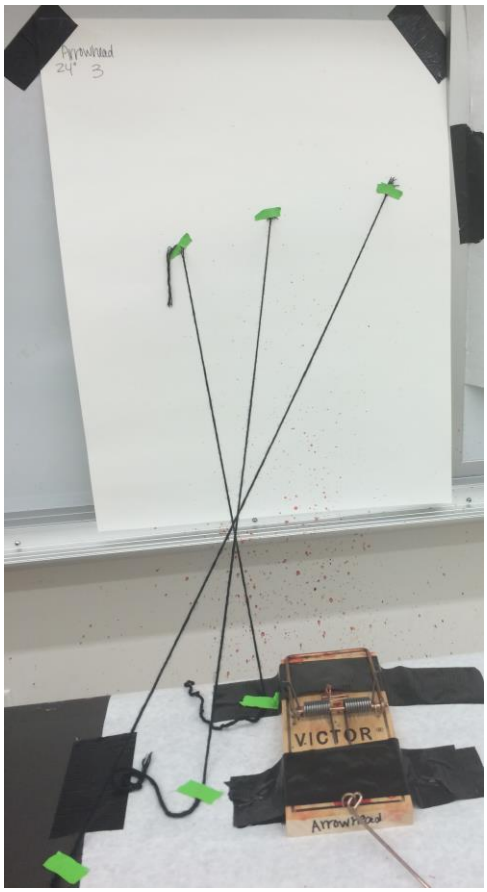

Figure 5. Three point convergence to determine point of origin

Experiment Two: Impact Spatter Pattern on Substrates

Analysis of impact spatter patterns were separated based on the substrate the products were spattered onto (denim, tile, wood, and concrete). Notes were taken observing the spatter patterns present on each substrate from each known distance (18 inches away, 24 inches away, and 36 inches away). Photographs were also taken showing overall appearance of the substrate after spatter as well as images of small sections of droplets or individual droplets to show size, color, or any unusual appearance.

The spatter seen on denim from human blood was a deep red color that continued to be a red-brown color after drying. It was difficult to visualize human blood droplets on the navy blue denim color, even from spatter that originated 18 inches away (see figure 6).

The color of the blood on the sponge prior to impact was also a deep red color. Overall spatter and size of droplets decreased as the distance from the rat trap to the substrate increased. The denim used for the 24 inch (see figure 7) and 36 inch spatter was the inside portion of the denim, a lighter color than the portion of denim used for the 18 inch spatter. The smallest stains were observed with the denim stain at 36 inches (three feet) from the substrate in which only two blood droplets were seen on the denim (see figure 8). When examining a lighter denim, the blood was more easily visualized. It was still difficult, however, to identify any stains from human blood on denim from more than several inches away.

Figure 6. A. Sponge and denim after spatter from 18 inches. B. Denim and surrounding surface from spatter 18 inches away. C. Close up of blood from spatter 18 inches away

Figure 7. A. Overall picture of human blood on denim from 24 inches away. B. Close up of denim with bloodstains visible.

Figure 8. A. Wide shot of human blood at 36 inches. B. Close up of one of the blood droplets from spatter at 36 inches.

Both Evident® and Arrowhead synthetic blood products appeared to be a lighter red than human blood, both on the sponge as well as after spatter. When the synthetics dried on the denim, the red color was lighter and brighter than the deep red color seen with the human blood. The droplets from both synthetics were easier to see on the denim than the human blood, yet still difficult to visualize on a darker denim color. This was noticed at all distances for both synthetics as well as the human blood. At 18 inches from the substrate, the synthetics were consistent with each other in terms of overall spatter and droplet size. They were consistent with the human blood in approximate droplet size, yet the overall spatter around the substrate appeared to be narrower with the synthetics than with the human blood (see figure 9 for Evident® and figure 12 for Arrowhead). At 24 inches (two feet) from the substrate, both Evident® and Arrowhead saw few stains on and around the substrate (see figure 10 for Evident® and figure 13 for Arrowhead). At 36 inches, Arrowhead's spatter was consistent with the human blood spatter in that there were very few droplets seen on the substrate (see figure 14). The spatter from Evident® at 36 inches included more drops than were exhibited by the other two substances at 36 inches as well as more drops exhibited by Evident® at 24 inches (see figure 11). The droplets from Evident and Arrowhead at 24 inches were approximately 1 mm in diameter, and 0.5-0.8 mm in diameter at 36 inches. It is impossible to accurately calculate impact angles or point of origin from stains on denim at any of these distances, from any of the three blood products used. This is primarily due to the absorbent nature of denim. In addition, with darker denim colors, accurately identifying any stains at all can be difficult.

Figure 9. A. Evident® spatter from 18 inches B. Close up of spatter pattern on and around denim C. Close up of spatter droplets on denim from18 inch spatter

Figure 10. A. Evident spatter from 24 inches. B. Droplet from Evident 24 inch spatter.

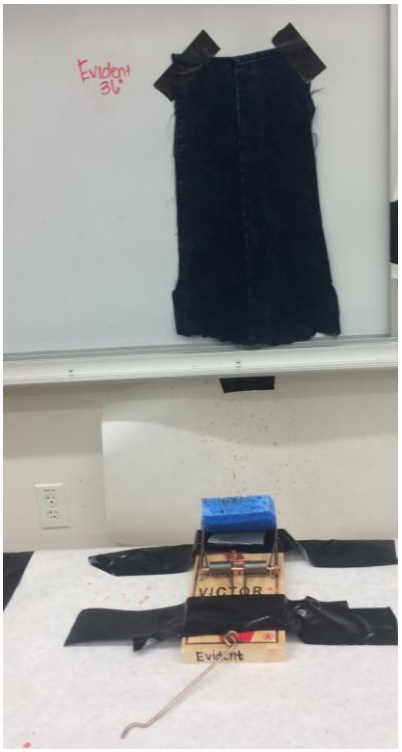

Figure 11. A. Overall image of Evident® spatter at 36 inches on denim B. Spatter droplets on denim

Figure 12. A. Arrowhead at 18 inches. B. Droplet from Arrowhead showing difficulty visualizing the droplets

Figure 13. A. Overall view of Arrowhead at 24 inches. B. Droplets from Arrowhead at 24 inches.

Figure 14. A. Overall view of Arrowhead at 36 inches. B. Droplet from Arrowhead at 36 inches.

On concrete, the human blood was also notably a deep red color at all three distances. As it dried on the concrete, the human blood became a deeper red, almost brown color. At 18 inches, there were numerous droplets, some greater than 2.5mm in diameter (see figure 15). Many of the droplets have irregular edges (spines) seen at 24 inches and 36 inches. Such irregular droplets would make determining impact angles and point of origin difficult, if not impossible to do accurately. The concrete surface used as a substrate for the 24 inch distance with human blood had been used in a previous project involving human blood. Due to this, there were several stains from human blood that demonstrated how dark blood can become when completely dry (see figure 16). The color of the blood used on this surface for spatter from 24 inches was consistent with the color from 18 inches, so

stains from this project could be differentiated from the previously existing stains (see figure 16). There was some spatter to the left and right of the concrete substrate seen at 24 inches. In addition, the spatter droplets here appeared to be overall smaller in size than in the previous stains. With the spatter from 36 inches onto concrete, there was only one clear droplet that could be identified on the concrete itself. This droplet was consistent in color with the droplets at 18 and 24 inches, and was similar in size to the droplet at 24 inches (see figure 17).

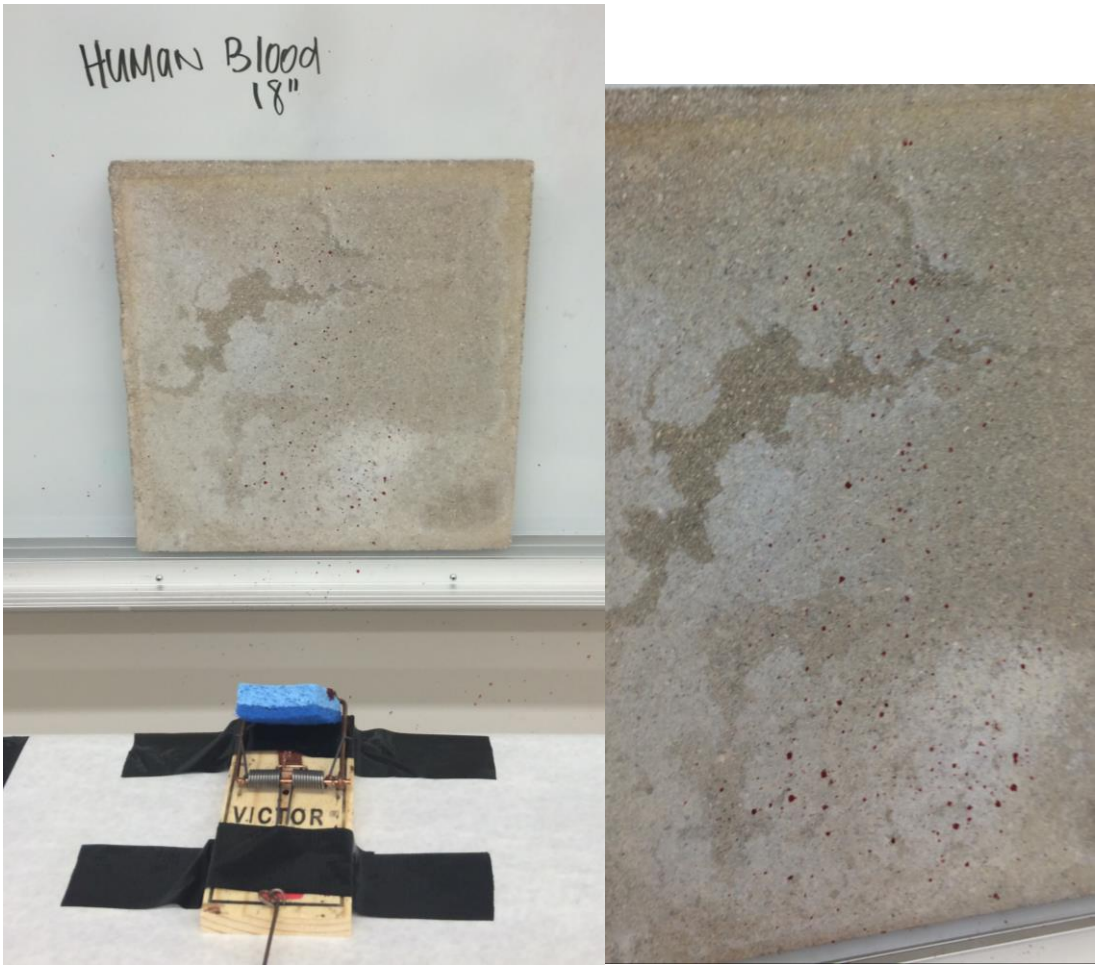

Figure 15. A. Overall of human blood on concrete at 18 inches. B. Droplets observed on the concrete

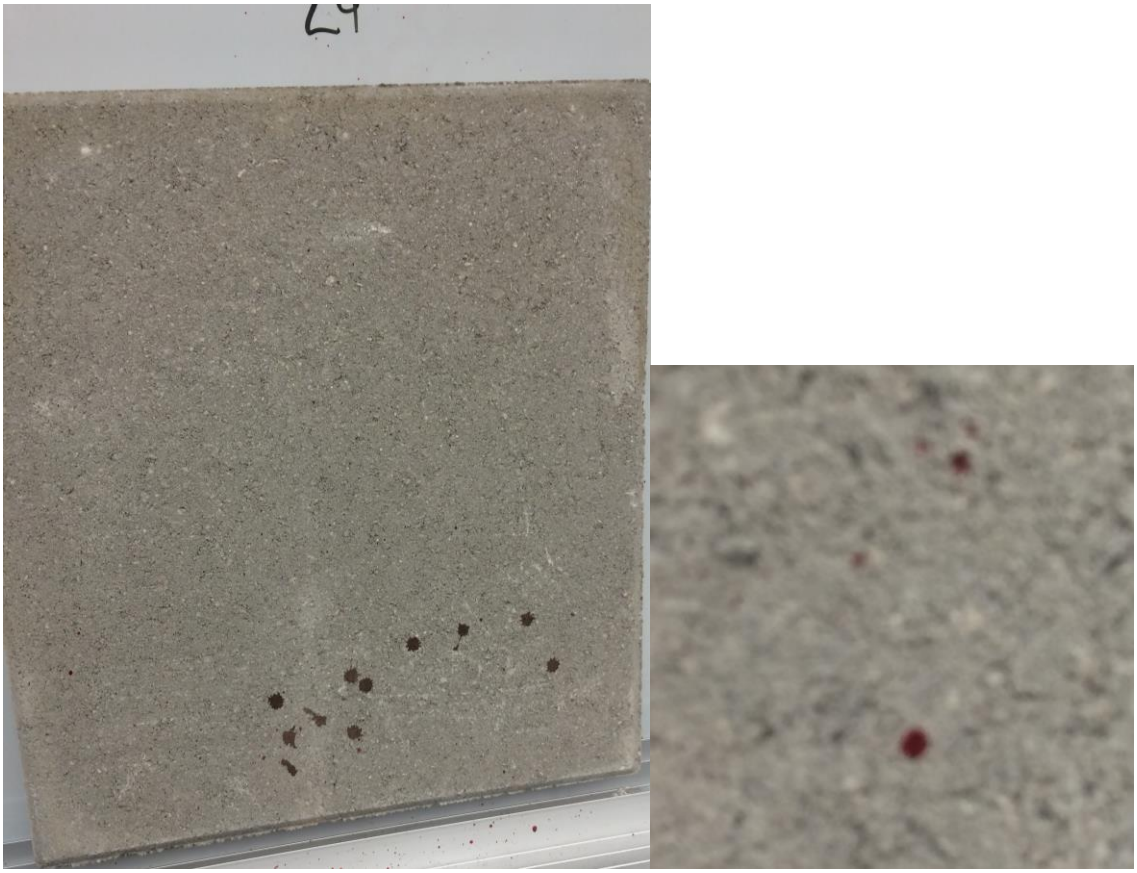

Figure 16. A. Overall image of human blood at 24 inches with brown droplets from previous project. B. Droplets from spatter at 24 inches.

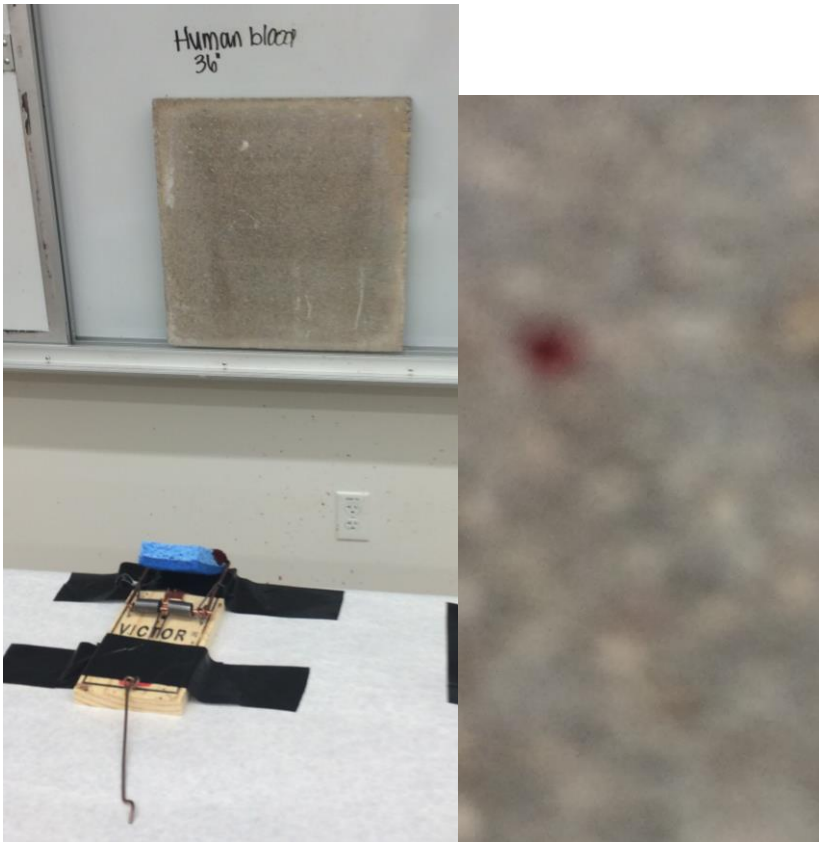

Figure 17. A. Overall appearance of human blood spatter from 36 inches. B. Single droplet from spatter at 36 inches.

Due to a single droplet being seen at 36 inches for human blood, that surface was used again for spatter from the Evident® spatter blood at 18 inches. The droplet from the human blood was circled so that it would not be confused with the droplets from the Evident® spatter. At 18 inches, the Evident® spatter onto concrete was generally consistent in size with the human blood spatter at 18 inches. The spatter appeared larger because several droplets landed close enough to overlap. However, the color is a bit lighter red on the sponge and on the concrete. When dry, the color of Evident® on concrete is also lighter than human blood on the same substrate. There was also not as much spatter to the sides of the substrate (as compared to spatter from the blood). However, with both the human

blood spatter and Evident® spatter, there was spatter below the substrate, and droplets on the floor (see figure 18). At 24 inches, there was considerable back spatter that hadn't been noticed with the previously conducted spatter experiments. It is not unusual for back spatter to occur in such a scenario. The droplets on the substrate were hard to see and light in color, as if they had dried on contact with the concrete. There were fewer drops seen at this distance than at 18 inches with the same product. Unlike the spatter from 24 inches with human blood (where droplets were mainly concentrated in the lower right corner), the spatter was more evenly distributed across the surface (see figure 19). At 36 inches, the droplets seen were equal to or larger in size than the droplets at 18 inches. It was easier to visualize the spatter at this distance on the concrete than at 24 inches away. The color also appeared to continue to be lighter in color than the human blood. The spatter pattern at 36 inches also appeared to cover more of the substrate area than the spatter from 18 inches (see figure 20).

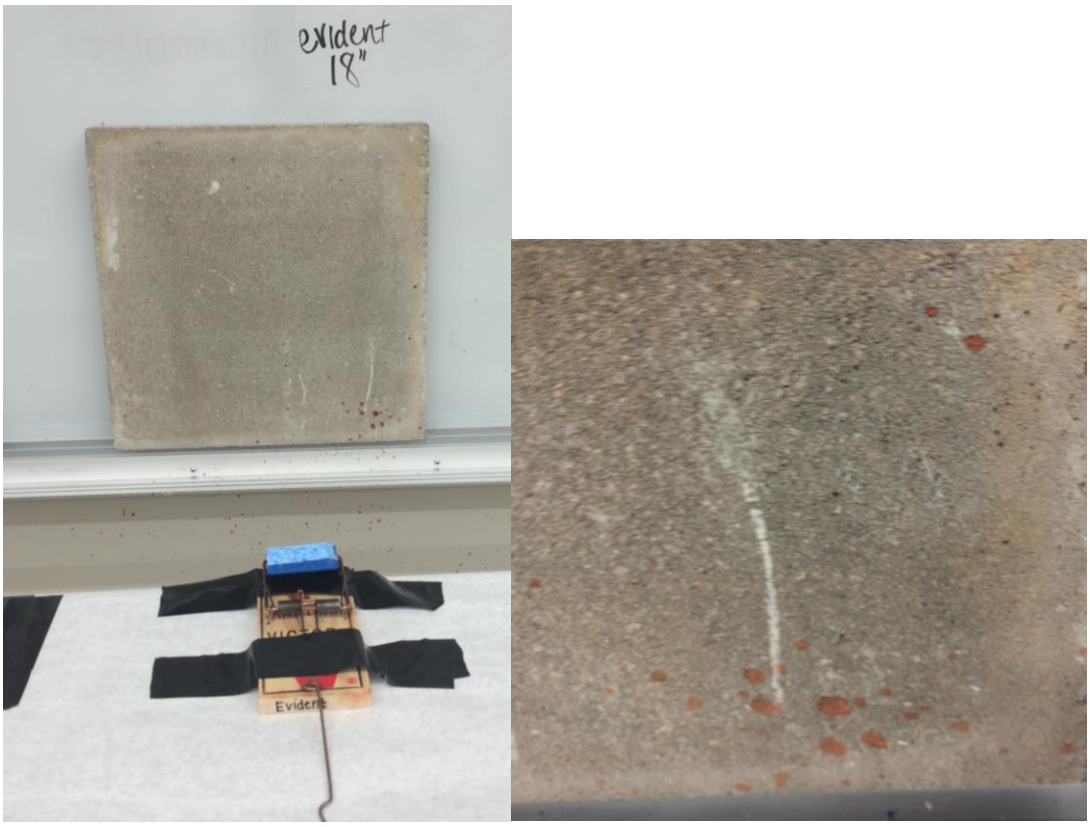

Figure 18. A. Overall spatter from Evident® blood product from 18 inches away B. Close up of spatter from Evident® 18 inches.

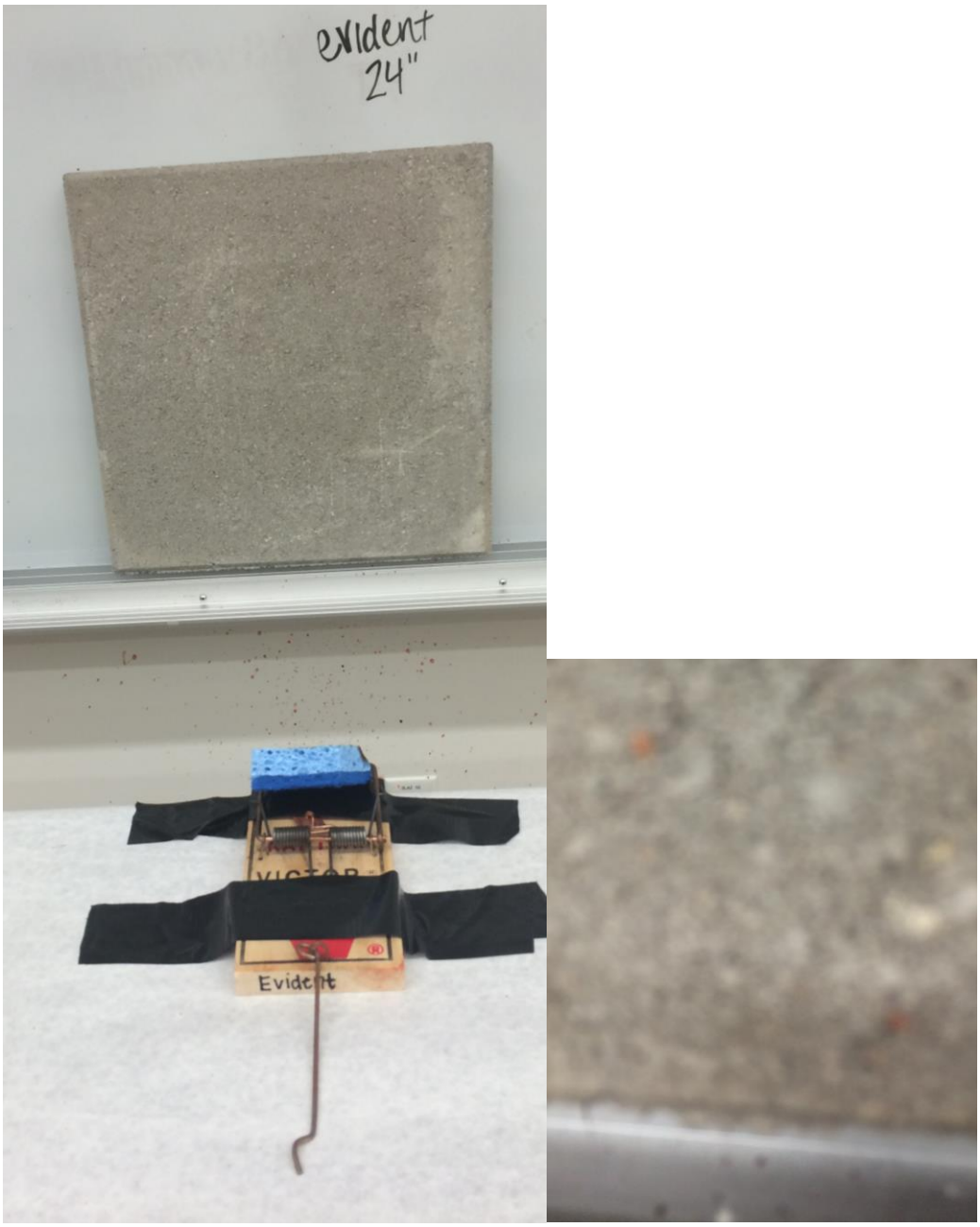

Figure 19. A. Overall image from Evident® 24 inches. B. 2 droplets of Evident® spatter from 24 inches.

Figure 20. A. Overall image of spatter from Evident® 36 inch distance. B. Spatter from Evident® product 36 inches from substrate.

As with human blood and Evident® spatter patterns on concrete, spatter from the Arrowhead blood product would cause difficulty in calculating impact angle and point of origin due to the shape of the droplets observed. At 18 inches, the spatter from Arrowhead was relatively light (lighter than human blood, but roughly on par with the color of the Evident® product) and was primarily seen on the lower portion of the concrete surface. The spatter pattern observed used less surface area on the concrete than either blood or Evident® at the same distance. The largest of the droplets seen was roughly 2.5mm in diameter (see figure 21). At 24 inches, there was back spatter, much like Evident® at the

same distance. However, the back spatter was merely heard hitting surfaces and what surfaces it came into contact with could not be identified. There were some stains at this distance that were lighter in color, others that were darker in color. However, even the darkest stains seen here were not as dark as human blood on concrete. The stains at this distance varied in size from roughly 2.5mm in diameter to slightly less than 1mm in diameter. The spatter here mostly appeared on the left side of the substrate and the bottom portion of the substrate (see figure 22). At 36 inches, there were few droplets seen from the Arrowhead product on the concrete substrate. The light color observed was consistent with the color of the rest of the Arrowhead spatter on concrete. The droplets seen were approximately 1mm by 1mm. There was not much spatter around the substrate on the wall, and there may have been some back spatter at this distance (see figure 23).

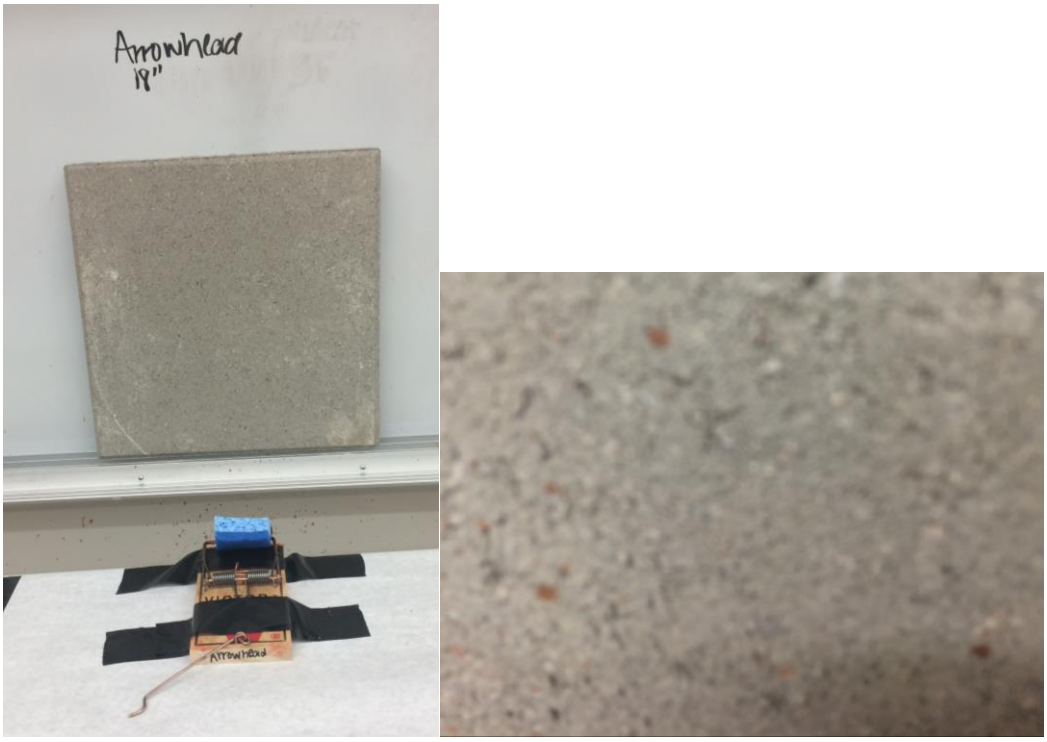

Figure 21. A. Overall Arrowhead 18 inch substrate B. Droplets from Arrowhead's 18 inch spatter

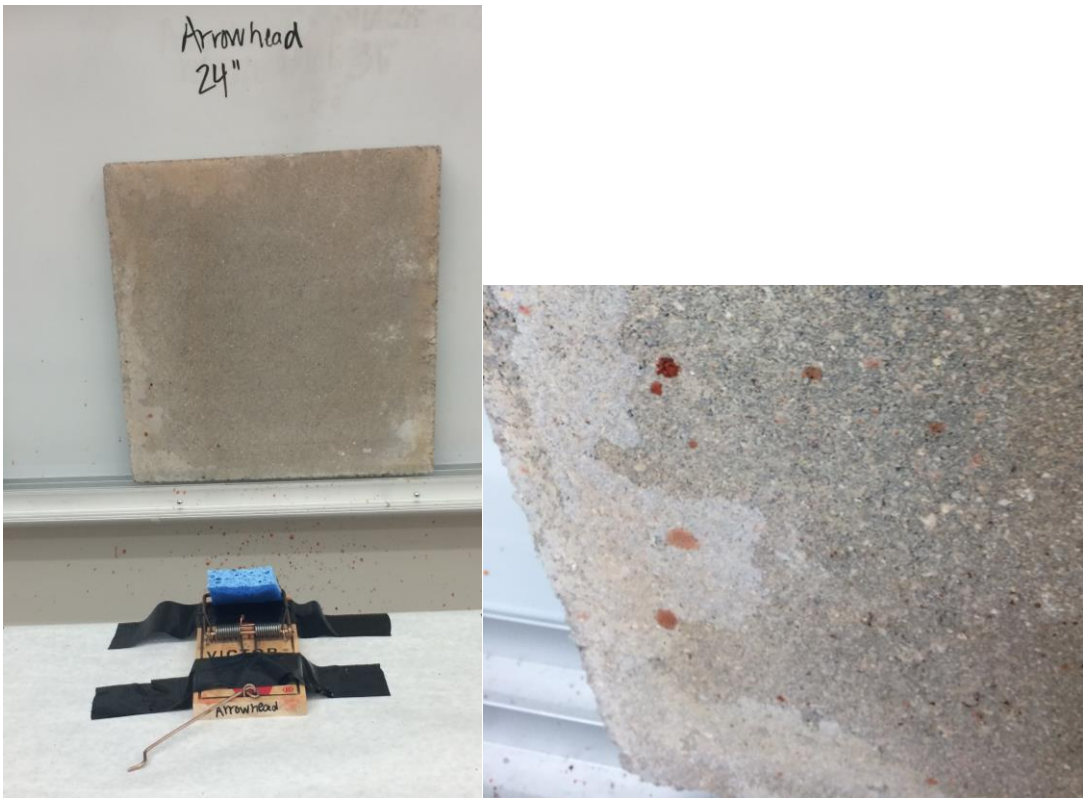

Figure 22. A. Overall spatter from Arrowhead product from 24 inches B. Droplets from lower left corner of Arrowhead 24 inch spatter

Figure 23. A. Arrowhead 36 inches B. Droplets from 36 inch distance with Arrowhead product

It would be difficult to determine impact angles and point of origin from a substrate such as wood due to the irregular nature of the spatter droplets. This was consistent for all three substances. In the human blood experiments, at 18 inches, it was noted that most of the spatter observed was below the substrate, with not much spatter impact on the surface of the wood. This may be due to substrate placement, and if the wood were placed lower, more spatter may have been present on the substrate. The color of the blood in this experiment was consistent with the color in the rest of the experiments. The droplets observed on the wood ranged from approximately 1mm in diameter to 2.5mm in diameter (see figure 24). At 24 inches, the individual droplets were overall smaller than at 18 inches, with most approximately 1mm in diameter. Though the dark blood color contrasted with

the light wood color, the droplets were difficult to see, especially from a distance. In similarity to the spatter at18 inches, there was a portion of the spatter pattern below the substrate as well as on the floor between the impact surface and the substrate. The portion of spatter seen on the substrate was primarily concentrated on the bottom half (see figure 25). The results at 36 inches were fairly consistent with the results at 24 inches. The spatter appearing on the substrate was on the lower portion, and due to the small size (approximately 1mm in diameter), was difficult to see from a distance (see figure 26).

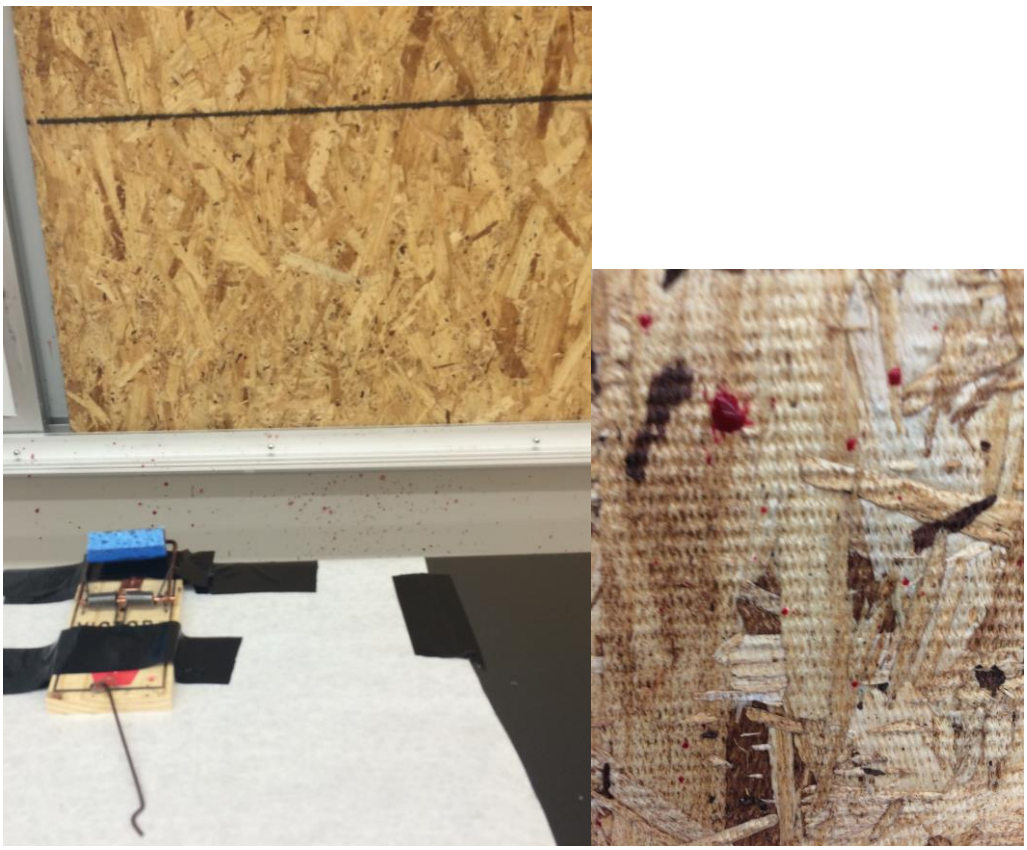

Figure 24. A. Spatter from 18 inches with human blood. B. Droplets from human blood

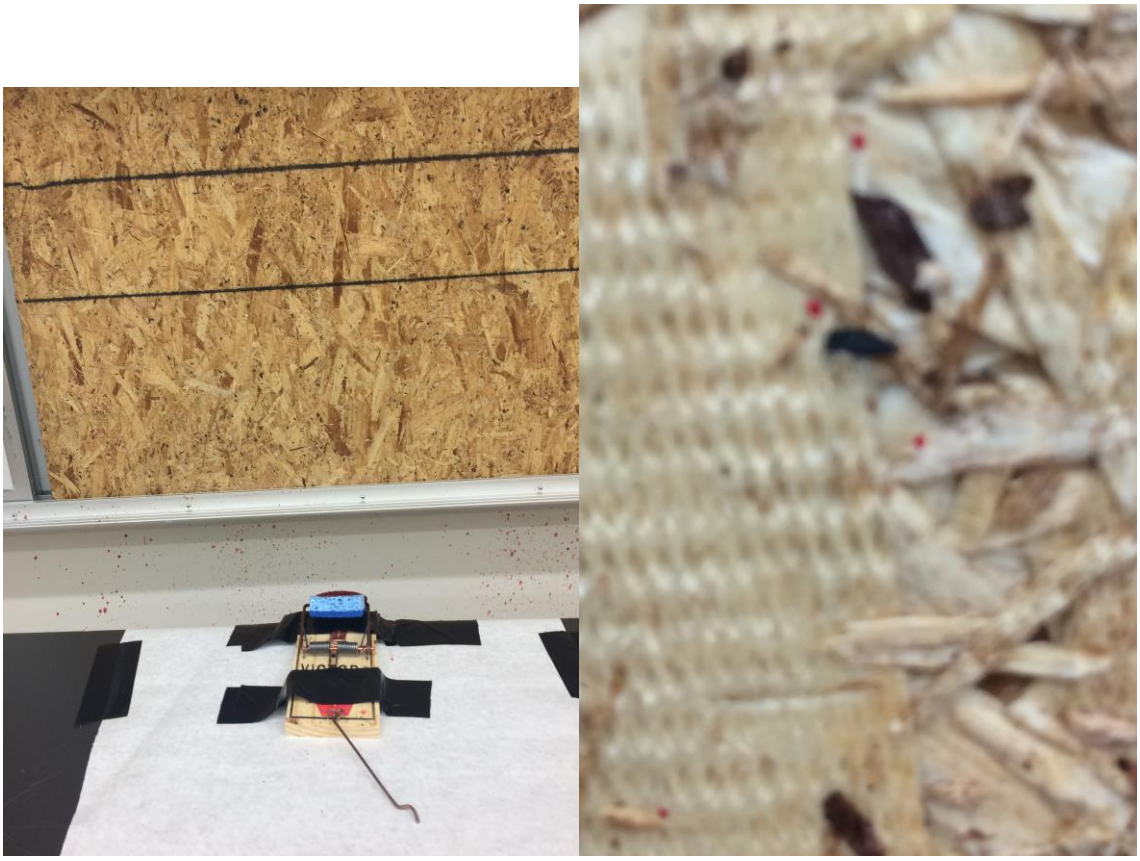

Figure 25. A. Spatter from 24 inches. B. Droplets from 24 inches with human blood

Figure 26. A. Human blood on wood from 36 inch spatter. B. Droplets from blood at 36 inches.

The color of the Evident® product continued to be a lighter color than the human blood. With this product, there was back spatter that occurred at all three distances measured. The back spatter that occurred may have been more than what had occurred with human blood, and may have affected the visible forward spatter patterns. There was not much spatter observed at 18 inches, and the spatter that was observed was difficult to visualize on the wood (see figure 27). The visualized spatter showed some size variation within the droplets, but no droplets were exceptionally large or exceptionally small. At 24 inches, there was some spatter observed below the substrate, similar to what occurred with the human blood. Some of the spatter at this distance could be seen from a greater distance, yet there was not much visible overall (see figure 28). At 36 inches from the substrate, there were more droplets overall than with 18 inches or 24 inches. The droplets at this distance were consistent in size and continued to be difficult to see from a distance (see figure 29).

Figure 27. A. Wood with Evident® spatter from 18 inches. B. Droplets from Evident® 18 Inch spatter.

Figure 28. A. Evident® 24 inches from distance. B. Droplets of Evident® from 24 inch spatter

Figure 29. A. Substrate Evident® 36 inch spatter B. Droplets from Evident 36 inch spatter

At 18 inches from the wood with Arrowhead, there was not much splatter on the substrate. There was some spatter observed below it, as well. The droplets seen on the wood were mostly concentrated on the lower portion of the surface of the substrate. When dry, the Arrowhead was lighter than human blood, and was consistent in color with Evident® droplets. There was some size variation in the spatter droplets, but none were exceptionally large or small (see figure 30). At 24 inches, the spatter was more widespread across the wood than the spatter from 18 inches. The droplets were all roughly 1-2 mm in size (see figure 31). At 36 inches, the amount of spatter observed on the wood was roughly consistent with what was observed at 18 inches, and less than what was observed at 24

inches. The spatter was primarily at the bottom portion of the substrate (similar to the spatter from 18 inches), and the droplets were approximately the same size as the droplets at 24 inches (see figure 32).

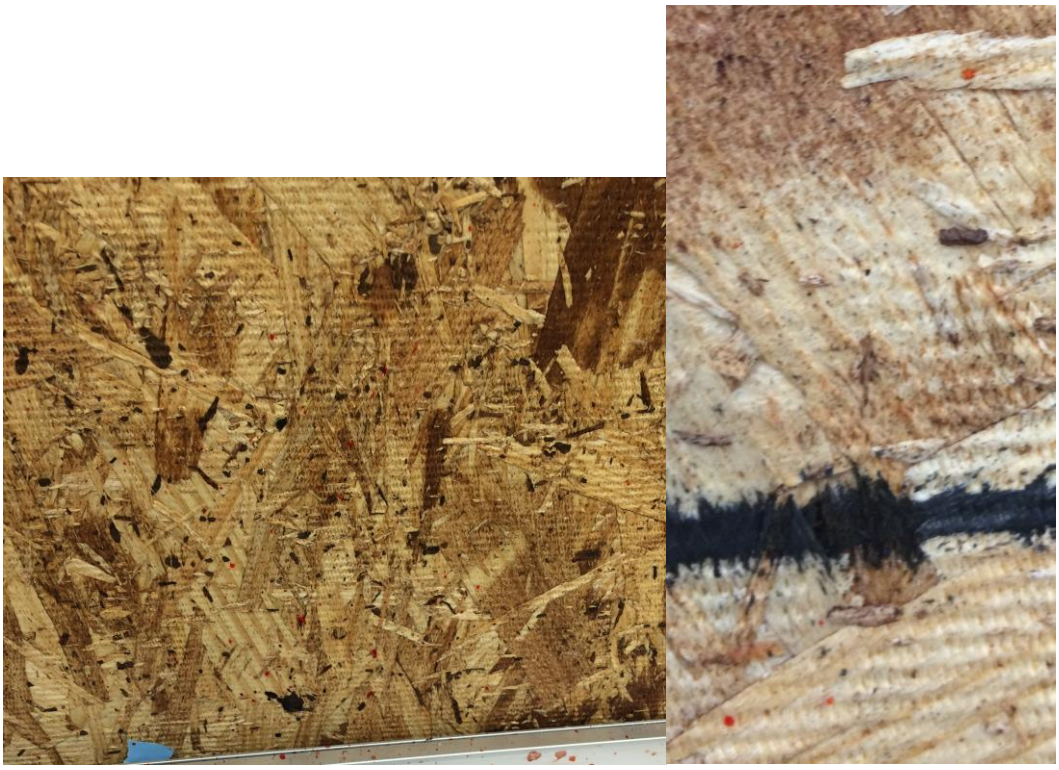

Figure 30. A. Arrowhead 18 inches B. Droplets from Arrowhead 18 inch spatter

Figure 31. A. Arrowhead 24 inches B. Droplets from Arrowhead 24 inch spatter

Figure 32. A. Arrowhead 36 inches on wood B. Droplets of Arrowhead on wood from 36 inch spatter

On the porcelain tile, determining impact angles would be difficult with all blood products used. This is due to the spatter droplets traveling down the surface of the tile after impact, affecting any ability to accurately determine length or width. This particular observance may have occurred due to the smoothness of the tile surface (in addition to gravity) that is not exhibited by wood, concrete, or denim. This was especially noted with the two synthetic blood products. The human blood continued to be a dark red color, with both Evident® and Arrowhead products being a lighter red. Human blood with an impact 18 inches away exhibited droplets with the largest approximately 1-1.5mm in size. There was some spatter observed below the substrate, and due to the light color and smooth surface of the tile, it was not as difficult to visualize spatter as with concrete, wood, or denim (see figure 33). At 24 inches, the spatter was similar in size to the spatter at 18 inches with the droplets appearing more concentrated around the 1-1.5mm size (see figure 34). At 36 inches, there was not much spatter seen on the substrate. However, several drops could be easily observed from this distance. The droplets were fairly consistent in size with the droplets from 18 inches away and 24 inches away. There was some spatter below the substrate from this distance, similar to 18 inches (see figure 35).

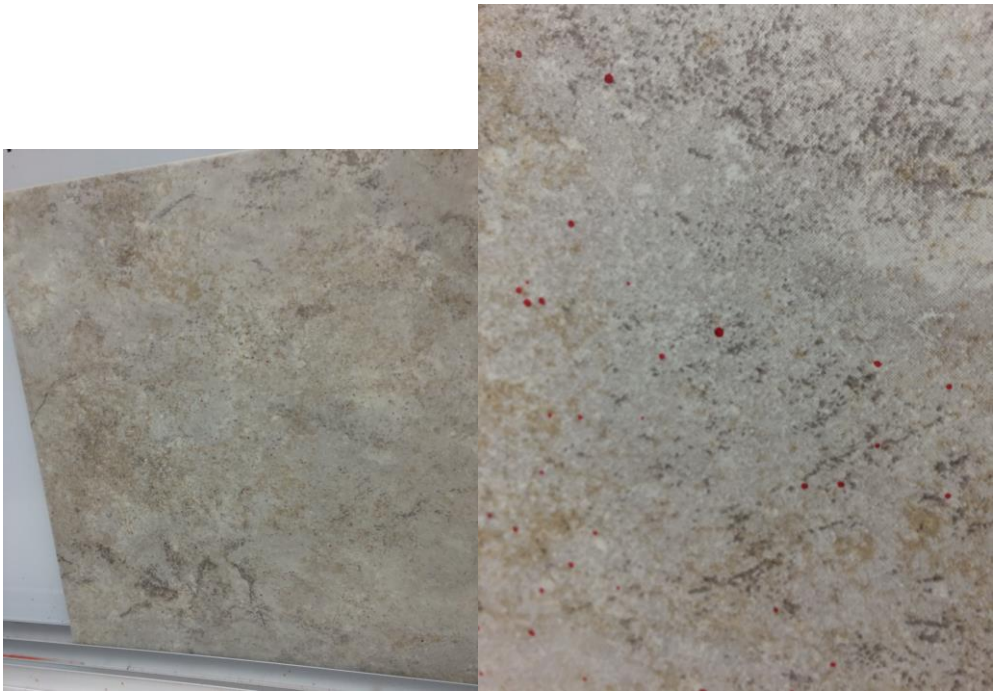

Figure 33. A. Human blood 18 inches B. Droplets from human blood 18 inches

Figure 34. Human blood 24 inches. Droplets of human blood on tile from 24 inches

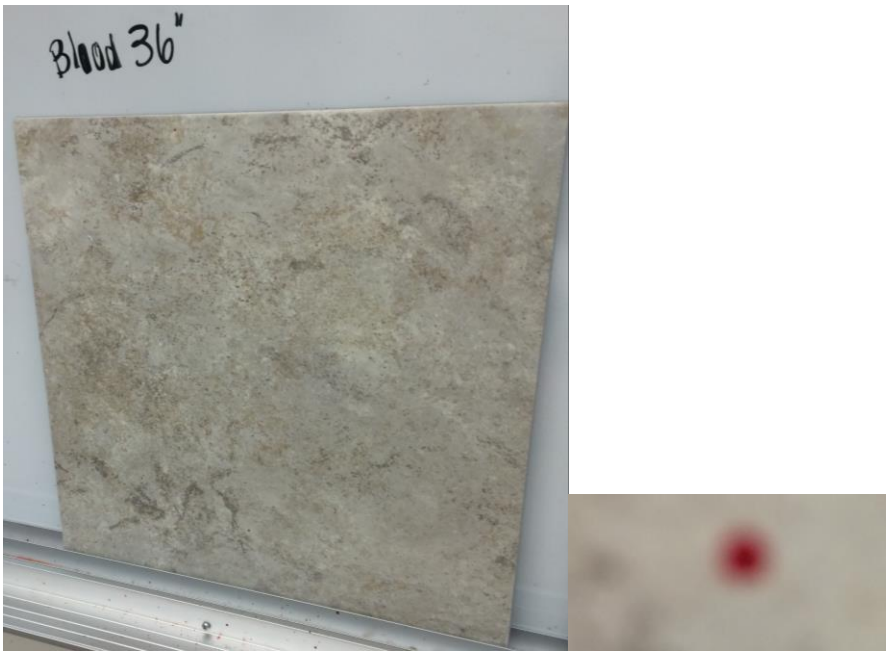

Figure 35. A. Human blood spatter from 36 inches B. Droplet of blood from 36 inch spatter

At a distance of 18 inches with the Evident® product, there were several large droplets that moved down the tile surface with gravity after impact. Many of the droplets were fairly large (3-5mm), which was much larger than the droplets from blood. However, there were some droplets observed that were approximately the same size as the droplets observed from human blood. Especially when moving on the tile surface, the color of Evident® was much lighter than human blood (see figure 36). At 24 inches, there was not much spatter observed. The spatter that was observed was much lighter and fainter than Evident®'s typical color. The droplets that were observed, however, were approximately 1-2mm in size (see figure 37). The impact from 36 inches away also led to not much spatter being observed. The spatter from 36 inches was similar to what was seen at 24 inches, however the size of the droplets was larger. With this spatter, there were some droplets

affected by gravity, changing their size. The color of the product at this size was lighter than 18 inches, but darker than 24 inches (see figure 38).

Figure 36. A&B Evident® spatter from 18 inches away showing droplets on tile

Figure 37. A. Evident® spatter from 24 inches on tile B. Droplets from Evident® spatter from 24 inches

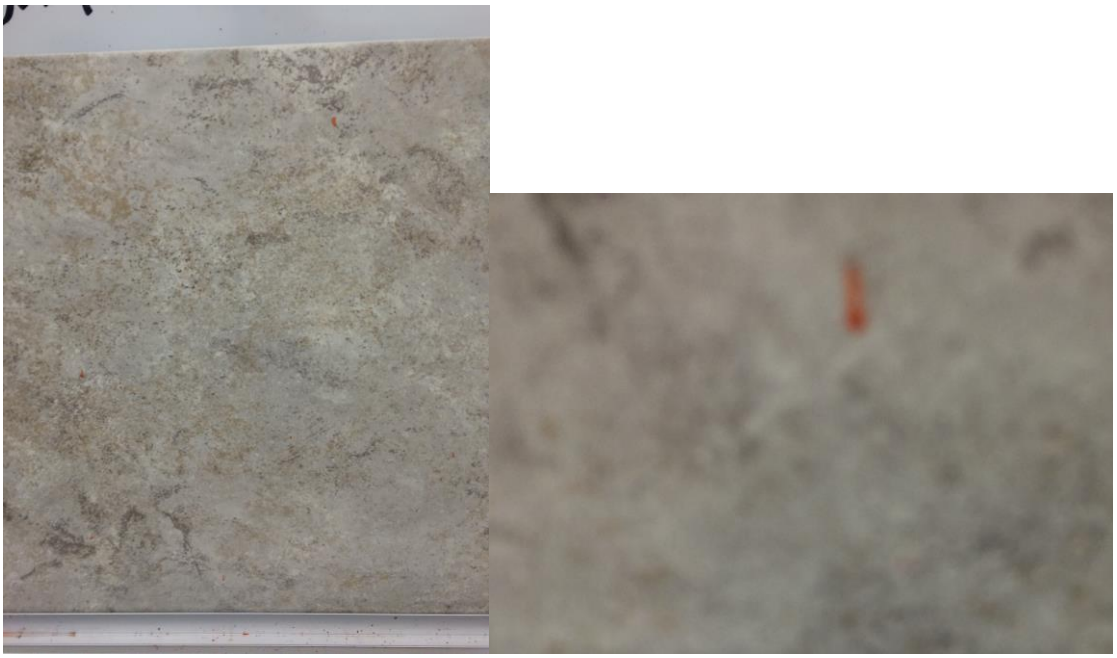

Figure 38. A. Overall Evident® spatter from 36 inches. B. Evident® droplet from 36 inch spatter

With spatter from 18 inches away, Arrowhead's spatter was scattered across the substrate and approximately 1-1.5mm in diameter at the largest. The color was lighter than blood, but continued to be consistent with Evident®'s color at 18 inches (see figure 39). From 24 inches away, the spatter was larger overall than from 18 inches, and the color was lighter than that from 18 inches. Some of the drops exhibited the same gravitational pull seen with some of the Evident® results (see figure 40). The results from 36 inches were consistent in size and color with 18 inches and 24 inches, however, there was no observed gravitational flow from any of the droplets (see figure 41).

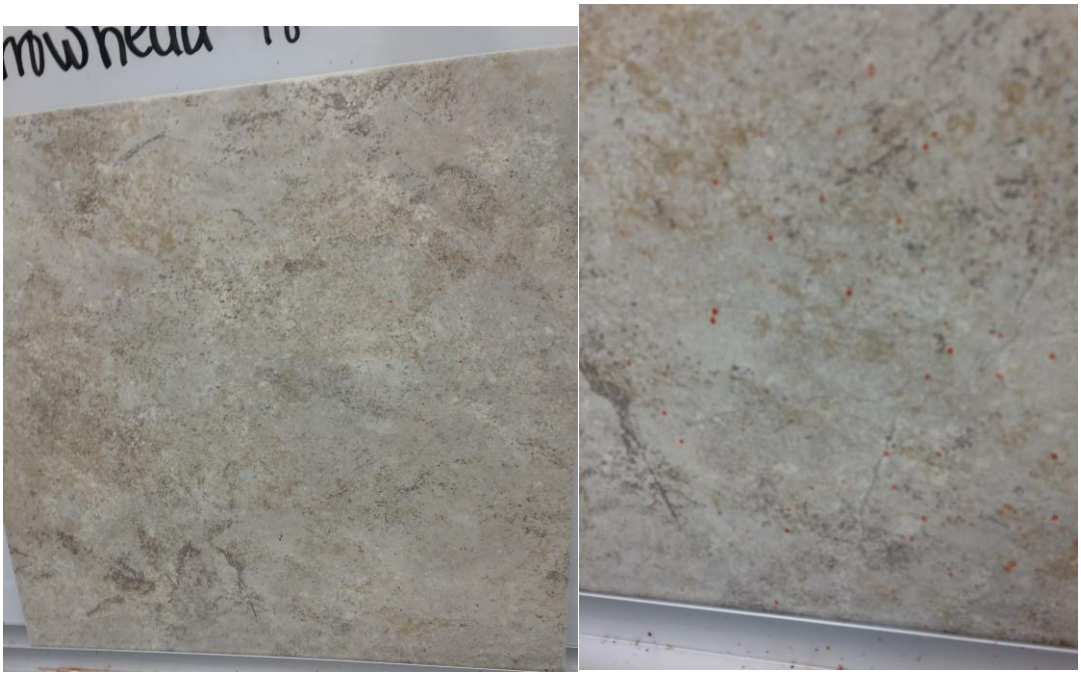

Figure 39. A. Overall Arrowhead 18 inches B. Droplets from Arrowhead's 18 inch spatter

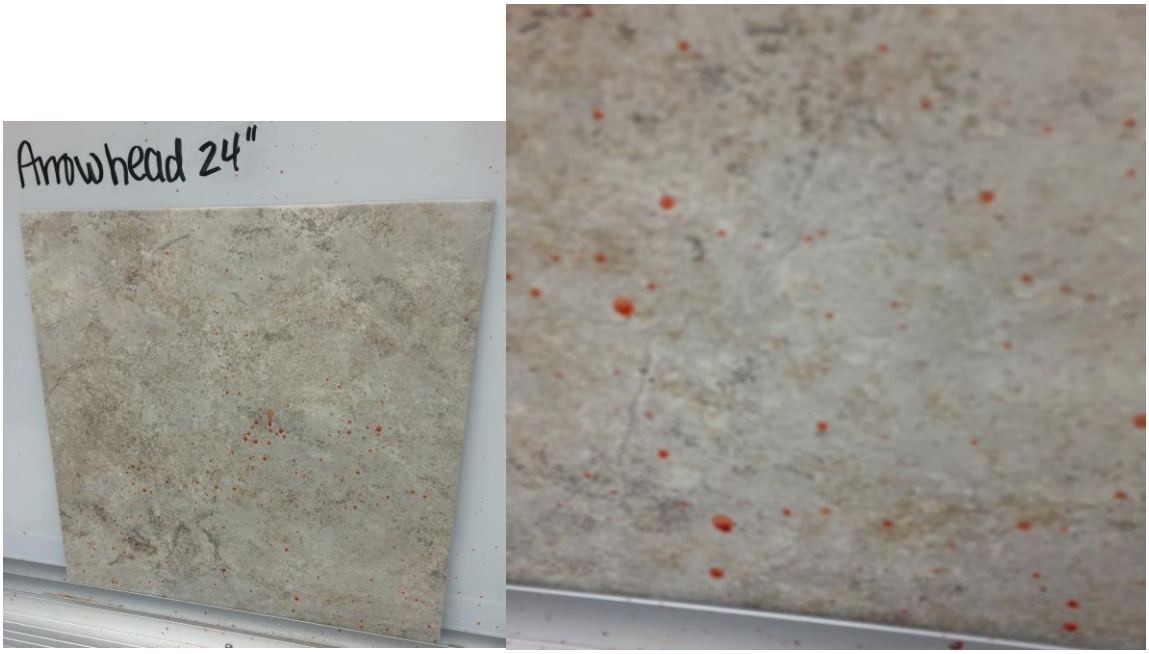

Figure 40. A. Overall Arrowhead spatter from24 inches B. Arrowhead droplets from 24 inch spatter

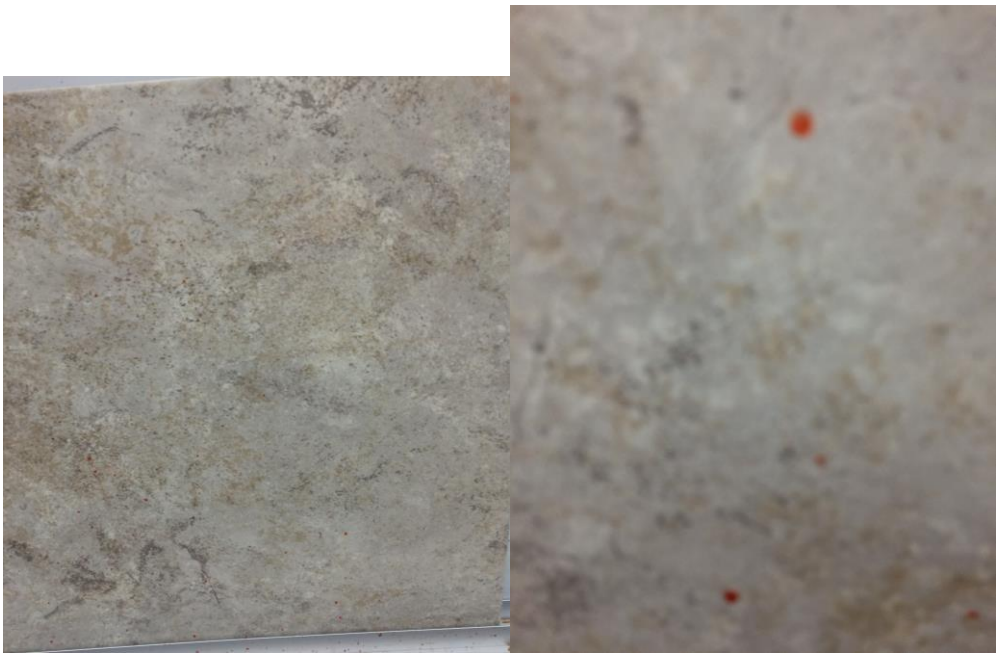

Figure 41. A. Arrowhead 36 inches on tile B. Arrowhead droplets from 36 inch spatter

CHAPTER 4
CONCLUSIONS

The performed experiments were conducted to observe and contrast the behavior of human blood as well as two synthetic blood substitutes. One aim was to analyze performance in fluid dynamic testing to determine whether results were comparable among the three blood products. Another aim was to evaluate the possibility of using synthetic blood products in place of human blood in educational environments- especially in bloodstain pattern analysis courses- to reduce costs and improve safety in teaching and training opportunities.

When applied to sponges in order to conduct the experiments, the human blood appeared much thicker than either synthetic substitute (Evident® and Arrowhead). There was some separation of portions of the human blood product after sitting for a period of time which required remixing prior to use. The bottles of both synthetic blood substitutes indicated a need to shake thoroughly prior to use. Both the Evident® and Arrowhead products could be stored at room temperature, and only Arrowhead had an expiration date noted (approximately 18 months after purchase). Unlike the synthetic blood products, the human blood needed to be refrigerated, and required a more complex disposal method. In terms of cost, Evident® spatter training blood costs $24 for an eight ounce bottle, Arrowhead is $32 for an eight ounce bottle, and expired human blood from a blood center is $50 for 360 milliliters.

The performed experiments included point of origin calculations from three known distances (18 inches, 24 inches, and 36 inches) on poster board as well as observing spatter patterns produced from 18 inches, 24 inches, and 36 inches away on four substrate types. The four substrates were denim, wood, concrete, and tile. Other than the point of origin calculations for 18 inches from the poster board, there were no significant differences between the three blood products in calculating point of origin. There were also no significant differences between the three blood products in the appearance of spatter on denim, wood, or concrete at any of the tested distances. On the tile, the synthetic products indicated (at varying distances) that their viscosity was not the same as human blood, as seen in their dripping down the surface of the substrate. More testing on tile especially will need to be conducted to determine whether either synthetic product can be used in such a scenario for training purposes. Although slight differences in color are noted between the synthetic spatter substitutes and human blood, the differences are negligible for training purposes in most situations.

When considering whether to use human blood or a synthetic substitute, it is important to know what is being measured to ensure selection of the most appropriate product. There may be times when human blood products are needed for medical purposes, and are unavailable for use in blood spatter training. In such a scenario, synthetic substitutes are acceptable substances to use. If work is being conducted relying on the thickness of blood, or an analyst's ability to get a positive serological result or DNA profile from a crime scene sample, human blood may be the most appropriate tool to use. If, however, blood spatter analysis training is being conducted where trainee safety and/or product cost is the primary factor, both Evident® and Arrowhead synthetic blood products

perform sufficiently similar to human blood to be used. Evident® spatter blood and Arrowhead spatter blood perform similarly to each other in experiments, so synthetic blood choice is at the discretion of individuals conducting training sessions.

The statistically significant differences in calculated point of origin seen at 18 inches were interesting, especially considering it being the shortest distance tested and no significant differences between products were identified at 24 inches or 36 inches away from the substrate. There are several possible reasons such a difference could be observed. These reasons include temperature variation, changes in humidity levels, and variations in force applied to the product from the rat trap. In addition, it is possible that less than ideal droplets were selected at this distance for impact angle calculations or that human error occurred.

It should be noted that determining point of origin for human blood, Evident® and Arrowhead would be difficult, if not impossible on denim, wood, concrete, or tile due to the nature of these substrates. However, it would be beneficial to conduct additional replicates of the three substances on these substrates to ensure accurate results. In addition, it would be beneficial to conduct experiments to compare point of origin calculations with these three blood products at distances between 4 inches and 18 inches to observe how the three products behave at short distances. Further testing for point of origin should be conducted with more replicates at all three distances tested here. In the future experiments, normality tests should also be conducted prior to statistical analysis to ensure the results fall in a normal distribution.

APPENDIX

Material Safety Data Sheet

SPATTER BLOOD

SECTION 1- IDENTITY

NAME	ADDRESS		
Evident Crime Scene Products, Inc.	739 Brooks Mill Rd., Union Hall, VA 24176		
TELEPHONE 800-576-7606	FOR ADDITIONAL INFORMATION CONTACT: Technical Support		DATE PREPARED: January 1,2010
COMMON NAME (USED ON LABEL) Spatter Blood			CHEMICAL FAMILY: N/A (Chemical mixture)
CHEMICAL NAME: Does Not Apply	FORMULA: Does not apply	TRADE NAME & SYNONYMS:	

SECTION 2- HAZARDOUS INGREDIENTS

HAZARDOUS COMPONENT	CAS#	TLV	PEL
NONHAZARDOUS NOT REGULATED CONTAINS NO HAZARDOUS MATERIALS AS DEFINED IN 29 CFR 111910.1200 OR CFR TITLE 49			
Synthetic Blood is a proprietary dilute aqueous mixture containing nonhazardous components. The purpose of this mixture is to provide a blood substitute for educational and training purposes			

PEL: Permissible Exposure Limit established by Occupational Safety and Health Administration
TLV: Threshold Limit Value established by the American Conference of Governmental Industrial Hygienists

PHYSICAL DATA

BOILING POINT: Approx. 212F	SPECIFIC GRAVITY: >1	VAPOR PRESSURE: UNDETERMINED	VAPOR DENSITY: UNDETERMINED
PERCENT VOLATILE (VOL) 90%+	SOLUBILITY (WATER) Miscible	REACTIVITY IN WATER: None	EVAPORATION RATE: Low

APPEARANCE AND ODOR:
A reddish-colored fluid

SECTION 4- FIRE AND EXPLOSION DATA

FLASH POINT: Noncombustible	AUTO IGNITION TEMPERATURE N/A	FLAMMABLE LIMITS IN AIR (% by VOLUME) LOWER: UPPER:

EXTINGUISHING MEDIA:
N/A

UNUSUAL FIRE AND EXPLOSION HAZARDS:

SPECIAL FIRE FIGHTING PROCEDURES:
Wear self-contained breathing apparatus and protective clothing

CONTINUED ON REVERSE SIDE

SECTION 5- HEALTH INFORMATION

PRIMARY ROUTES OF EXPOSURE
Inhalation, ingestion, or absorption through skin

SIGNS & SYMPTOMS OF EXPOSURE
1: ACUTE OVEREXPOSURE:
May cause gastric, nasal, or skin irritation

2: CHRONIC OVEREXPOSURE:
None known

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE:
May cause eye, skin, or respiratory irritation

CHEMICAL /COMPONENT LISTED AS CARCINOGEN OR POTENTIAL CARCINOGEN:
None

OTHER EXPOSURE LIMITS:
Not established

EMERGENCY & FIRST AID PROCEDURES:

EYES: Flush with cool tap water for at least 15 minutes
SKIN: Wash thoroughly with warm water and soap
RESPIRATORY: Remove to fresh air, if distress continues, administer oxygen and contact physician
INGESTION: Drink large amounts of water, rinse mouth with water

IN ALL CASES IF IRRITATION OR DISTRESS PERSISTS, CONTACT PHYSICIAN OR NEAREST POISON CONTROL CENTER

SECTION 6- REACTIVITY DATA

STABILITY:	CONDITIONS TO AVOID:
Stable	high temperatures

INCOMPATIBILITY (MATERIALS TO AVOID)
None known

HAZARDOUS DECOMPOSITION PRODUCTS:
Fumes of carbon Monoxide and Carbon Dioxide under fire conditions,

HAZARDOUS POLYMERIZATION:	CONDITIONS TO AVOID (POLYMERIZATION)
Will not occur	Not applicable for polymerization

SECTION 7- SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS LEAKED OR SPILLED:
For small spills, absorb on paper towels or other absorbent material

WASTE DISPOSAL METHOD:
Dispose of wastes in accordance with current Federal, State, and Local codes and guidelines.

SECTION 8- PERSONAL PROTECTION INFORMATION

RESPIRATORY PROTECTION:
Particulate mask recommended if splashes or spatter is anticipated

VENTILATION:
Room ventilation is expected to be adequate except during spills or fires, However additional ventilation is recommended.

PROTECTIVE GLOVES:
Suggested when contact with skin is possible

EYE PROTECTION:
Suggested when the potential of splashes or contact with the eyes or face is possible

OTHER PROTECTIVE CLOTHING OR EQUIPMENT:
An eye wash fountain and safety shower should be readily available where the potential for splashes or eye contact with the reagent exists

SECTION 9- SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING:
Store and handle according to package and MSDS directions. Store in cool, well-ventilated area.

OTHER PRECAUTIONS:
Do not ingest, get in eyes, on skin, or on clothing. Wash thoroughly after handling.

TRANSPORTATION
NONHAZARDOUS NOT REGULATED
CONTAINS NO HAZARDOUS MATERIALS AS DEFINED IN 29 CFR 111910.1200 OR CFR TITLE 49

Material Safety Data Sheet

SYNTHETIC BLOOD

SECTION 1- IDENTITY

NAME Arrowhead Forensics	ADDRESS 14400 College Blvd., Lenexa, KS 66215	
TELEPHONE (913)894-8388	FOR ADDITIONAL INFORMATION CONTACT:	DATE PREPARED: January 1, 2009
COMMON NAME (USED ON LABEL) Synthetic Blood		CHEMICAL FAMILY: N/A (Chemical mixture)
CHEMICAL NAME: Does Not Apply	FORMULA: Does not apply	TRADE NAME & SYNONYMS:

SECTION 2- HAZARDOUS INGREDIENTS

HAZARDOUS COMPONENT	CAS#	TLV	PEL
CONTAINS NO HAZARDOUS MATERIALS AS DEFINED IN 29 CFR 111910.1200 OR CFR TITLE 49			
Synthetic Blood is a proprietary dilute aqueous mixture containing Hemoglobin, amino acids, protein, and other nonhazardous components. The purpose of this mixture is to provide a blood substitute for the chemical testing for the presence of blood for educational and training purposes			

PEL: Permissible Exposure Limit established by Occupational Safety and Health Administration
TLV: Threshold Limit Value established by the American Conference of Governmental Industrial Hygienists

PHYSICAL DATA

BOILING POINT: Approx. 212F	SPECIFIC GRAVITY: >1	VAPOR PRESSURE: UNDETERMINED	VAPOR DENSITY: UNDETERMINED
PERCENT VOLATILE (VOL) 90%+	SOLUBILITY (WATER) Miscible	REACTIVITY IN WATER: None	EVAPORATION RATE: Low
APPEARANCE AND ODOR: A reddish-colored fluid			

SECTION 4- FIRE AND EXPLOSION DATA

FLASH POINT: Noncombustible	AUTO IGNITION TEMPERATURE N/A	FLAMMABLE LIMITS IN AIR (% by VOLUME) LOWER: UPPER:
EXTINGUISHING MEDIA: N/A		
UNUSUAL FIRE AND EXPLOSION HAZARDS:		
SPECIAL FIRE FIGHTING PROCEDURES: Wear self-contained breathing apparatus and protective clothing		

CONTINUED ON REVERSE SIDE

SECTION 5- HEALTH INFORMATION

PRIMARY ROUTES OF EXPOSURE
Inhalation, ingestion, or absorption through skin

SIGNS & SYMPTOMS OF EXPOSURE
1: ACUTE OVEREXPOSURE:
May cause gastric, nasal, or skin irritation

2: CHRONIC OVEREXPOSURE:
None known

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE:
May cause eye, skin, or respiratory irritation

CHEMICAL /COMPONENT LISTED AS CARCINOGEN OR POTENTIAL CARCINOGEN:
None

OTHER EXPOSURE LIMITS:
Not established

EMERGENCY & FIRST AID PROCEDURES:

EYES: Flush with cool tap water for at least 15 minutes
SKIN: Wash thoroughly with warm water and soap
RESPIRATORY: Remove to fresh air, if distress continues, administer oxygen and contact physician
INGESTION: Drink large amounts of water, rinse mouth with water

IN ALL CASES IF IRRITATION OR DISTRESS PERSISTS, CONTACT PHYSICIAN OR NEAREST POISON CONTROL CENTER

SECTION 6- REACTIVITY DATA

STABILITY:	CONDITIONS TO AVOID:
Stable	

INCOMPATIBILITY (MATERIALS TO AVOID)
None known

HAZARDOUS DECOMPOSITION PRODUCTS:
Toxic Fumes of carbon Monoxide, Carbon Dioxide, and Nitrogen Oxides under fire conditions,

HAZARDOUS POLYMERIZATION:	CONDITIONS TO AVOID (POLYMERIZATION)
Will not occur	Not applicable for polymerization

SECTION 7- SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS LEAKED OR SPILLED:
For small spills, absorb on paper towels or other absorbent material

WASTE DISPOSAL METHOD:
Dispose of wastes in accordance with current Federal, State, and Local codes and guidelines.

SECTION 8- PERSONAL PROTECTION INFORMATION

RESPIRATORY PROTECTION:
Particulate mask recommended if splashes or spatter is anticipated

VENTILATION:
Room ventilation is expected to be adequate except during spills or fires, However additional ventilation is recommended.

PROTECTIVE GLOVES:
Suggested when contact with skin is possible

EYE PROTECTION:
Suggested when the potential of splashes or contact with the eyes or face is possible

OTHER PROTECTIVE CLOTHING OR EQUIPMENT:
An eye wash fountain and safety shower should be readily available where the potential for splashes or eye contact with the reagent exists

SECTION 9- SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING:
Store and handle according to package and MSDS directions. Store in cool, well-ventilated area.

OTHER PRECAUTIONS:
Do not ingest, get in eyes, on skin, or on clothing. Wash thoroughly after handling.

TRANSPORTATION
NONHAZARDOUS NOT REGULATED
CONTAINS NO HAZARDOUS MATERIALS AS DEFINED IN 29 CFR 111910.1200 OR CFR TITLE 49

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