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HELEN ANN SCHUMACHER

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THE EFFECTS OF WEATHERING ON THE PERSISTENCE OF GUNSHOT RESIDUE ON CLOTHING.

By

Helen Ann Schumacher

AN ABSTRACT OF A THESIS

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ABSTRACT

THE EFFECTS OF WEATHERING ON THE PERSISTENC OF GUNSHOT RESIDUES ON CLOTHING

By

Helen Ann Schumacher

Determining the distance at which a weapon has been fired is vital in reconstructing a crime scene involving a firearm and target. There are situations when firearm examiners have received articles of clothing that have been taken from a victim found out of doors. The purpose of this study is to examine the effect of various weather conditions on the persistence of GSR on a clothing sample. Visual and chemical examinations were carried out on test-fired targets fired from six and twelve inches that had been exposed to environmental conditions in central Michigan during a ten-week time period. Detailed daily weather conditions were recorded and related to the results of the of the visual and chemical examinations on the test-fired targets. The conclusion is that exposure of gunshot residue targets to different environmental conditions always leads to a loss of residues that vary depending on the condition.

ACKNOWLEDGMENTS

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LIST OF ABBREVIATIONS

Gunshot Residue(s) (GSR)
Modified Griess Test (MGT)

INTRODUCTION

Determining the distance at which a weapon has been fired is vital in reconstructing a crime scene involving a firearm and target. Investigators frequently request firearm examiners to execute a muzzle-to-target distance determination on evidence collected from a crime scene. Often the firearm examiner studies a victim or the victim's clothing for traces of evidence left by the discharge of the firearm.

The particulate emitted from the muzzle of a firearm are referred to as gunshot residues (GSR). GSR consists of metallic particles, metallic compounds, and partially combusted and unburned powder particles. The detection of specific gunshot residues by visual and chemical examinations assists in establishing the distance between the muzzle of a firearm and a target.

The purpose of this thesis project was to conduct a practical study to examine the effects of weathering on the persistence of gunshot residue on a clothing sample. Since there has been a minimal amount of research done on this topic, this is an exploratory study examining the effects of all weather conditions. Information obtained from this study can be utilized to design a project using specific controlled weather variables.

This study evaluated the effect that wind, temperature and precipitation separately had on the retrieval of a gunshot residue pattern in muzzle-to-target distance determinations. The hypothesis is that wind, temperature and precipitation will have a negative effect on the visual GSR pattern and the retrieval of a GSR pattern through chromophoric techniques. Visual and chemical examinations were carried out on test-fired targets from known distances that had been exposed to environmental conditions in central Michigan during a ten-week time period. Detailed daily weather conditions were recorded and related to the results of the visual and chemical examinations on the test-fired targets.

This study will provide valuable insight into the persistence of specific gunshot residues subjected to various weather conditions. The results of this study will benefit investigators at an out of doors crime scene in determining if weather related loss of evidence is a concern. Crime laboratory examiners may refer to these results to strengthen a muzzle-to-target distance determination testimony. Overall, this practical study can be used to supplement individuals' knowledge of GSR persistence.

Chapter 1

GENERAL INFORMATION ON MUZZLE-TO-TARGET DISTANCE DETERMINATIONS

Introduction: What is Gunshot Residue?

In order to understand how to execute muzzle-to-target distance determinations, it is important to know the sequence of events and by-products formed and expelled when a firearm is discharged. In order for a gun to discharge, the firing pin or striker of the firearm must strike the primer which is located at the base of the cartridge. The primer components ignite, sending a flame into the powder chamber. This causes the powder to ignite, producing gases that generate extremely high pressures, and in turn, propel the bullet out of the gun's barrel. A cloud of debris, known as gunshot residue (GSR), exits the muzzle in a roughly conical pattern. This cloud of debris cools quickly and the vaporized materials within the cloud condense and are deposited as particulate.

The deposition of gunshot residues on a target is a vital component of a muzzle-to-target distance determination. GSR contains the products of decomposition of the propellant, primer, cartridge case, coatings on the cartridge case, projectile, the projectile coating, primer foils, and contamination of the barrel. GSR consists largely of burned and unburned propellant, finely divided particles of metal particulate from the bullet and microscopic particles of primer residue.

The amount of GSR present on target material is dependent on the distance of firing. When the muzzle of a gun is discharged while pressed against a target, the powder gases are unable to disperse into the air. Thus, GSR present may not be readily apparent on the outer portion of the target, however the path of the bullet through the object must be examined. If the weapon is fired at a close distance, most of the particles discharged will be present on the target material. It is important to note that larger particulate, such as unburned propellant, are able to travel faster and further than smaller particles. Therefore, at great distances, the finer particles, such as carbonaceous products, are not present or not as concentrated as at closer ranges.

Factors Affecting Gunshot Residue Deposition

Gunshot residue patterns can differ significantly due to various conditions in which the firearm was discharged. Ten principle factors have been identified to either individually or collectively influence the pattern imprint on the target surface (Barnes & Helson, 1974). These factors follow in descending order of importance:

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

10.) weapon type (revolver, autopistol, etc).

Before an examination may be initiated, various pieces of information must be collected. Identifying or locating the weapon and type of ammunition used is vital in determining the range a shot was fired. GSR patterns from two firearms of the same caliber and manufacturer, but differing in barrel length, can have vastly different GSR patterns. In a longer barrel, the propellant undergoes a more complete combustion resulting in fewer residues exiting the muzzle. Due to various additives and powder types in propellant, ammunition manufactured by different companies can produce different patterns. Therefore, a complete analysis of a GSR pattern requires test firing at various ranges with the suspected weapon and ammunition. Comparison tests require that the targets be comprised of the same quantity and type of material as the target at the crime scene. If the shooting occurred out of doors, knowledge of the weather conditions, such as wind speed and wind direction, at the time of shooting are also important to consider.

Microscopic and Visual Examination of GSR Patterns

In a muzzle-to-target distance determination, the first step is a microscopic and visual examination of the target noting the presence and location of the GSR pattern. Five distinct patterns are associated with close-range GSR deposition: starburst, blossom or petal, carbonaceous film, particulate, and bullet wipe. With most handguns, a close-range GSR deposition is classified as a shot fired at a range of one to twelve inches (Saferstein, 1988). The distance at which the firearm was discharged affects whether or not each pattern except bullet wipe will appear on the target. The following five paragraphs explain each pattern in detail.

A starburst pattern appears as a cross-rip design and may be observed on both skin and clothing. The presence of this pattern indicates that the firearm was discharged at contact or near contact with the target. The starburst pattern may not be present if bulky or loosely woven clothing are the target material.

A blossom or petal pattern appears on the target material as a distinct gray floral or petaloid pattern. This pattern consists of carbonaceous and other fine decomposition products of the propellant. The pattern resembles the overlapping petals of a flower. This delicate, distinct pattern outlines the boundaries of the target and can be visualized on a target if the handgun was discharged in a range of one to approximately ten inches (Nichols, 1998).

A carbonaceous film pattern creates a homogenous gray film that immediately surrounds the bullet entry hole. It lacks the floral design observed in the petal pattern. This pattern can be visualized on a target if the handgun was discharged in a range between one to twenty-one inches (Nichols, 1998).

A particulate pattern consists of unburned and partially burned powder grains, carbonaceous particles, bullet jacket materials, lead shavings, dirt, or other items that have been ejected from the bore of the firearm. The presence or absence of the propellant particles can be extremely important in determining the sequence of events. For handguns, this pattern can be located on the target at ranges up to 30 inches (Sellier, 1991). Particulate patterns tend to be the most persistent of the patterns, since these particles have a tendency to adhere more strongly to fabrics or skin. Upon contact, these hot particles will melt to the surface of the target.

Regardless of distance, a bullet wipe encircles the bullet entry hole as a dark gray to black ring. During a bullet's passage through the firearm bore and air until it strikes the target, carbon, dirt, bullet lubricant, primer residues, lead, and other materials deposit on the surface of the bullet. As the bullet enters a target, these items are transferred from the bullet to the surface around the bullet entry hole.

Chromophoric Techniques for Recovery of GSR Patterns

Since the GSR pattern is a vital part of a muzzle-to-target distance determination, it is important that a pattern is recovered from the target material to be compared with those obtained from test firings. At times, the gunshot residue pattern may be visible, but more than likely a chromophoric technique must be employed to obtain an image of the pattern. In a chromophoric test, residues that can not be seen by the unaided human eye are converted to colored species via specific chemical reactions. The following paragraphs describe two techniques applied to suspect GSR patterns to determine if nitrite and lead compounds are present and to visualize a distribution pattern of these compounds.

The Modified Griess Test (MGT) is a chemically-specific chromophoric test for the presence of nitrite compounds. Nitrite residues are formed in GSR by the burning or partial burning of smokeless powder. The MGT consists of a series of chemical reactions that result in the conversion of any nitrite compounds present to a bright orange dye (see

Appendix A for materials and procedure). This technique furnishes an image of the pattern of nitrite residues on a target. This pattern is preserved in a medium that may be used for later side-by-side comparisons with patterns fired from known distances. Nitrate particles, such as unburned powder particles, will not be detected by the MGT unless the particles are coated with burned powder residues. Due to the test's nondestructive nature, it is usually the first test performed on the target material, since it will not interfere with subsequent testing.

The MGT test is not specific for only nitrites generated in the discharge of a firearm. Research has uncovered that some brands of disinfectant and deodorizers used in hospital rooms and emergency rooms contain sodium nitrites which can cause a false positive reaction in the MGT (Lutz & Templin,1983). The presence of these products may cause a hazy reaction to occur on the actual MGT medium. However, the FBI reports that it is unlikely that this source of nitrites would skew the results of the examination.

The Sodium Rhodizonate test is an inexpensive and rapid chromophoric test used to detect the presence of lead. A lead pattern present on a target's surface is primarily from the combustion of the primer mixture which contains lead styphnate. Lead particles are also generated from friction caused by a lead bullet/barrel interaction and from surface erosion on a bullet's base. The Sodium Rhodizonate test consists of spraying a specific sequence of previously-prepared reagent solutions to the surface of a victim's garment. (see Appendix B for materials and procedure). The presence of lead is confirmed by a blue-violet color.

Results and Interpretation of GSR Examinations

Residues noted both visually and through chromophoric techniques can indicate the muzzle-to-target distance. After the firearm examiner has studied the target material collected from the crime scene both visually and chemically, he/she must compare these results to test-fired targets obtained from the suspect firearm and ammunition at known distances. The patterns obtained are compared for size and density in relation to the pattern obtained from the victim or garment.

The MGT results are more accurate than the Sodium Rhodizonate test results. In the MGT, nitrite compounds are generally distributed in a homogenous manner over the target in a concentric area and are reproducible. Thus, a MGT pattern retrieved from a victim or a victim's clothing is extremely useful. By examining side by side comparisons of the MGT pattern from the victim and the MGT patterns generated from known distances, the firearm examiner can provide a bracketed distance from which the firearm was discharged from the target.

On the other hand, the distribution of lead is a non-reproducible occurrence dependent on various uncontrolled and unknown variables, such as a heavily leaded or dirty barrel. Therefore, a lead pattern cannot be solely used to determine the shooting distance. Examining the patterns retrieved through test-fired targets at known distances, a firearm examiner can provide a minimum and maximum distance from which the firearm was discharged.

An important rule for firearm examiners to follow in muzzle-to-target distance determinations is that an examination does not consist of noting the absence of specific residues. Instead, an examination consists of noting the physical effects and residues present on the target and using that as a basis for reproduction and comparison. If a GSR pattern is not found, it does not mean one was not present. A number of other conclusions could be made:

1) The shots were fired from beyond a maximum distance for deposition of residues.
2) An object may have been in the path of the bullet at the instant of discharge.
3) Medical personnel or investigators mishandled the evidence.
4) Inclement weather conditions occurred.

Overall, a firearm examiner must remember many outside influences may alter a muzzle-to-target distance determination.

Chapter 2

EXPERIMENT: THE EFFECTS OF WEATHERING ON THE PERSISTENCE OF A GUNSHOT RESIDUE PATTERN ON A CLOTHING SAMPLE

Relevant Research

Few studies on the persistence of gunshot residue patterns on clothing samples subjected to various environmental conditions have been conducted. In 1988, Haviva Even, Pinchas Bergmen, Eliot Springer, and Asne Klein conducted a study evaluating the effects of water-soaking on firing distance estimations. Their project studied whether soaking would have a noticeable influence on gunpowder particles and lead concentration. Test-fired targets were collected at distances of 25cm, 50cm, and 100cm. Test-fired targets from each distance were soaked in deionized water for 1, 24, and 48 hours. Circles of 8 and 12 mm radius were cut out around the bullet entrance hole and subjected to an atomic absorption analysis on both dry and water-soaked targets. Both dry and water-soaked targets were also subjected to a MGT to determine the number of gunpowder particles in both internal and external rings, 4.5 cm and 14.5 cm, respectively. The study's results revealed a poor reproducibility of powder particles in both dry and water-soaked targets at various distances, which the authors attributed to the ease of losing particles from the target. The results from the influence of water-soaking on the lead concentration were ambiguous.

In 1989, David A. Lindman published results from a year-long study on the persistence of gunshot residue patterns subjected to weather conditions. In Lindman's study, twelve test-fired targets were hung on the interior portion of a security fence surrounding his work place, twelve test-fired targets were buried in the ground, and twelve test-fired targets were buried on the edge of a swamp. Once a month, Lindman removed one target from each location and processed the cloth using the FBI's proximity determination method. The results revealed the number of grains observed in the air samples reduced with time. The circle within which the grains were located expanded over time. The buried samples displayed similar visual observations. Unlike the samples exposed to air, the buried samples did not vary in diameter. On the other hand, the MGT results indicated that the number of sight specific reactions dropped after the third month. Also, the sodium rhodizonate test displayed a reduction of the lead pattern area in the buried samples.

M. Bonfanti and A. Gallusser of Switzerland studied problems encountered in the detection of gunshot residues (1995). Their project evaluated the persistence of gunshot residue on clothing subjected to different climate conditions. In their study, test-fired targets were left in stagnant water, running water, snow, and the floor of a forest for approximately 96 hours. The residues lost on targets subjected to climate conditions were determined by reference to samples stored under laboratory conditions. The targets left in stagnant water lost all of the visible gunshot residue, revealed a high loss of nitrated residues, and failed to reveal any lead residues. The targets placed in running water also lost any trace of visible gunshot residue, the MGT revealed a small loss in nitrated residues and the diameter of the circle containing the lead residues decreased.

There was a medium loss of visual and nitrated residues and a heavy loss of lead residues on the target placed on humid soil. There was a low loss of visual and nitrated residues and the diameter of the circle containing lead residues decreased by half on the targets placed in snow. Their conclusion was exposure of gunshot residue samples to different environmental conditions always led to a loss of residues that vary depending on the conditions.

Experimental Design and Methods

A project was designed that was similar to the three studies previously mentioned but encompassed an area of GSR retrieval that had not been explored. The general idea of the study was similar to David Lindman's study in which test-fired patterns were placed outside. However, parameters different from Lindman's were employed in this study. Test-fired targets were obtained from two different distances, six and twelve inches, using a 9mm handgun and ammunition. Targets were placed outside and collected on a weekly basis. The main difference between this study and others conducted was that the main objective was to relate the loss of GSR to the daily weather conditions recorded during the period of time the targets were placed outside.

The study took place at the Michigan State Police Lab in East Lansing, MI. During the latter part of February 2000, preparation was made to start the project. This included researching the subject, obtaining four boxes of Federal 9mm Luger ammunition from the same lot (see Appendix C for ammunition details), and labeling 8.5 x 8.5 cotton twill cloths with appropriate week and firing distance. A 9mm handgun and ammunition was chosen because this caliber and ammunition are commonly used in crimes committed in Michigan.

On March 2, 2000, 96 test-fired targets, 48 fired from six inches, and 48 fired from twelve inches, were obtained. Twenty targets from each distance were used as laboratory controls to be compared with test-fired patterns placed outside, eighteen targets from each distance were placed outside and collected after a certain period of time, and ten targets from each distance were extras to be used if needed.

The test-fired targets were shot by securing a 9 mm Smith & Wesson Model 69 semiautomatic pistol to a bench rest. The bench rest ensured the bullet was discharged at a 90° angle and that the distance could be accurately controlled. The barrel was not cleaned between shots. Lieutenant Michael Burritt, Michigan State Police firearms examiner, pulled the trigger.

For contrast and easy examination, the target material consisted of 8.5 x 8.5 inch white cotton twill cloths. The piece of cloth was fastened to a piece of cardboard with masking tape at the front of a bullet trap. Each test-fired target was stapled to the inside of a file folder. The targets were stored at the East Lansing Michigan State Police Laboratory.

This project was separated into three steps. The first step generated a database of information consisting of the visual and chemical appearances of the GSR patterns for the test-fired targets fired from six and twelve inches. Forty of the 96 test-fired targets were used in this step. The test-fired targets were visually examined and a GSR worksheet (see Appendix D for an example of the worksheet) was filled out for each target. The microscopic and visual observations of the GSR deposition on the targets were recorded.

The presence of the following patterns were recorded: ripping or tearing, petal or blossom, carbonaceous film, bullet wipe, and particulate. The presence of these patterns was indicated with a yes or no. Transparent overlays, prepared with concentric circles of one through eight inch diameter, were used to record the diameter of the petal, carbonaceous film, and particulate patterns. A designation of dark, medium, or light was given to the density of the carbonaceous film pattern.

Next, each target was scanned into Adobe Photoshop, one of the most commonly used graphic program which produces high quality pictures. For the targets fired from six inches, a six by six inch box was scanned, while targets fired from twelve inches, a seven by seven inch box was scanned. These images were imported into Scion Image to count the number of powder particles. Scion Image is an image processing and analysis program developed by the National Institute of Health (NIH). Scion Image has the capability to detect changes in gray scales which enables the program to count the number of particles. The powder particles counted consisted of both intact disc powder particles and partially combusted powder particles. For targets fired from six inches, a four by four inch box was counted and for targets fired from twelve inches, a six by six inch box was counted. A larger box was counted for the targets fired from twelve inches because the particulate pattern was distributed further from the bullet entry hole than the particulate pattern on targets fired from six inches. An average powder particle count and standard deviation was obtained.

After the number of powder particles was counted, two chromophoric tests were performed. Each target was processed using the MGT followed by the Sodium

Rhodizonate test. After the Sodium Rhodizonate test, the targets were scanned into Photoshop.

The second step of the project involved placing the targets outside and recording the weather conditions. Before the targets were placed outside, a visual examination was executed and a gunshot residue worksheet was filled out. Next, each target was scanned into Photoshop. Then, the powder particles were counted by hand. A transparent overlay was placed on top of the target and a marker was used to mark each powder particle as it was counted. The second step was separated into two studies. The first study analyzed various weather conditions effect on the visual GSR pattern and the recovery of a GSR pattern on a weekly basis. The second study evaluated the persistence of specific GSR patterns placed outside and collected weekly over a five week time period.

On March 3, 2000, five targets fired from each distance and one blank cotton twill cloth were placed outside the Michigan State Police, East Lansing Headquarters. Long nails were placed into the corners of each target to secure the target to the ground. Targets were fastened to the ground because it is common for a victim of an out of doors homicide to be found lying on or close to the ground. Therefore securing the targets to the ground simulated a victim lying on the ground. A downfall of fastening the targets to the ground is that in the case of a heavy accumulation of precipitation, there is a possibility the targets may lie in a puddle of water. This may disturb or destroy GSR that would not have normally been disturbed or destroyed thus possibly skewing the results. Since the targets are in direct contact with the soil, another concern was the possibility that some constituent in the soil may contribute to the results of the examination.

On the following Friday, March 10, 2000, one of each distance target was collected and replaced with other targets fired from six and twelve inches. After the second week, one of each distance persistence targets was collected along with the weekly collected targets. At the conclusion of the fifth week, the blank cotton twill cloth was collected and replaced with another. Also, four of each distance targets were brought outside to repeat the persistence study. The same collection patterns mentioned above were followed during the next five weeks.

The collected targets, including the two blank cotton twill cloths, were visually and chemically examined. First, each target was examined under a low power microscope to remove any debris that was not gunshot residue, such as dirt and sand. A gunshot residue worksheet was filled out for each exhibit. Next, each target was scanned into Photoshop and a particle count was obtained. Then, each target was analyzed for the presence of nitrite and lead compounds executing the MGT followed by the Sodium Rhodizonate test. The nitrite patterns on the piece of desensitized photographic paper were labeled and kept for reference. The sodium rhodizonate patterns were scanned into Photoshop. The relative loss of GSR was recorded for each target using the following designations: 1) low – less than two fifths of the residues lost; 2) medium – two fifth to less than three fifths of the residues lost; and 3) high – three fifths or more of the residues lost. Photographs of the targets before and after being placed outside, a nitrite pattern and a lead pattern for each target are in Appendices D and E. Images in this thesis are present in color.

The third and final step related the weather conditions recorded during the ten-week period to the results of the visual and chemical examinations performed on the targets. The following weather conditions were collected daily during the ten-week period: mean, maximum, and minimum temperature; amount of precipitation; wind speed; maximum wind speed; and general conditions in the morning, afternoon, and evening. The weather conditions were recorded from the following website: http://www.wunderground.com. The statistic program, SPSS, was used to statistically analyze the loss of powder particles on the targets after being placed outside for one week to each separate weather condition.

Chapter 3

RESULTS AND INTERPRETATIONS

Step 1:

Results of the Microscopic and Visual Examinations of Twenty Targets Fired From Six Inches

The microscopic and visual observations of the targets fired from six inches are recorded in Table 1. In general, almost all targets displayed a petal pattern out to a five inch diameter from the bullet entry hole. Some targets displayed a more distinct overlapping petal pattern than others. All targets displayed a dark carbonaceous film pattern encircling the bullet entry hole ranging one and a half to two and a half inches in diameter. The particulate pattern was dense around the bullet entry hole decreasing in density out to a six inch diameter around the bullet entry hole. All but two of the test-fired targets displayed dark bullet wipe rings. Figure 1 is an example of the GSR pattern on a target fired from six inches.

Table 1: Microscopic and visual observations on targets fired from six inches.

Test Number	Petal pattern (diameter around the bullet entry hole)	Carbonaceous film (diameter around the bullet entry hole)	Bullet Wipe	Rip/ Tear	Particulate pattern
Test 1	Yes; mostly w/in 5" diameter	Yes; dark 2½" diameter	Yes	No	Out to about 6"
Test 2	Yes; mostly w/in 5" diameter	Yes; dark 2" diameter	Yes	No	Out to about 6"
Test 3	Yes; slight petal pattern, mostly w/in 5" diameter	Yes; dark 2" diameter	Yes	No	Out to about 6"
Test 4	Yes; distinct, mostly w/in 5 in. diameter	Yes; dark 2" diameter	Yes	No	Out to about 6"
Test 5	Yes; mostly w/in 5" diameter	Yes; dark 1½" diameter	Yes	No	Out to about 6"
Test 6	Yes; mostly w/in 5" diameter	Yes; dark 2" diameter	Yes	No	Out to about 6"
Test 7	Yes; distinct, mostly w/in 5" diameter	Yes; dark 1½" diameter	Yes	No	Out to about 6"
Test 8	Yes; mostly w/in 5" diameter	Yes; dark 2" diameter	Yes	No	Out to about 6"
Test 9	Yes; mostly w/in 5" diameter	Yes; dark 2" diameter	Yes	No	Out to about 6"
Test 10	Yes; distinct, mostly w/in 5" diameter	Yes; dark 2" diameter	Yes	No	Out to about 6"
Test 11	Yes; mostly w/in 5" diameter	Yes; dark 2" diameter	Yes	No	Out to about 6"
Test 12	Yes; mostly w/in 5" diameter	Yes; dark 2½" diameter	Yes, partial	No	Out to about 6"
Test 13	Yes; distinct, mostly w/in 5" diameter	Yes; dark 2" diameter	Yes	No	Out to about 6"
Test 14	Yes, mostly w/in 5" diameter	Yes; dark 2" diameter	Yes	No	Out to about 6"
Test 15	Yes; mostly w/in 5" diameter	Yes; dark 1½" diameter	Yes, partial	No	Out to about 6"
Test 16	Yes; mostly w/in 5" diameter	Yes; dark 2" diameter	Yes	No	Out to about 6"
Test 17	Yes; distinct, mostly w/in 5" diameter	Yes; dark 2" diameter	Yes	No	Out to about 6"
Test 18	Yes; distinct, mostly w/in 5" diameter	Yes; dark 2½" diameter	Yes	No	Out to about 6"
Test 19	Yes; mostly w/in 5" diameter	Yes; dark 2" diameter	Yes	No	Out to about 6"
Test 20	Yes; mostly w/in 5" diameter	Yes; dark 2" diameter	Yes	No	Out to about 6"

Results of the Microscopic and Visual Examinations of Twenty Targets Fired From Twelve Inches.

The microscopic and visual observations for each of the twenty targets fired from twelve inches are recorded in Table 2. These targets displayed a light petal pattern that is not as distinct as the overlapping petal pattern on the targets fired from six inches. In general, a light to medium carbonaceous film pattern that covers a two to two and a half inch diameter area encircling the bullet entry hole was observed. The particulate pattern was homogenous throughout the surface of each target and was present out to approximately a seven inch diameter around the bullet entry hole. Each target possessed a bullet wipe, but seven out of the twenty targets displayed partial bullet wipe rings. Figure 2 is an example of the GSR pattern on a target fired from twelve inches.

Table 2: Microscopic and visual observations on targets fired from twelve inches.

TEST #	Petal pattern	Carbonaceous film (diameter around the bullet entry hole)	Bullet Wipe	Rip/ Tear	Particulate pattern
Test 1	No	Yes; light film, irregular 2" diameter	Yes, faint	No	Out to about 7"
Test 2	No	Yes; light film, irregular 2½" diameter	Yes	No	Out to about 7"
Test 3	Yes, faint, no distinct pattern	Yes; light film, irregular 2" diameter	Yes	No	Out to about 7"
Test 4	Yes; faint, no distinct pattern	Yes; medium dense film, 2" diameter	Yes; partial	No	Out to about 7"
Test 5	Yes; faint, no distinct pattern	Yes; medium dense film, 2½" diameter	Yes	No	Out to about 7"
Test 6	No	Yes; light film, 2" diameter	Yes	No	Out to about 7"
Test 7	Yes; faint, no distinct pattern	Yes; medium dense film, 2" diameter	Yes	No	Out to about 7"
Test 8	Yes; faint, no distinct pattern	Yes; light film, 2" diameter	Yes	No	Out to about 7"
Test 9	Yes; faint; no distinct pattern	Yes; medium dense film 2½" diameter	Yes, partial	No	Out to about 7"
Test 10	No	Yes; light film, 2" diameter	Yes	No	Out to about 7"
Test 11	No	Yes; light film, 2" diameter	Yes	No	Out to about 7"
Test 12	Yes; faint, no distinct pattern	Yes; medium dense film, 2½" diameter	Yes	No	Out to about 7"
Test 13	Yes; faint, no distinct pattern	Yes, medium dense film, 2" diameter	Yes, partial	No	Out to about 7"
Test 14	Yes; faint, no distinct pattern	Yes, light film, 2" diameter	Yes, partial	No	Out to about 7"
Test 15	Yes; faint, no distinct pattern	Yes, light film, 2½" diameter	Yes	No	Out to about 7"
Test 16	No	Yes, light film, 2" diameter	Yes, partial	No	Out to about 7"
Test 17	Yes; faint, no distinct pattern	Yes, light film, 2½" diameter	Yes	No	Out to about 7"
Test 18	Yes; faint, no distinct pattern	Yes, medium dense film, 2½" diameter	Yes, partial	No	Out to about 7"
Test 19	No	Yes; light film, 2" diameter	Yes	No	Out to about 7"
Test 20	Yes; faint, no distinct pattern	Yes; light film 2½" diameter	Yes	No	Out to about 7"

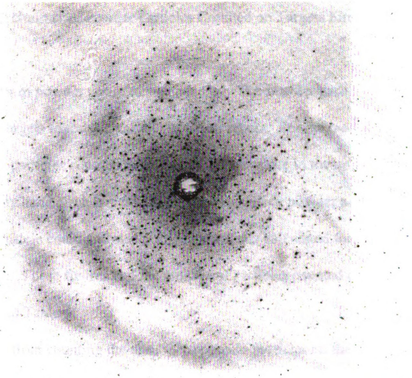

Figure 1: An example of a GSR pattern on a target fired from six inches. This target is Test 4.

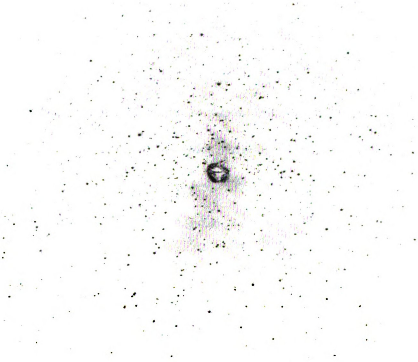

Figure 2: An example of a GSR pattern on a target fired from twelve inches. This target is Test 12.

Comparison of the Number of Powder Particles Counted on Targets Fired From Six and Twelve Inches

The number of powder particles was counted. The powder particles were hand counted on a few targets to test the validity of Scion Image. For the most part, the number of powder particles counted by Scion image was close to the number of powder particles counted by hand. The largest difference was sixteen powder particles. An average powder particle count and standard deviation was calculated for the targets fired from each distance. These figures and the number of particles counted on each target are listed in Table 3 and Table 4.

The results from counting the number of powder particles on the targets indicated that the reproducibility of the powder particles on the targets fired from six and twelve inches are similar. For the targets fired from six inches, the highest number of powder particles counted on a target was 693 and the lowest number of powder particles counted on a target was 515. The average number of powder particles distributed on a target fired from six inches was 605 with a standard deviation of 46. Regarding targets fired from twelve inches, the highest number of powder particles counted was 580 and the lowest number of powder particles counted was 404. The average number of powder particles distributed on a target fired from twelve inches was 469 with a standard deviation of 47.

Table 3: Powder particles counted on targets fired from six inches.

Test Number	Particles Counted	Particles Hand Counted
Test 1	642	638
Test 2	580	
Test 3	538	
Test 4	595	
Test 5	613	
Test 6	632	
Test 7	643	
Test 8	569	
Test 9	537	
Test 10	583	
Test 11	615	
Test 12	579	
Test 13	660	
Test 14	600	
Test 15	581	
Test 16	666	653
Test 17	644	
Test 18	693	
Test 19	515	523
Test 20	619	
Highest	693	
Lowest	515	
Average	605	
Standard Deviation	46	

Table 4: Powder particles counted on targets fired from twelve inches.

Test Number	Particles Counted	Particles Hand Counted
Test 1	456	
Test 2	453	
Test 3	488	
Test 4	564	
Test 5	457	
Test 6	467	
Test 7	580	
Test 8	507	
Test 9	510	
Test 10	423	
Test 11	427	423
Test 12	459	
Test 13	501	
Test 14	435	
Test 15	415	
Test 16	404	
Test 17	423	437
Test 18	469	
Test 19	449	
Test 20	491	
Highest	580	
Lowest	404	
Average	469	
Standard Deviation	47	

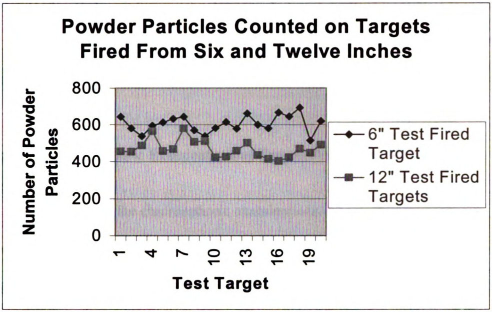

Figure 3: A comparison of the number of powder particles counted on targets fired from six and twelve inches.

There is a difference in the number of powder particles distributed on targets fired from six and twelve inches. A graph of these results appear in Figure 3. The number of powder particles counted on a target fired from six inches will generally contain more powder particles than a target fired from twelve inches. According to the results, on average there are 136 more powder particles on a target fired from six inches compared to the number of powder particles on a target fired from twelve inches. Statistically, Univariate Analysis of Variance indicated there was a significant difference between the number of powder particles counted on targets fired from six and twelve inches, $F=62.835$; $df = 1$; $p = .000$[1]. Overall, the results indicated that it is possible for a target

[1] The statistical analysis was conducted using the powder particle counts on the targets fired from six and twelve inches before being placed outside for one week.

fired from twelve inches to have a powder particle count similar to a target fired from six inches and vice versa.

Results of the Chromophoric Examinations of Targets Fired From Six and Twelve Inches

The results from the chromophoric examinations did not display excellent results. When executing the MGT on the targets fired from six inches, an orange haze accompanied the nitrite pattern on the piece of desensitized photographic paper. During one step in the procedure (see Appendix A), a piece of cheese cloth saturated in acetic acid had to be wrung out before placed on top of the target material. The orange haze might have been caused by too much acetic acid on the piece of cheese cloth. For the most part, the general nitrite pattern was visible. There were a few targets fired from six inches in which the orange haze masked the nitrite pattern. The targets fired from twelve inches processed by the MGT displayed better results. For reasons unknown to the author, the application of the solutions during the Sodium Rhodizonate test failed to exhibit a complete reaction of the lead residues on the targets. The Sodium Rhodizonate test was done on extra test-fired targets at a later time. There was a dark reaction on these targets and the results were recorded.

The nitrite pattern obtained from the MGT was similar to the visual powder particle pattern on the targets fired from both distances. The nitrite pattern on targets fired from six inches was dense around the bullet entry hole decreasing in density out to a six inch diameter around the bullet entry hole. The density of the nitrite pattern from targets fired from twelve inches was homogenous throughout the surface of each target and was present to approximately a seven inch diameter around the bullet entry hole. Figure 4 and Figure 5 are examples of the nitrite pattern on a piece of desensitized photographic paper from targets fired from six and twelve inches.

The results from the Sodium Rhodizonate test supplied more information than the visual examination. On the targets fired from six inches, there was a dark reaction around the visible petal pattern and carbonaceous film pattern area. A light reaction in areas that had not displayed a visible pattern also appeared and occurred to approximately a seven inch diameter from the bullet entry hole. On the targets fired from twelve inches, there was a dark reaction around the carbonaceous film area and a medium to light reaction around the petal pattern area. Again, a light reaction appeared in areas that had not displayed a visible pattern. A reaction could be seen out to an eight inch diameter from the bullet entry hole. Examples of the lead pattern on targets fired from six and twelve inches can be observed in Figure 6 and Figure 7.

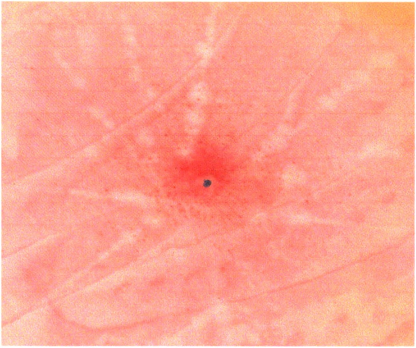

Figure 4: An example of a nitrite pattern on a piece of desensitized photographic paper from a target fired from six inches. This is from Test 1.

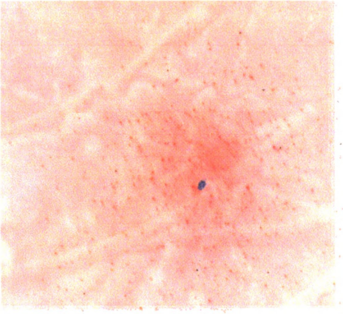

Figure 5: An example of a nitrite pattern on a piece of desensitized photographic paper from a target fired from twelve inches. This is from Test 6.

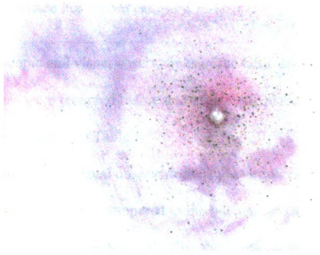

Figure 6: An example of the lead pattern on a target fired from six inches. This target is Extra 4.

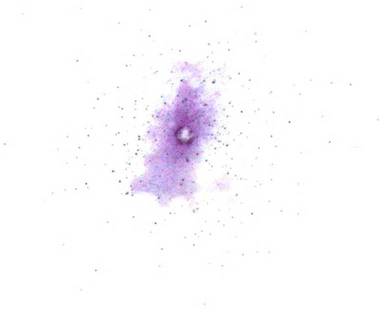

Figure 7: An example of the lead pattern on a target fired from twelve inches. This target is Extra 5.

STEP 2:

Comparison of the Microscopic and Visual Observations From Targets Fired From Six Inches and Placed Outside For One Week.

The microscopic and visual observations of the GSR deposition on the targets fired from six inches were recorded before and after being placed outside for one week. These observations are listed in Table 5.

The microscopic and visual observations of the targets fired from six inches before being placed outside were compared to the microscopic and visual observations of the targets collected after one week outside. The following observations were made on the targets collected after one week outside. A petal pattern was not visible on the targets, with the exception of Week 4 which had a faint, partial petal pattern visible. While all of the targets lost some of the carbonaceous film pattern, the relative loss of carbonaceous film pattern on the targets collected from Weeks 2,3,4,5 and 8 was estimated to be medium. The carbonaceous film pattern on these targets closely resembled the pattern before being placed outside. On the targets collected from Weeks 1, 6, 7 and 9, there was a relatively high loss of the carbonaceous film pattern. The carbonaceous film pattern on these targets did not resemble the pattern before being placed outside. The carbonaceous film pattern was not visible on the target collected from Week 10. A bullet wipe was visible on all of the targets. There was no additional ripping or tearing around the bullet entry hole on any of the targets. The relative loss of particulate pattern on all of the targets was low. On the targets collected from Weeks 7 and 10, the diameter of the particulate pattern decreased by one inch.

Table 5: Microscopic and visual observations of the GSR deposition on the targets fired from six inches before and after being placed outside for one week.

WEEK Number	**Petal Pattern** (diameter around the bullet entry hole)	**Carbonaceous film** (diameter around the bullet entry hole)	**Bullet Wipe**	**Rip/ Tear**	**Particulate Pattern**
Week 1 Before	Yes; mostly w/in 5" diameter	Yes; dark film 1½" diameter	Yes	No	Out to about 6"
After	No	Faint film 1½" diameter	Faint	No	Out to about 6"
Week 2 Before	Yes; medium; mostly w/in 5" diameter	Yes; dark film 1½" diameter	Yes	No	Out to about 6"
After	No	Yes, medium dense film 1½" diameter	Yes	No	Out to about 6"
Week 3 Before	Yes; mostly w/in 5" diameter	Yes; dark film 2" diameter	Yes	No	Out to about 6"
After	No; dirty target	Yes; medium dense film 2" diameter	Yes	No	Out to about 6"
Week 4 Before	Yes; distinct, mostly w/in 5" diameter	Yes; dark film 2" diameter	Yes	No	Out to about 6"
After	Faint petal pattern on top outer ring of pattern	Yes; medium dense film 2" diameter, similar to before pattern	Yes	No	Out to about 6"
Week 5 Before	Yes; mostly w/in 5" diameter	Yes, dark film 2½" diameter	Yes	No	Out to about 6"
After	No	Yes, light film 2½" diameter, similar to before but light!	Yes	No	Out to about 6"
Week 6 Before	Yes; distinct, mostly w/in 5 in. diameter	Yes; dark film 2½" diameter	Yes	No	Out to about 6"
After	No	Yes; light film 2" diameter (some missing) kind of resembles before	Yes; partial	No	Out to about 6"
Week 7 Before	Yes; medium, mostly w/in 5" diameter	Yes; dark film 2" diameter	Yes	No	Out to about 6"
After	No; dirty pattern	Yes; faint film 2" diameter, kind of resembles before	Yes; partial	No	Out to about 5"
Week 8 Before	Yes; distinct, mostly w/in 5" diameter	Yes, dark film 2" diameter	Yes	No	Out to about 6"
After	No	Yes; medium dense film 2" diameter, resembles before pattern	Yes	No	Out to about 6"

Table 5 (cont'd).

Week 9 Before	Yes; distinct, mostly w/in 5" diameter	Yes, dark film 2½" diameter	Yes	No	Out to about 6"
After	No	Yes; faint film 2" diameter, partially resembles before	Yes	No	Out to about 6"
Week 10 Before	Yes; medium, mostly w/in 5"	Yes; dark film 2½" diameter	Yes	No	Out to about 6"
After	No	Faint	Yes; partial	No	Out to about 5"

Comparison of the Microscopic and Visual Observations From Targets Fired From Twelve Inches and Place Outside For One Week.

The microscopic and visual observations of GSR deposition on targets fired from twelve inches were recorded before and after being placed outside for one week. These observations are listed in Table 6.

The visual and microscopic observations for the targets fired from twelve inches before being placed outside were compared to the microscopic and visual observations on the targets collected after one week outside. The following observations were made on the targets collected after one week outside. A petal pattern was not visible on the targets. More than half of the carbonaceous film pattern was lost on the targets collected from Weeks 4,5, and 8 while a carbonaceous film pattern was not visible on the targets collected from the other weeks. A bullet wipe was visible on the targets. There was no additional ripping around the bullet entry hole on any of the targets. There was a relatively low loss of particulate pattern on the targets collected from Weeks 4 and 8. However, on targets collected from Weeks 1,2,3,5,6 and 9, a medium relative loss of particulate pattern was estimated. The targets collected from Weeks 7 and 10 lost over half of the particulate pattern .

Table 6: Microscopic and visual observations of the GSR deposition on targets fired from twelve inches before and after being placed outside for one week.

Week Number	Petal Pattern	Carbonaceous film (diameter around the bullet entry hole)	Bullet Wipe	Rip/ Tear	Particulate pattern
Week 1 Before	Yes, faint no distinct pattern	Yes, medium film 2½" diameter	Yes	No	Out to about 7"
After	No	No	Yes, partial	No	Out to about 6"
Week 2 Before	Faint	Yes, light film 2" diameter	Yes	No	Out to about 7"
After	No	No	Yes; partial	No	Out to about 6"
Week 3 Before	Faint	Yes; light film 2" diameter	Yes; partial	No	Out to about 7"
After	No	No	Yes; partial	No	Out to about 6"
Week 4 Before	Faint	Yes; light film 2" diameter	Yes; partial	No	Out to about 7"
After	No	Faint	Yes; partial	No	Out to about 7"
Week 5 Before	Faint	Yes, light film 2" diameter	Yes; partial	No	Out to about 7"
After	No	Faint	Yes; partial	No	Out to about 6"
Week 6 Before	Yes; light petal pattern	Yes, light film 2½" diameter	Yes	No	Out to about 7"
After	No	No	Yes	No	Out to about 6"
Week 7 Before	Faint	Yes; medium dense film 2½" diameter	Yes; partial	No	Out to about 7"
After	No	No	Yes; partial	No	Out to about 6"
Week 8 Before	Faint	Yes; light film 2" diameter	Yes	No	Out to about 7"
After	No	Faint	Yes	No	Out to about 7"
Week 9 Before	Faint	Yes, light film 2½" diameter	Yes	No	Out to about 7"
After	No (dirty target)	No (dirty target)	Yes, partial	No	Out to about 6"
Week 10 Before	Faint	Yes; light film 2" diameter	Yes, partial	No	Out to about 7"
After	No	No	Yes, partial	No	Out to about 5"

Relative Loss of Visible GSR on Targets Fired From Six and Twelve Inches After Being Placed Outside For One Week.

By comparing the deposition of GSR on the targets before and after subjected to various weather conditions for one week, the relative loss of visible GSR was estimated. These results are listed in Table 7 and Table 8. In general, there was a low loss of visible GSR on the targets fired from six inches. The targets fired from twelve inches displayed a medium loss of visible GSR .

Table 7: Estimated relative loss of visible GSR on targets fired from six inches.

Week Number	**Relative GSR Loss**
Week 1	Medium
Week 2	Low
Week 3	Low
Week 4	Low
Week 5	Low
Week 6	Low
Week 7	High
Week 8	Low
Week 9	Medium
Week 10	High

Table 8: Estimated relative loss of visible GSR on targets fired from twelve inches.

Week Number	**Relative GSR Loss**
Week 1	Medium
Week 2	Medium
Week 3	Medium
Week 4	Medium
Week 5	Medium
Week 6	Medium
Week 7	High
Week 8	Medium
Week 9	Medium
Week 10	High

Results from the Number of Powder Particles Counted on Targets Fired From Six and Twelve Inches Before and After Being Placed Outside for One Week.

The number of powder particles counted on each target before and after being placed outside was recorded. The number of powder particles that were lost and the percentage of particles lost was calculated. The results are listed on Table 9 and Table 10.

Table 9: The number of powder particles counted on targets fired from six inches before and after being placed outside for one week.

Week Number	Particle Count Before	Particle Count After	Loss of Particles	Percentage of particles lost
Week 1	613	436	177	28.9
Week 2	662	466	196	29.6
Week 3	586	463	123	21
Week 4	536	439	97	18.1
Week 5	581	444	137	23.6
Week 6	670	484	186	27.8
Week 7	577	383	194	33.6
Week 8	639	500	139	21.8
Week 9	602	426	179	29.9
Week 10	598	368	230	38.5

Table 10: The number of powder particles counted on targets fired from twelve inches before and after being placed outside for one week.

Week Number	Particle Count Before	Particle Count After	Loss of Particles	Percentage of particles lost
Week 1	528	357	171	32.4
Week 2	443	320	123	27.8
Week 3	460	330	130	28.3
Week 4	428	326	102	23.8
Week 5	469	359	110	23.5
Week 6	434	334	100	23.1
Week 7	505	229	276	54.7
Week 8	478	414	64	13.4
Week 9	513	409	104	20.3
Week 10	432	252	180	41.7

The average percentage of powder particles lost was similar for targets fired from six and twelve inches. The average percentage of powder particles lost for the targets fired from six inches was 27%. The lowest percentage of powder particles lost was 18.1% on Week 4 and the highest percentage of powder particles lost was 38.5% on Week 10. The average percentage of powder particles lost for the targets fired from twelve inches was 29%. The lowest percentage of powder particles lost was 13.4% on Week 8 and the highest percentage of powder particles lost was 54.7% on Week 10.

A comparison of the percentage of lost powder particles counted on the targets fired from six and twelve inches appears in the form of a graph in Figure 8. Overall, the percentage of lost powder particles on the targets fired from six inches corresponded to the percentage of lost powder particles on the targets fired from twelve inches. There was a significant difference in the percentage of powder particles counted on the targets collected on Week 7. On these targets, the percentage of powder particles lost on the target fired from twelve inches was over twenty percent higher than the percentage of powder particles lost on the target fired from six inches.

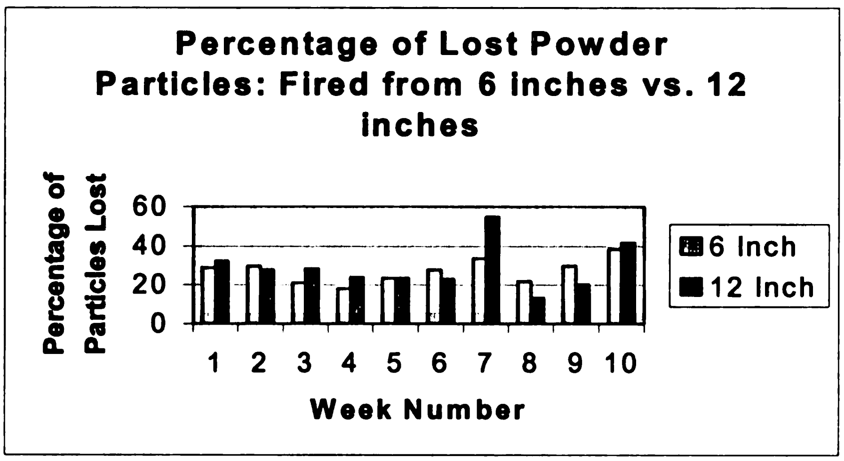

Figure 8: A comparison of the percentage of lost powder particles on targets fired from six and twelve inches.

Results of the Chromophoric Examinations on Targets Fired From Six and Twelve Inches Collected After One Week Outside.

The MGT gave a positive reaction in targets fired from six inches, however, comparison with nitrite patterns obtained from the test targets indicated a loss of sight specific reactions. There was a relatively low loss of nitrite pattern on the targets collected from Weeks 1,2,3,4,5 and 9. Approximately half of the nitrite pattern was lost on the target collected from Week 8. A significant amount of nitrite pattern was lost on targets processed from Weeks 6,7 and 10. The approximate diameter and estimated relative loss of the nitrite pattern obtained on each target are listed in Table 11.

Targets fired from twelve inches, gave a positive MGT reaction. However, comparison with the nitrite patterns obtained from test targets indicated a loss of sight specific reactions. The relative loss of nitrite pattern on targets collected from the Weeks 1,2,3,4 and 5 was low. Approximately half of the nitrite pattern was lost on targets collected from Weeks 8 and 9. A significant amount of nitrite pattern was lost on targets processed from Weeks 6,7 and 10. The approximate diameter and estimated relative loss of nitrite pattern obtained from each target are listed in Table 12.

Table 11: The approximate diameter and estimated relative loss of nitrite pattern obtained from targets fired from six inches after being placed outside for one week.

Week Number	MGT: Nitrite Pattern	Relative Loss
Week 1	Out to about 6"	Low
Week 2	Out to about 6"	Low
Week 3	Out to about 6"	Low
Week 4	Out to about 6"	Low
Week 5	Out to about 6"	Low
Week 6	Out to about 3"	High
Week 7	Out to about 4"	High
Week 8	Out to about 6"	Medium
Week 9	Out to about 6"	Low
Week 10	Out to about 4"	High

Table 12: The approximate diameter and estimated relative loss of nitrite pattern obtained from targets fired from twelve inches after being placed outside for one week.

Week Number	MGT: Nitrite Pattern	Relative Loss
Week 1	Out to about 7"	Low
Week 2	Out to about 7"	Low
Week 3	Out to about 7"	Low
Week 4	Out to about 7"	Low
Week 5	Out to about 7"	Low
Week 6	Out to about 6"	High
Week 7	Out to about 5"	High
Week 8	Out to about 7"	Medium
Week 9	Out to about 6"	Medium
Week 10	Out to about 5"	High

The Sodium Rhodizonate test yielded positive results on targets fired from six inches which had remained outside for one week. However, comparison with lead patterns obtained on test targets indicated a loss of lead residues. There was a relatively low loss of lead pattern on targets collected from Weeks 1,2,3 and 4. Approximately half of the lead pattern was lost on Weeks 5,6, 8 and 10. Over half of the lead pattern was lost on targets from Weeks 7 and 9. The lead pattern on targets that lost half or more of the lead residues appeared hazy and light. A detailed description of the pattern and estimated lead pattern loss on each target are listed in Table 13

Table 13: A description of the lead pattern obtained by the Sodium Rhodizonate test and estimated lead residue loss on targets fired from six inches.

Week Number	**Petal Pattern** (diameter around the bullet entry hole)	**Carbonaceous Film** (diameter around the bullet entry hole)	**Relative Loss**
Week 1	Yes; mostly w/in 5 in diameter, similar to before	Yes; dark reaction 1½ in. diameter, similar to before	Low
Week 2	Yes; faint, similar to before, some lost	Yes, dark reaction 1½ in. diameter, similar to before pattern	Low
Week 3	Yes; similar to before, some lost	Yes; dark reaction 2 in. diameter around bullet entry hole, similar to before pattern	Low
Week 4	Yes; similar to before pattern, mostly w/in 5 in. diameter	Yes; dark reaction 2 in. diameter, similar to before pattern(have lots of the light film)	Low
Week 5	Yes; faint; mostly w/in 5 in. diameter, similar to before pattern	Yes; medium dense reaction 2 ½ in. diameter, similar to before pattern but light(hazy!)	Medium
Week 6	Slight reaction, nothing distinct	Yes; medium dense reaction 2 in. diameter, does not resemble before pattern	Medium
Week 7	No	Yes; medium dense reaction 1½ in. diameter, hazy	High
Week 8	Yes; faint	Yes; medium dense reaction 2 in. diameter, resembles before pattern	Medium
Week 9	Yes; faint	Yes, light reaction 2 in., hazy	High
Week 10	Yes; faint; partially resembles before	Yes, medium dense reaction 2½ in. diameter, hazy	Medium

The results from the Sodium Rhodizonate test on targets fired from twelve inches exhibited faint reactions. A majority of the targets lost approximately half of the lead pattern. Targets collected from Weeks 6,7 and 9 lost almost all of the lead pattern displaying only a faint reactions around the bullet entry hole. A detailed description of the pattern and estimated lead pattern loss on each target are listed in Table 14.

Table 14: A description of the lead pattern obtained by the Sodium Rhodizonate test and estimated lead residue loss on targets fired from twelve inches.

Week Number	Petal Pattern	Carbonaceous Film (diameter around the bullet entry hole)	Relative Loss
Week 1	Faint; partial pattern	Yes, light reaction 1½ in. diameter, lost bottom pattern	Medium
Week 2	No	Yes, light reaction 2 in. diameter, resembles before	Medium
Week 3	No	Yes; light reaction 2 in. diameter, hazy	Medium
Week 4	Faint	Yes; light reaction 2 in. diameter; resembles before, a little hazy	Medium
Week 5	Faint	Yes, light reaction 2in. diameter; hazy	Medium
Week 6	No	Faint; hazy	Very High
Week 7	No	Faint	Very High
Week 8	Faint	Yes; light reaction 2 in. diameter, hazy	Medium
Week 9	No	Faint	Very High
Week 10	No	Yes, light reaction 2 in. diameter, hazy	Medium

Persistence of the Microscopic and Visual GSR on Targets Fired From Six Inches, Placed Outside and Collected Weekly Over a Five Week Time Period

The microscopic and visual observations of the GSR deposition on the targets fired from six inches were recorded before and after placed outside and collected weekly over a five week time period. These observations are listed in Table 15.

The persistence of the visible GSR deposition on the targets fired from six inches was examined with the following observations made on the targets that had been placed outside. The visible petal pattern was not present on the examined targets. There was a high loss of carbonaceous film pattern on each target and eventually the carbonaceous film pattern was no longer visible. A bullet wipe was not present after five weeks. There was no additional tearing of the targets. At first, a relatively low amount of particulate pattern was lost. After the fifth week, the particulate pattern rapidly decreased in density and diameter. During the second five week study, the loss of GSR appeared to degrade faster than the first five week study.

Table 15: Microscopic and visual observations of the GSR deposition on targets fired from six inches before and after being placed outside and collected weekly over a five week time period.

Week Number	Petal Pattern	Carbonaceous Film (diameter from the bullet entry hole)	Bullet Wipe	Rip/ Tear	Particular Pattern
Week 2 1P Before	Yes; medium, mostly w/in 5"	Yes; dark film 2" diameter	Yes	No	Out to about 6"
After	No	Yes; faint film 1½" diameter, partially resembles before	Yes; partial	No	Out to about 6"
Week 3 1P Before	Yes; distinct; mostly w/in 5" diameter	Yes; dark film 2" diameter	Yes	No	Out to about 6"
After	No	Yes; faint film 1½" diameter, barely resembles before	Yes; partial	No	Out to about 6"
Week 4 1P Before	Yes; mostly w/in 5" diameter	Yes, dark film 2" diameter	Yes	No	Out to about 6"
After	No	Faint	Yes; partial	No	Out to about 5"
Week 5 1P Before	Yes; medium; mostly w/in 5" diameter	Yes; dark film 2"	Yes	No	Out to about 6"
After	No	No	No	No	Out to about 5"
Week 7 2P Before	Yes; medium, mostly w/in 5" diameter	Yes, medium dense film 2½" diameter	Yes	No	Out to about 6"
After	No	Faint	Yes	No	Out to about 6"

Table 15 (cont'd).

Week 8 2P Before	Yes; medium, mostly w/in 5" diameter	Yes; medium dense film 2" diameter	Yes	No	Out to about 6"
After	No	No	Yes; partial	No	Out to about 5"
Week 9 2P Before	Yes; distinct; mostly w/in 5" diameter	Yes; dark film 2" diameter	Yes	No	Out to about 6"
After	No	No	Yes; partial	No	Out to about 5"
Week 10 2P Before	Yes; mostly w/in 5" diameter	Yes, medium dense film 2" diameter	Yes	No	Out to about 6"
After	No, dirty pattern	No	No	No	Out to about 5"

Persistence of the Microscopic and Visual Observations on the Targets Fired From Twelve Inches, Placed Outside and Collected Weekly Over a Five Week Time Period.

The microscopic and visual observations of the GSR deposition on the targets fired from twelve inches were recorded before and after being placed outside and collected weekly over a five week time period. These observations are listed in Table 16.

The persistence of the visual GSR deposition on the targets fired from twelve inches was examined. The following observations were made on the targets that had been placed outside. Visible petal and carbonaceous film patterns were not present. The presence of a bullet wipe was faint after five weeks. There was no additional tearing of the bullet entry hole. There was a steady loss of particulate pattern as the weeks progressed. In the second five week study, the loss of GSR appeared to degrade faster than the first five week study.

Table 16: Microscopic and visual observations of the GSR deposition on targets fired from twelve inches before and after being placed outside and collected weekly over a five week time period.

Week Number	**Petal Pattern**	**Carbonaceous Film (diameter around the bullet entry hole)**	**Bullet Wipe**	**Rip/ Tear**	**Particular Pattern**
Week 2 1P Before	Yes; light, no distinct pattern	Yes, medium dense film, 2½" diameter	Yes; partial	No	Out to about 7"
After	No	No	Yes, partial	No	Out to about 6"
Week 3 1P Before	Faint	Yes, medium dense film, 2½" diameter	Yes; partial	No	Out to about 7"
After	No	No	Yes; partial	No	Out to about 6"
Week 4 1P Before	Faint, no distinct pattern	Yes, medium dense film, 2" diameter	Yes	No	Out to about 7"
After	No	No	Faint	No	Out to about 6"
Week 5 1P Before	Yes, light	Yes, medium dense film, 2½" diameter	Yes	No	Out to about 7"
After	No	No	Faint	No	Out to about 6"
Week 7 2P Before	Faint	Yes, light film 2" diameter	Yes	No	Out to about 7"
After	No	No	Faint	No	Out to about 6"
Week 8 2P Before	Faint	Yes; light film 2" diameter	Yes, partial	No	Out to about 7"
After	No (dirty target)	No (dirty target)	Faint	No	Out to about 6"
Week 9 2P Before	Faint	Yes, light film 2½" diameter	Yes; partial	No	Out to about 7"
After	No (dirty target)	No (dirty target)	Faint	No	Out to about 6"
Week 10 2P Before	Faint	Yes; light film, 2" diameter	Yes, partial	No	Out to about 7"
After	No (dirty target)	No (dirty target)	Faint	No	Out to about 5"

The relative loss of visible GSR was estimated on each target fired from six and twelve inches. These results are listed in Table 17 and Table 18. In general, a low loss of visible GSR was estimated on targets fired from six inches. A couple of the targets' visible GSR patterns were inconsistent with the other weeks patterns. For example, the target collected on the second week of the first five week study lost approximately half of the visible GSR while the following weeks lost less than half of the visible GSR. The second inconsistency occurred on the target collected from the fourth week of the second five week study. This target lost over half of the visible GSR while the following week lost less than half of the visual GSR. In general, more than half of the visible GSR were lost on the targets fired from twelve inches. There were no inconsistencies observed.

Table 17: Estimated relative loss of visible GSR on targets fired from six inches

Week Number	Relative GSR Loss
Week 2 1P	Medium
Week 3 1P	Low
Week 4 1P	Low
Week 5 1P	Low
Week 7 2P	Low
Week 8 2P	Low
Week 9 2P	High
Week 10 2P	Low

Table 18: Estimated relative loss of visible GSR on targets fired from twelve inches.

Week Number	Relative GSR Loss
Week 2 1P	Low
Week 3 1P	Medium
Week 4 1P	High
Week 5 1P	High
Week 7 2P	High
Week 8 2P	High
Week 9 2P	High
Week 10 2P	High

Results From the Number of Powder Particles Counted On Targets Fired From Six and Twelve Inches Before and After Being Placed Outside and Collected Weekly Over a Five Week Time Period.

The number of powder particles counted on each target before and after being placed outside was recorded. The number and percentage of powder particles that were lost was calculated. The results are listed on Table 19 and Table 20.

The persistence of the powder particles on the targets was examined. In general, the targets steadily lost a number of powder particles the longer that the target was left outside. Comparing the percentage of powder particles lost on the targets fired from six inches and twelve inches indicated that the powder particles are more persistent on targets fired from six inches.

Table 19: The number of powder particles counted on targets fired from six inches that had been placed outside and collected weekly over a five week time period.

Week Number	Particle Count Before	Particle Count After	Loss of Particles	Percentage of particles Lost
W2 1P	601	373	228	38
W3 1P	616	488	128	20.8
W4 1P	567	428	139	24.5
W5 1P	618	363	255	41.3
W7 2P	584	391	193	33
W8 2P	527	316	211	40
W9 2P	636	310	326	51.3
W10 2P	540	325	215	40

Table 20: The number of powder particles counted on targets fired from twelve inches that had been placed outside and collected weekly over a five week time period.

Week Number	Particle Count Before	Particle Count After	Loss of Particles	Percentage of particles Lost
W2 1P	470	342	128	27.2
W3 1P	517	311	206	39.8
W4 1P	503	320	183	36.4
W5 1P	512	231	281	54.9
W7 2P	484	186	298	61.6
W8 2P	473	187	286	60.5
W9 2P	510	183	327	64.1
W10 2P	515	162	353	68.5

Persistence of the Nitrite Pattern From Targets Fired From Six and Twelve Inches, Placed Outside and Collected Weekly Over a Five Week Time Period.

The approximate diameter and estimated relative loss of the nitrite pattern for targets fired from six and twelve inches are listed in Table 21 and Table 22. Targets fired from six inches, displayed a relatively low loss of nitrite pattern during the first five week study. The loss of nitrite pattern during the second five week study displayed inconsistent results. Regarding targets fired from twelve inches, approximately half of the nitrite pattern was lost during the first five week study. In the second five week study, however, the nitrite pattern degraded much more quickly. The results from this study indicate that the nitrite pattern is more persistent on targets fired from six inches than on targets fired from twelve inches.

Table 21: The approximate diameter and estimated relative loss of the nitrite pattern from targets fired from six inches.

Week Number	MGT: Nitrite Pattern	Relative Loss
Week 2 1P	Out to about 6"	Low
Week 3 1P	Out to about 6"	Low
Week 4 1P	Out to about 6"	Low
Week 5 1P	Out to about 6"	Low
Week 7 2P	Out to about 4"	High
Week 8 2P	Out to about 4"	Medium
Week 9 2P	Out to about 6"	Low
Week 10 2P	Out to about 4"	High

Table 22: The approximate diameter estimated relative loss of the nitrite pattern from targets fired from twelve inches.

Week Number	MGT: Nitrite Pattern	Relative Loss
Week 2 1P	Out to about 7"	Medium
Week 3 1P	Out to about 7"	Medium
Week 4 1P	Out to about 7"	Medium
Week 5 1P	Out to about 7"	Medium
Week 7 2P	Out to about 5"	Very high
Week 8 2P	Out to about 5"	Very high
Week 9 2P	Out to about 5"	High
Week 10 2P	Out to about 4"	Very high

Persistence of Lead Patterns on Targets Fired From Six and Twelve Inches, Place Outside and Collected Weekly Over a Five Week Time Period.

A detailed description of the lead pattern obtained from the Sodium Rhodizonate test and estimated lead residues loss for targets fired from six and twelve inches are listed in Table 23 and Table 24. Loss of lead pattern on targets fired from six inches was low until the fifth week during the first five week study. During the second five week study, over half of the lead pattern was lost after two weeks. Targets fired from twelve inches, displayed a high loss of lead pattern during both of the five week studies. The results from this study indicate that the lead pattern is more persistent on targets fired from six inches than targets fired from twelve inches.

Table 23: A description of the lead residue pattern obtained by the Sodium Rhodizonate test and estimated lead residue loss on targets fired from six inches.

Week Number	Petal Pattern	Carbonaceous Film (diameter around the bullet entry hole)	Relative Loss
W2 1P	Yes; faint; partially resembles before	Yes; medium dense reaction 1½ in. diameter, hazy	Low
W3 1P	Yes; faint, partially resembles before	Yes; medium dense reaction 2 in. diameter, hazy	Low
W4 1P	Yes; partially resembles before	Yes; medium dense reaction 2 in. diameter, hazy	Low
W5 1P	No	Yes; light reaction 1½" in. diameter, hazy	High
W7 2P	Faint	Yes; light reaction 1½ in. diameter, hazy	High
W8 2P	No	Faint	High
W9 2P	No	No	No reaction
W10 2P	No	Faint	High

Table 24: A description of the lead residue pattern obtained by the Sodium Rhodizonate test and estimated lead residue loss on targets fired from twelve inches.

Week Number	Petal Pattern	Carbonaceous Film (diameter around the bullet entry hole)	Relative Loss
W2 1P	Faint	Yes, light reaction 2 in. diameter circle around bullet entry hole, kind of resembles before	Medium
W3 1P	No	Light reaction, hazy	High
W4 1P	No	Faint reaction	No reaction
W5 1P	No	No	No reaction
W7 2P	No	Faint reaction	Very high
W8 2P	No	No	No reaction
W9 2P	No	No	No reaction
W10 2P	No	Faint reaction	Very high

Results from the Microscopic, Visual and Chromophoric Examinations of the Blank Cotton Twill Cloths.

The two cotton twill cloths were examined both visually and through chromophoric techniques for the presence of GSR. There were no visible traces of GSR on the blank. Neither the MGT nor the Sodium Rhodizonate test gave positive results.

Step 3

Results from the Weather Conditions.

A detailed description of daily weather conditions in Lansing, Michigan from March 3, 2000 to May 11, 2000 are listed in Appendix F. Table 25 lists the maximum, minimum, and average temperature, precipitation, average wind speed and average maximum wind speed for each week.

Results from the Statistical Analysis

In order to access the significance of the weather data, Univariate Analysis of Variances were conducted on the number of powder particles counted on the targets before and after being placed outside for one week and each separate weather condition. A summary of the statistical analysis is located in Table 26.

Table 25: The maximum, minimum, and average temperature, precipitation, average maximum wind speed and average wind speed in Lansing, Michigan from March 3, 2000 to May 11, 2000

Week Number	Max. Temp. (^{0}F)	Min. Temp. (^{0}F)	Temp. (Ave.) (^{0}F)	Precipitation (Inches)	Max. Wind Speed (Ave.) (mph)	Wind Speed (Ave.) (mph)
Week 1 3/3/00 –3/9/00	78.8	17.6	45.8	.25" snow	15.62	9.2
Week 2 3/10/00-3/17/00	60.1	21.2	34	Light snow and misty	17.43	10.3
Week 3 3/18/00-3/23/00	64.4	15.8	39.7	Misty all week long, no significant	11.51	7.27
Week 4 3/24/00-3/30/00	59.0	19.4	45.6	Trace 2 days, misty	17.75	11.63
Week 5 3/31/00-4/6/00	62.6	19.4	44.9	Misty 1 day light snow	19.07	9.97
Week 6 4/7/00-4/13/00	48.2	19.4	33.1	Light snow 5 days	14.63	8.6
Week 7 4/14/00-4/20/00	71.6	37.4	49.1	Light rain 2 days, thunderstorm	16.11	9.79
Week 8 4/21/00-4/27/00	62.6	28.4	44.6	1 day light rain	14.96	8.02
Week 9 4/28/00-5/4/00	79.0	33.8	55.5	1 day light rain	12.33	7.47
Week 10 5/5/00-5/11/00	75.9	58.3	65.4	Thunderstorm 1.37"	23.3	11.5

Table 26: A statistical summary of the results from the Univariate Analysis of Variances conducted on the number of powder particles counted on the targets fired from six and twelve inches before and after being placed outside and with each separate weather condition.

	Base Model	Wind Speed	Max Wind Speed	Temperature	Precipitation
Distance					
Marginal Means					
6 "	406.92	423.984	418.167	401.947	418.129
12 "	366.98	349.916	355.733	371.953	350.871
Parameter Est.	39.941	74.069	620434	29.994	67.259
Partial Eta Sq.	0.043	0.144	0.113	0.028	0.184
St. Error	45.956	45.095	43.811	43.875	37.829
Sig.	0.397	0.12	0.173	0.504	0.097
Pretest					
Parameter Est.	0.495	0.246	0.331	0.567	0.284
Partial Eta Sq.	0.142	0.042	0.078	0.201	0.076
St. Error	0.295	0.295	0.289	0.282	0.264
Sig.	0.112	0.416	0.261	0.062	0.3
Weather					
Parameter Est.		-15.396	-6.491	-1.9	-76.34
Partial Eta Sq.		0.213	0.201	0.157	0.498
St. Error		7.39	3.238	1.101	20.495
Sig.		0.054	0.062	0.104	0.002

Relating the Various Weather Conditions to the Visual and Chromophoric GSR Patterns and the Statistical Analysis of the Loss of Powder Particles on Targets Fired From Six and Twelve Inches

The study's results indicate that the GSR pattern deposited on an item of clothing at a close distance that has been subjected to various weather conditions will lose some of the GSR pattern. The following sections address the degradation of GSR by wind, precipitation, and temperature on targets fired from six and twelve inches.

The Degradation of GSR by Wind

The results from this study indicate that wind does not drastically effect the loss of GSR on a target fired from six or twelve inches. This is evident by examining the visual and chromophoric results from targets collected on Week 4 and Week 10 (see Appendix D and E). The above mentioned weeks had the windiest weather conditions with maximum gusts up to 32 miles per hour, however each target displayed significant differences in the loss of GSR patterns. Less than half of the visible GSR, nitrite patterns and lead patterns were lost on targets collected from Week 4. Over half of the visible GSR, nitrite patterns, and lead patterns were lost on targets collected from Week 10. Figure 10 and Figure 11 chart the percentage of particles lost on targets fired from six and twelve inches and the average wind speed for each week in the study. The targets collected from Week 4 had a low percentage of particles lost. On the other hand, the targets collected from Week 10 had a high percentage of powder particles lost. These results indicate some other factor must have caused the significant loss of GSR on the targets collected from Week 10.

Statistically, the significance of the loss of powder particles on targets fired from six and twelve inches placed outside for one week and the average wind speed and the average maximum wind speed were different. Univariate Analysis of Variance indicated a significant difference between the average wind speed and the loss of powder particles, $p = 0.054$. No significant difference was found between the maximum wind speed and the loss of powder particles, $p = 0.062$ (see Table 26).

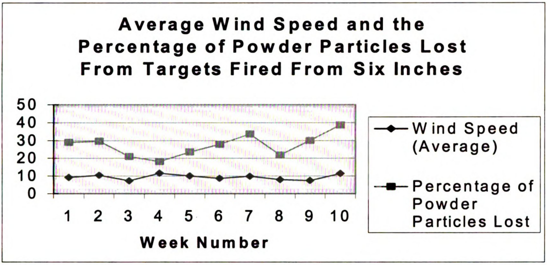

Figure 10: Comparison of the average wind speed and the percentage of particles lost from targets fired from six inches.

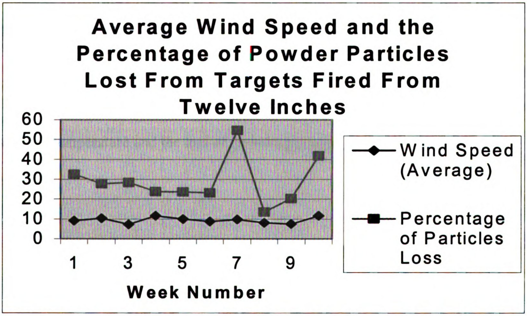

Figure 11: Comparison of the average wind speed and the percentage of powder particles lost from targets fired from twelve inches.

The Degradation of GSR Pattern by Temperature

Examined results of this study, show no direct relationship linking the loss of GSR to the differences in temperature. This is evident by examining the visual, chromophoric, and statistical results from the targets (see Appendices D and E and Table 26). Figure 12 and Figure 13 are graphs that chart the percentage of powder particles lost and the average temperature for each week. Week 10 had the highest average temperature during the ten week period and the targets collected from that week lost a significant number powder particles. The temperatures during the seventh week averaged in the high 40's which was typical to the other weeks average temperatures. The patterns collected from this week also lost a significant number of powder particles. The retrieval of a GSR pattern through chromophoric techniques were most effected on targets collected from Weeks 6,7 and 10. The average temperatures during these weeks ranged from the lowest average weekly temperature, 33.1 degrees Fahrenheit, to the highest weekly temperature, 65.4 degrees Fahrenheit. These results indicate that some other factor must have caused the significant loss of GSRs on the targets collected from Weeks 6, 7 and 10. Univariate Analysis of Variance revealed no significant difference between the average temperature and the loss of powder particles, $p = 0.104$ (see Table 26).

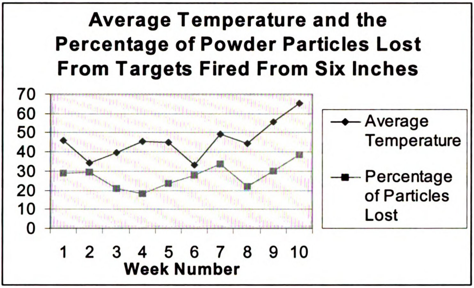

Figure 12: Comparison of the average temperature and the percentage of particles lost on targets fired from six inches.

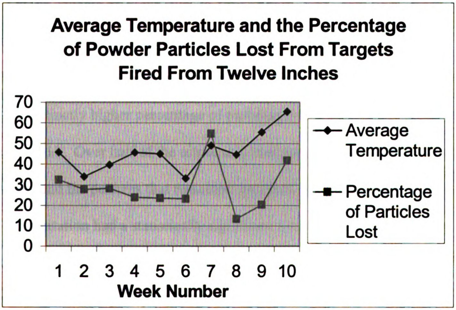

Figure 13: Comparison of the average temperature and the percentage of particles lost on targets fired from twelve inches.

The Degradation of GSR by Precipitation

The results from this study indicate the amount and form of precipitation does have an effect on the GSR present on targets. Each week's targets were subjected to some form of precipitation outside (refer to Table 25 or Appendix G). This study indicates a small amount of precipitation does not significantly effect visual GSR and the retrieval of a GSR pattern through chromophoric techniques. The results display that large amounts of rainfall or snow will effect the visual GSR pattern and the retrieval of a GSR pattern through chromophoric techniques.

A large amount of snow fell during the sixth week. Targets collected from this week, displayed a medium to low relative loss of visible GSR patterns. On the other hand, a majority of the nitrite pattern and lead pattern was lost on targets collected from this week (see Appendix D and E).

On the seventh and tenth weeks, thunderstorms produced a heavy down fall of rain totaling over one inch accumulation. The visible GSR and retrieval of a GSR pattern through chromophoric techniques were most effected on targets collected from these weeks. A distinctly higher percentage of particles were lost on the targets collected from Weeks 7 and 10. Over half of the nitrite and lead patterns were lost on the targets from these weeks and the patterns that remained appeared hazy (see Appendix D and E).

Precipitation had a statistically significant negative effect on the loss of powder particles. Univariate Analysis of Variance indicated there was a significant difference between the amount of precipitation and the loss of powder particles, $p = 0.002$.

Precipitation accounted for approximately 50% ($r^2 = 49.8$) of the variation in powder particle loss (see Table 26).

The results from targets collected from Week 9 are inconsistent with results from the other targets subjected to similar weather conditions. Targets subjected to moderate precipitation had a low loss of GSR pattern. The targets collected from Week 9 lost a significant amount of nitrite and lead pattern similar to the loss of GSR on the targets collected from Weeks 6,7 and 10. The author could not account for this inconsistency.

The results of this study indicate that the loss of the GSRs on the targets fired from six and twelve inches could be directly related to the quantity of precipitation. This is a plausible result since nitrite particles are water soluble. Therefore, significant amounts of rainfall or snow will dissolve nitrite compounds resulting in a loss of sight specific reactions. Lead particles are not water soluble but the patterns are fragile. Thus, it is plausible that large quantities of water could disturb or wash away lead particles on targets.

Chapter 4

SUMMARY AND CONCLUSIONS

This study was designed as an exploratory examination to assess various weather conditions' effect on GSR persistence on a clothing sample. The visual and chromophoric GSR examinations on targets fired from six and twelve inches and placed outside were related to the weather conditions.

A database of information was collected recording the GSR patterns on targets fired from six and twelve inches. The database displayed a difference in the GSR deposition on targets fired from six and twelve inches. Targets fired from six inches displayed more visible GSR and GSR retrieved through chromophoric techniques than targets fired from twelve inches. On the targets fired from twelve inches, the GSR patterns were distributed over a larger area than the targets fired from six inches. Targets fired from six inches generally had more powder particles. It is possible for a target fired from twelve inches to have a powder particle count similar to targets fired from six inches and vice versa. A statistical analysis indicated that the distance from which the firearm is discharged does effect the number of powder particles on the target.

The persistence of the GSRs on targets fired from six and twelve inches was examined by placing five targets outside and collecting one target weekly over a five week time period. The following conclusions were reached. The visible petal pattern and carbonaceous film pattern were fragile and can be easily lost. Nitrite residues were more persistent than lead residues. This result indicated that the MGT is a more reliable procedure to execute than the Sodium Rhodizonate test. The particulate pattern appeared to be the most persistent pattern. The diameter and the number of powder particles on the particulate pattern decreased as the weeks progressed. Overall, the visual GSR and GSR patterns retrieved through chromophoric techniques were more persistent on targets fired from six inches than fired from twelve inches.

The results from the persistency study agree and disagree with a study conducted by David Lindman (1989). This study's results coincide with Lindman's conclusion that the number of powder particles decreased the longer the target was outside. In Lindman's study, the circle within which the powder particles were located expanded over time. The study performed here demonstrated that the circle within which the powder particles were located decreased over time.

The results from this study indicated that the GSR pattern on clothing fired from a close distance and subjected to weather conditions will lose some of the GSR pattern. The following conclusions were made. Over half of the GSR pattern was lost on targets subjected to heavy rainfall or a large accumulation of snow indicating the amount of GSR pattern loss is dependent on the amount of precipitation. Because of the design of the experiment, whether the loss of residue is a threshold or linear phenomenon could not be determined. Statistically, precipitation accounted for approximately 50% of the loss of powder particles on the targets. An experiment designed on a much larger scale should be conducted to support this result. All of the results supported the hypothesis that precipitation would have a negative effect on the visual GSR pattern and the retrieval of a GSR pattern through chromophoric techniques.

These results agree with the results collected in a study conducted by M. Bonfanti and A. Gallusser (1995). In the results from their study, targets subjected to large quantities of water lost all visible gunshot residue, revealed a high loss of nitrite residues, and failed to reveal lead residues. Targets placed in snow displayed a low loss of visual and nitrite residues and the diameter of the circle containing the lead residues decreased by half. Both of these results were similar to the results collected from the targets placed outside and subjected to significant amounts of precipitation.

Examining the visual GSR patterns and the GSR patterns retrieved through chromophoric techniques, wind did not drastically effect the loss of GSR on targets. No statistically significant difference between the loss of powder particles and the average maximum wind speed was found. There was a statistically significant difference between the loss of powder particles and the average wind speed. The author could not account for the difference in significance between the wind speed and the maximum wind speed data. An experiment designed on a much larger scale should be conducted to determine the significance of wind and the loss of powder particles. These contradicting results neither supported nor denied the hypothesis that wind would have a negative effect on the visual GSR pattern and the retrieval of a GSR pattern through chromophoric techniques.

Examining the visual GSR patterns and GSR patterns retrieved through chromophoric techniques, a relationship could not be found between temperature and a loss of GSR patterns on targets. No statistically significant difference between the loss of powder particles and the maximum temperature was found. These results did not support the hypothesis that temperature would have a negative effect on the visual GSR pattern and the retrieval of a GSR pattern through chromophoric techniques.

The results from this study also indicated that generally targets subjected to weather conditions, not including a large accumulation of precipitation, exhibited a low loss of GSR. These targets displayed a low loss of visible GSR, powder particles, nitrite pattern, and lead pattern. A muzzle-to-target distance determination is possible with targets collected under these conditions.

Chapter 5

SUGGESTIONS FOR FUTURE RESEARCH

Many different research projects could expand upon this study. This study used one manufacturer and caliber of firearm, one manufacturer and type of ammunition, and two different firing distances. A study using different materials and parameters than previously mentioned could be conducted.

A persistence study for a longer time period could be perused to develop a time frame for the disappearance of visible GSR or a GSR pattern retrieved through chromophoric techniques.

A separate study could be conducted that monitors specific weather conditions. This study could entail simulating wind, temperature and precipitation and study the effect that each has on the visible GSR pattern or the retrieval of a GSR pattern.

This study was conducted during the spring in mid-Michigan. Comparing the results from this study to the results obtained from a study conducted in a different climate or season would be interesting. Another suggestion is placing the targets in different locations such as up in a tree, in a ditch, or under debris.

APPENDICES

APPENDIX A

MODIFIED GRIESS TEST – FBI LABORATORY PROTOCOL

Modified Griess Test – FBI Laboratory Protocol

Materials

1. Processing of previously desensitized photographic paper –

    a. Prepare a solution of 7.7 grains (0.5 grams) of sulfanilic acid in 100 milliliters of distilled water.

    b. Prepare a solution of 4.3 grains (0.28 grams) of alpha-naphthol in 100 milliliters of methanol.

    c. Combine the equal volumes of the above solutions.

    d. Pour the combined solutions into a non-reactive photo processing tray and briefly dip pre-cut sheets of desensitized photographic paper into the tray. Simply submerge the sheets completely and remove them.

    e. Set the sheets aside to dry on an uncontaminated surface.

    f. Place the remaining solution in an uncontaminated storage container and seal.

    g. Note: In lieu of desensitized photographic paper, ordinary laboratory filter paper may be processed in the same manner for used in the Modified Griess Test. Economy may dictate that this alternative be used.

    h. Shelf life for this reagent is known through experience to be at least two months and probably a great deal longer.

2. Preparation of nitrite test swabs –

    a. Prepare a solution of 9.3 grains (0.6 grams) of sodium nitrite in 100 milliliters of distilled water

b. Soak the cotton-tipped ends of a package of six inch swabs (typically, one hundred/package) in the solution.

c. Set the swabs aside to dry. Store in a sealed container.

3. Preparation of a 15% acetic acid solution –

   a. Combine 150 milliliters of glacial acetic acid with 850 milliliters of distilled water. Remember to gently pour the acid into the water to preclude the potential spattering of undiluted acid.

   b. Store in an appropriate uncontaminated sealed container.

Procedure

1. Test the four corners of the emulsion-coated side of the desensitized and chemically treated photographic paper for sensitivity to nitrite compounds. This is easily accomplished by saturating a nitrite test swab in a small amount of 15% acetic acid solution and dabbing the four corners. An orange color should appear at each corner, confirming such sensitivity before going further. Being able to testify to this sensitivity in court could be a critical issue.
2. Place the evidence or known-distance test questioned side down on the emulsion-coated side of the treated photographic paper. Index seams, buttons, button holes, rips, pockets, suspected bullet holes, tears, cuts, etc., for possible future reference in court by marking with a lead pencil. DO NOT USE INK at this point because it may transfer back onto the tested item.

3. Soak a piece of nitrite-free cheesecloth in the 15% acetic acid solution (in a large beaker) and wring it out. Place the cheesecloth on the questioned item or known-distance test as the third layer of the "sandwich". Press the "sandwich" with a hot iron. On many irons the setting for "cotton" is appropriate. (Note that nitrite-contaminated cheesecloth will cause a generalized orange background coloration. Although undesirable, this is not a fatal flaw as long as individual point reactions are still visible against the background.)
4. Discard the cheesecloth and separate the questioned item or known-distance test-firings from the photographic paper. Any orange indications on the paper are the result of a chromophoric reaction chemically specific for the presence of nitrite residues.
5. Retain any photographic paper showing positive results as a part of the raw data for inclusion in your notes. When dry, the photographic paper should be marked appropriately in ink with your symbol and case/file.

APPENDIX B

SODIUM RHODIZONATE TEST

Sodium Rhodizonate Test

Materials

1. Preparation of a 15% acetic acid solution* –
    a. Combine 150 milliliters of glacial acetic acid with 850 milliliters of distilled water. Remember to gently to pour the acid into the water to preclude the potential spattering of undiluted acid.
    b. Store in an appropriate uncontaminated sealed container.
2. Preparation of the sodium rhodizonate solution
    a. Place a small amount of sodium rhodizonate in a small beaker and add sufficient water to make a saturated solution approximately the color of strong tea. The solution is saturated if a slight sediment is noted on the bottom of the beaker after stirring with a clean glass stirring rod.
    b. Make only enough solution for immediate use and do not store the solution. Shelf life is currently unknown.
3. Preparation of 2.8 pH buffer solution.
    a. Dissolve 29.3 grains (1.9 grams) of sodium bitartrate and 23.1 grains (1.5 grams) of tartaric acid per 100 milliliters of distilled water. This usually requires both heat and agitation to complete in a reasonable period of time. A combination hot plate/magnetic stirrer is convenient for this and saves a great deal of time and effort.
    b. Store the solution in an uncontaminated and sealed container. Contaminated containers and water, or simply containers left open to the air, can allow the formation of what appear to be microscopic life forms which cloud the solution.

While these do not interfere with the specificity or reliability of the test, they do tend to clog up reagent spraying equipment. Allow such material to settle before spraying.

4. Preparation of the dilute 5% hydrochloric acid solution.
   a. Combine 5 milliliters of concentrated acid with 95 millimeters of distilled water. Remember to gently pour the acid into the water to preclude potential spattering of undiluted acid
   b. Store the solution in an uncontaminated and sealed bottle.

Procedure

1. Direct application to an item of evidence.*
   a. Spray the appropriate area of the questioned item with a previously prepared solution of 15% acetic acid solution.
   b. Spray the appropriate area of the questioned item with a previously prepared saturated solution of sodium rhodizonate in water.
   c. Spray the same area of the questioned item with the previously prepared tartaric acid/sodium bitartrate buffer solution. This solution will eliminate the general yellow background color caused by the sodium rhodizonate, will establish a local pH of 2.8, and turn any lead and a few other metal which may be present to a pink color.
   d. Spray the same area with the previously prepared dilute hydrochloric acid solution. The presence of lead is specifically determined wherever the previous pink color fades out and leaves lead. Be very aware of the face that a positive

(blue-violet) result may abruptly fade out. Take good notes immediately after applying the dilute hydrochloric acid solution.

*Michigan State Police Laboratory's Firearm Section added this step. The step is taken from a research paper written by Clara E. Schous, Honor Intern, F.B.I. Laboratory, Washington, D.C.

APPENDIX C

MATERIALS USED IN THIS EXPERIMENT

Firearm Used:

- 9 mm Smith and Wesson Model 469 serial number A852781

Ammunition Used:

- 9 mm Luger ammunition by Federal – Law Enforcement Ammunition

  Bullet: 125 grain, jacketed hollow point,

  Propellant: disc powder, 5.09 grain powder load

Target Collection Materials:

- 8.5 x 8.5 inch cotton twill cloths
- Zero One bench rest
- Casewell Detroit Armor Company Bullet trap
- File folders
- Masking tape
- Nails, 6 inches long

Visual and Microscopic Examination:

- Scion Image download program from NIH web page: www.NIH.gov
- Microsoft Adobe Photoshop
- Epson ES1200C Scanner
- American Optical Stereomicroscope

Chemical Examination:

- Modified Griess Test: reagent (aqueous sulfanilic acid and alpha-napthol in methanol), desensitized photographic paper, 15% acetic acid solution, Sears Kenmore iron, cheese cloth

- Sodium Rhodizonate Test: saturated solution of sodium rhodizonate, buffer solution (sodium bitrate and tartaric acid in distilled water), 5% hydrochloric acid solution, 15% acetic acid solution, air pump

Statistical Analysis:

- SPSS

APPENDIX D

GUNSHOT RESIDUES WORKSHEET

GUNSHOT RESIDUE WORKSHEET

Specimen:____________________

Distance from target:___________

Date Set Out:_________________

Date Collected:_________________

MICROSCOPIC EXAMINATION:

Smoke: ____________________

Bullet wipe: ____________________

Ripping/tearing: ____________________

Gunpowder/type: ____________________

Particle Count: ____________________

CHEMICAL EXAMINATIONS:

Modified Griess Test ____________________

____

Sodium Rhodizonate ____________________

____

Other Observations:

____

____

APPENDIX E

PHOTOGRAPHS OF TARGETS FIRED FROM SIX INCHES BEFORE AND AFTER BEING PLACED OUTSIDE FOR ONE WEEK, THE NITRITE PATTERN, AND THE LEAD PATTERN

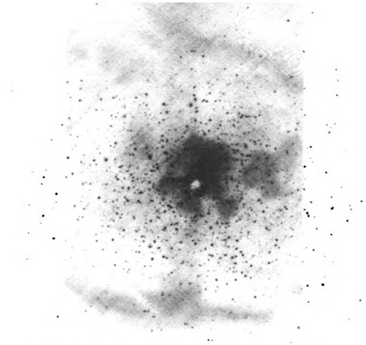

Figure 14: Week 1- the GSR pattern on a target fired from six inches

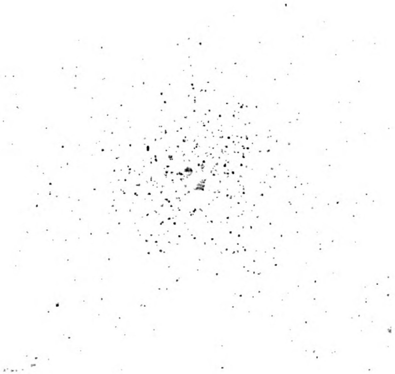

Figure 15: Week 1 – the GSR pattern on a target fired from six inches after being place outside for a week.

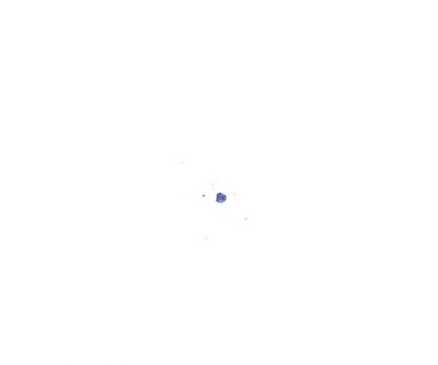

Figure 16: Week 1 – the nitrite pattern from the target fired at six inches after being placed outside for one week.

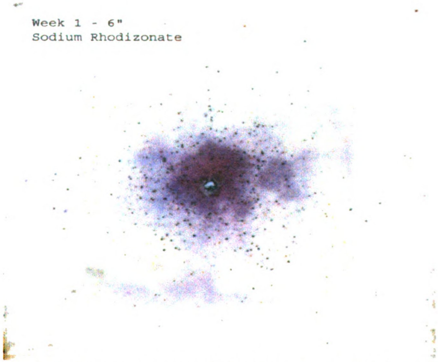

Figure 17: Week 1 – the lead pattern on a target fired at six inches after being placed outside for one week.

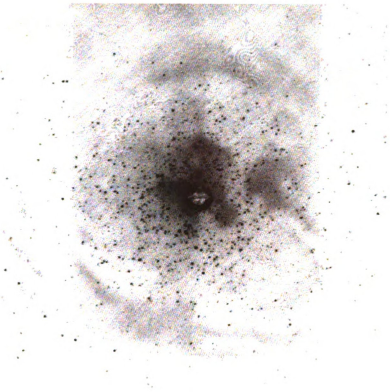

Figure 18: Week 2 – the GSR pattern on a target fired from six inches.

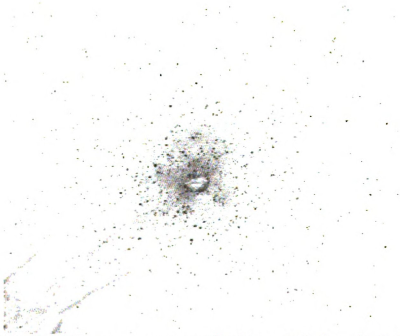

Figure 19: Week 2 – the GSR pattern on a target fired from six inches after being placed outside for one week.

Figure 20: Week 2 – the nitrite pattern from a target fired from six inches after being placed outside for one week.

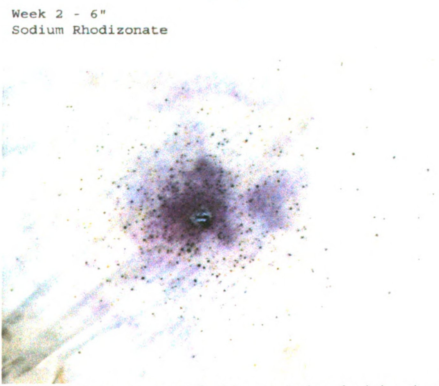

Figure 21: Week 2 – the lead pattern on a target fired from six inches after being placed outside for one week.

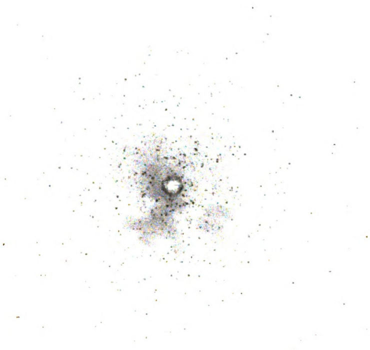

Figure 22: Week 3 – the GSR pattern on a target fired from six inches.

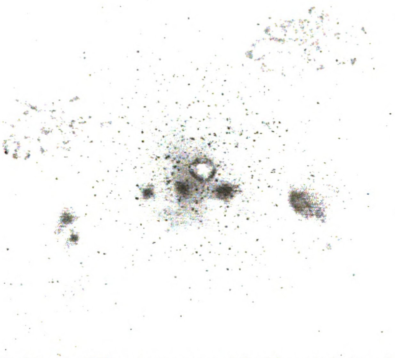

Figure 23: Week 3 – the GSR pattern on a target fired from six inches after being placed outside for one week.

Figure 24: Week 3 – the nitrite pattern on a target fired from six inches after being placed outside for one week.

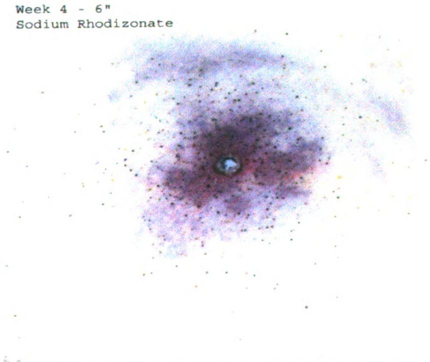

Figure 25: Week 3 – the lead pattern on a target fired from six inches after being placed outside for one week.

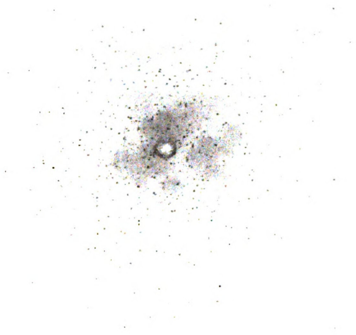

Figure 26: Week 4 – the GSR pattern on a target fired from six inches.

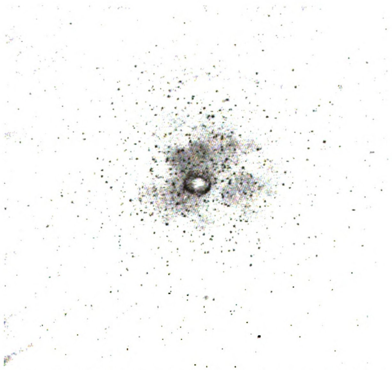

Figure 27: Week 4 – the GSR on a target fired from six inches after being placed outside for one week.

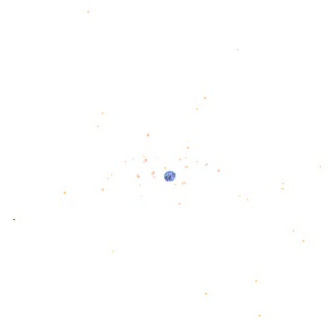

Figure 28: Week 4 – the nitrite pattern from a target fired from six inches after being placed outside for one week.

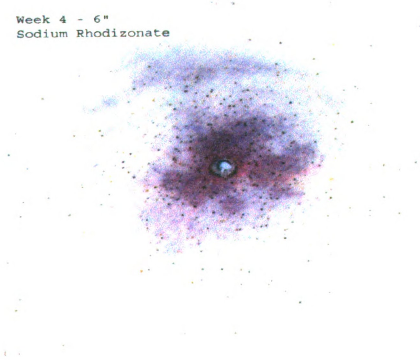

Figure 29: Week 4 – the lead pattern on a target fired from six inches after being placed for outside one week.

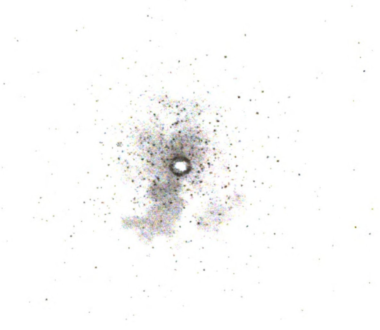

Figure 30: Week 5 – the GSR pattern on a target fired from six inches.

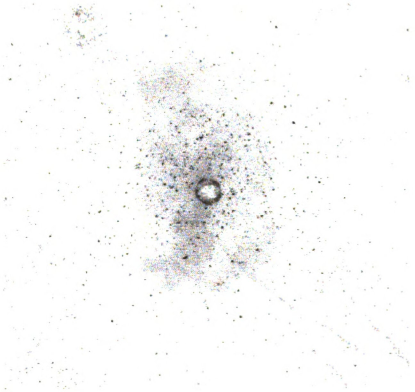

Figure 31: Week 5 – the GSR pattern on a target fired from six inches after placed outside for one week.

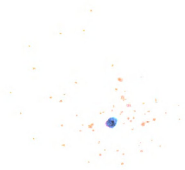

Figure 32: Week 5 – the nitrite pattern from a target fired from six inches after being placed outside for week.

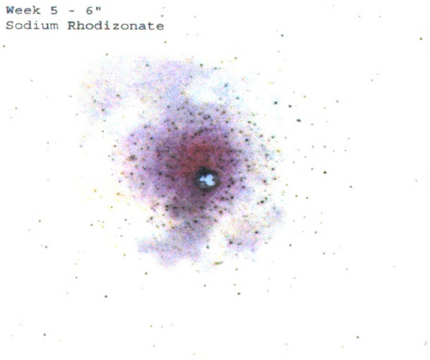

Figure 33: Week 33 – the lead pattern on a target fired from six inches after being placed outside for one week.

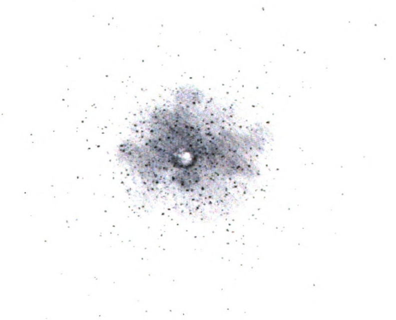

Figure 34: Week 6 – the GSR pattern on a target fired from six inches.

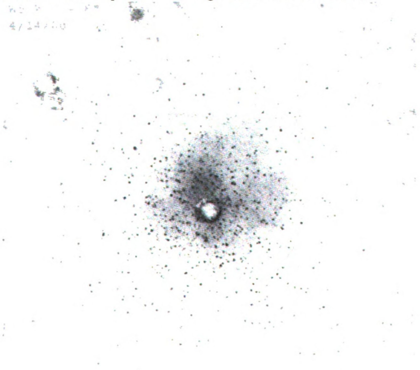

Figure 35: Week 6 – the GSR pattern on a target fired from six inches after being placed outside for one week.

Figure 36: Week 6 – the nitrite pattern from a target fired from six inches after being outside for one week.

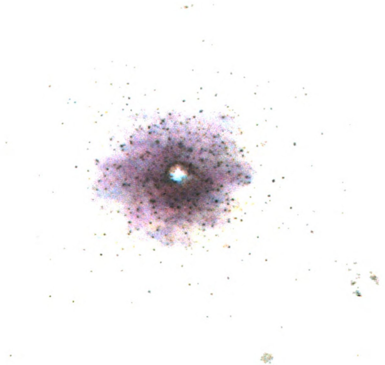

Figure 37: Week 6 – the lead pattern on a target fired from six inches after being placed outside for one week.

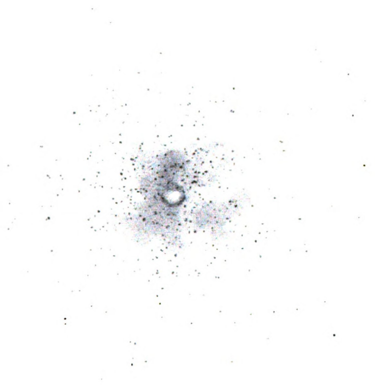

Figure 38: Week 7 – the GSR pattern on a target fired from six inches.

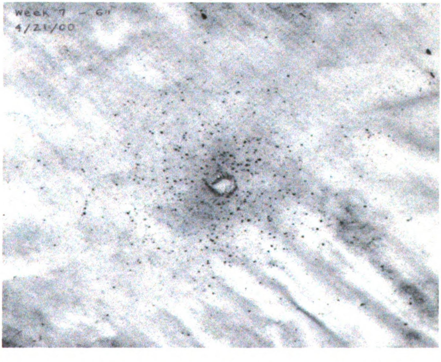

Figure 39: Week 7 – the GSR pattern on a target fired from six inches after being placed outside for one week.

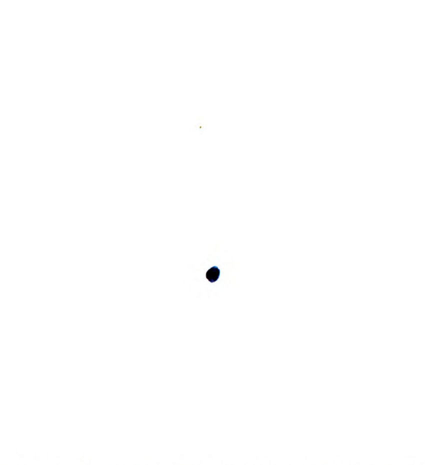

Figure 40: Week 7 – the nitrite pattern on a target fired from six inches after being placed outside for one week.

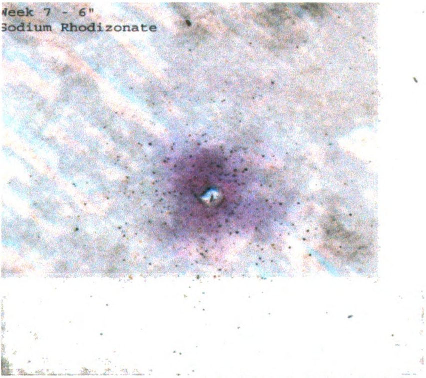

Figure 41: Week 7 – the lead pattern on a target fired from six inches after being placed outside for one week.

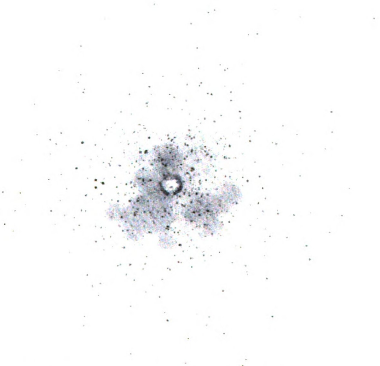

Figure 42: Week 8 – the GSR pattern on a target fired from six inches.

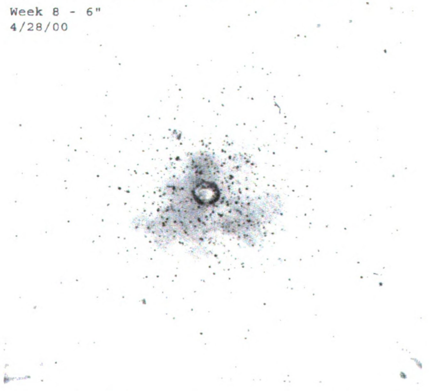

Figure 43: Week 8 – the GSR pattern on target fired from six inches after being placed outside for one week.

Figure 44: Week 8 – the nitrite pattern from a target fired from six inches after being placed outside for one week.

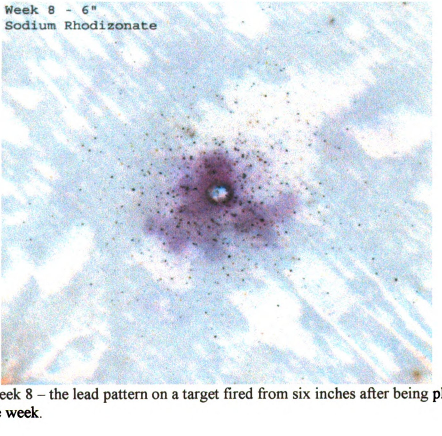

Figure 45: Week 8 – the lead pattern on a target fired from six inches after being placed outside for one week.

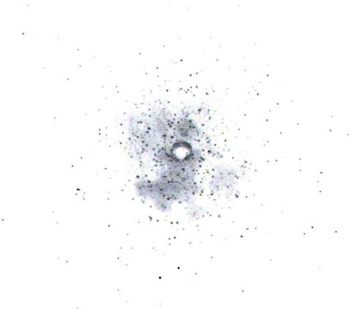

Figure 46: Week 9 – the GSR pattern on a target fired from six inches.

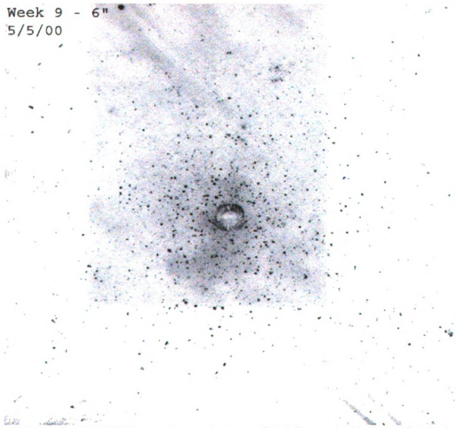

Figure 47: Week 9 – the GSR pattern on a target fired from six inches after being placed outside for one week.

Figure 48: Week 9 – the nitrite pattern on a target fired from six inches after being placed outside for one week.

Figure 49: Week 9 – the lead pattern on a target fired from six inches after being placed out side for one week.

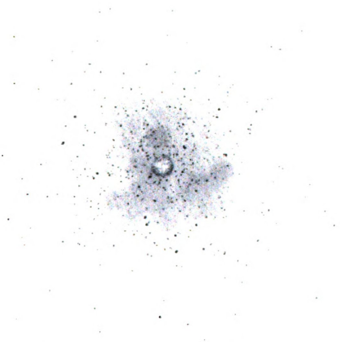

Figure 50: Week 10 – the GSR pattern on a target fired from six inches.

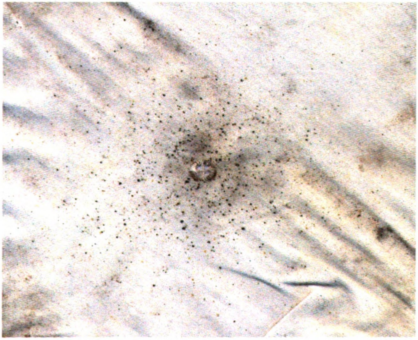

Figure 51: Week 10 – the GSR pattern on a target fired from six inches after being placed outside for one week.

Figure 52: Week 10 – the nitrite pattern from a target fired from six inches after being placed outside for one week.

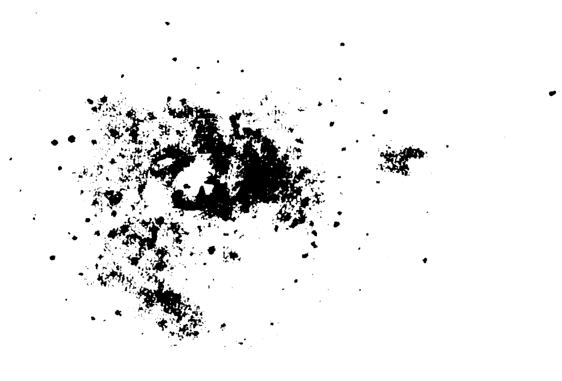

Figure 53: Week 10 – the lead pattern on a target fired from six inches after being placed outside for one week.

APPENDIX F

PHOTOGRAPHS OF TARGETS FIRED FROM TWELVE INCHES BEFORE AND AFTER BEING PLACED OUTSIDE FOR ONE WEEK, THE NITRITE PATTERN, AND THE LEAD PATTERN

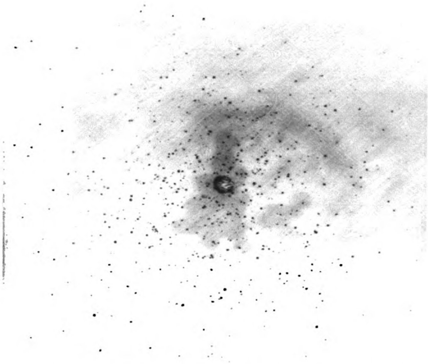

Figure 54: Week 1 – the GSR pattern on a target fired from twelve inches.

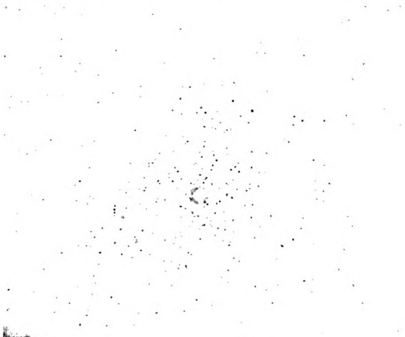

Figure 55: Week 1 – the GSR pattern on a target fired from twelve inches after being placed outside for one week.

Figure 56: Week 1 – the nitrite pattern from a target fired from twelve inches after placed outside for one week.

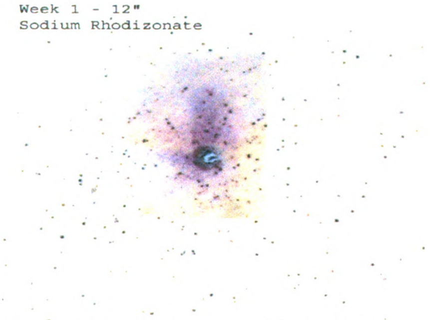

Figure 57: Week 1 – the lead pattern on a target fired from twelve inches after being placed outside for one week.

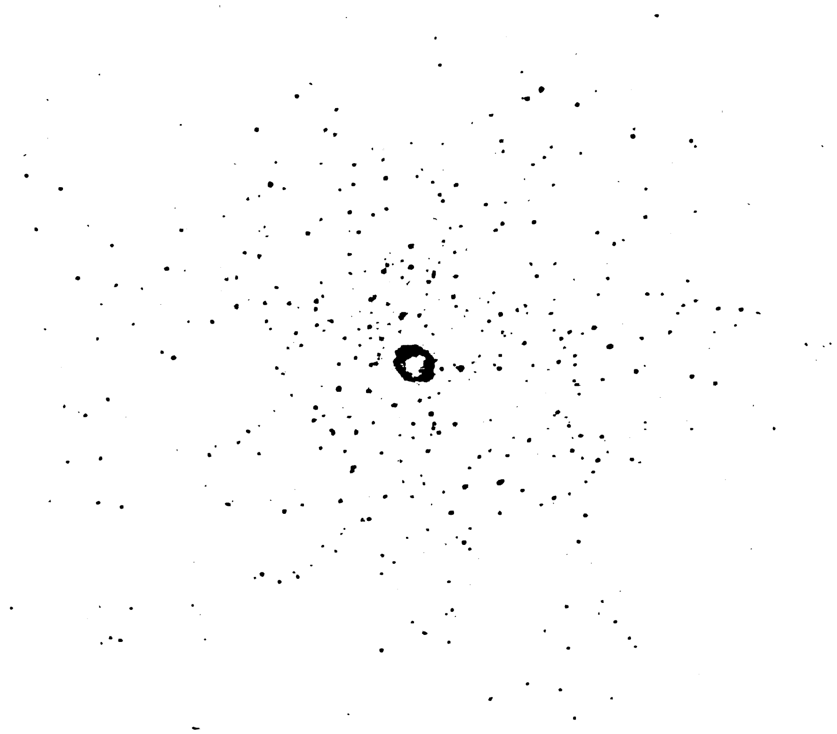

Figure 58: Week 2 – the GSR pattern on a target fired from twelve inches.

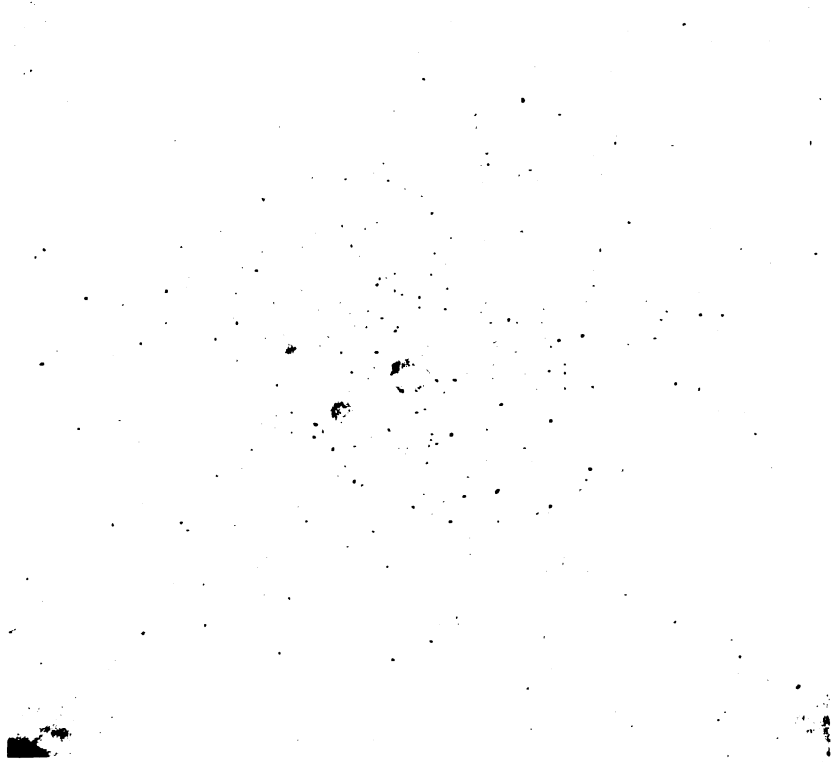

Figure 59: Week 2 – the GSR pattern on a target fired from twelve inches after being placed outside for one week.

Figure 60: Week 2 – the nitrite pattern from a target fired from twelve inches after being placed outside for one week.

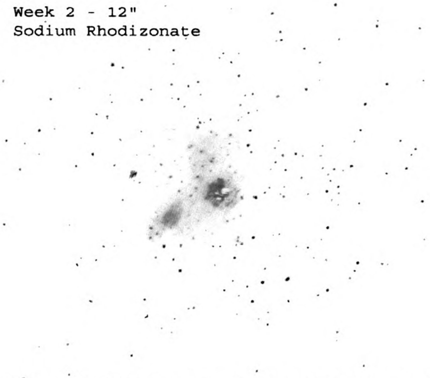

Figure 61: Week 2 – the lead pattern on a target fired from twelve inches after being placed outside for one week.

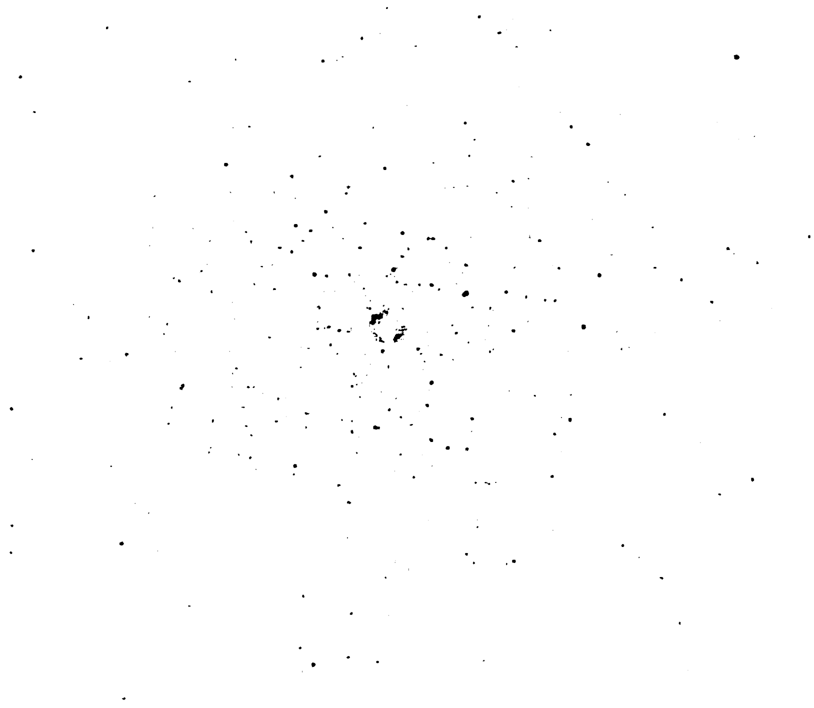

Figure 62: Week 3 – the GSR pattern on a target fired from twelve inches.

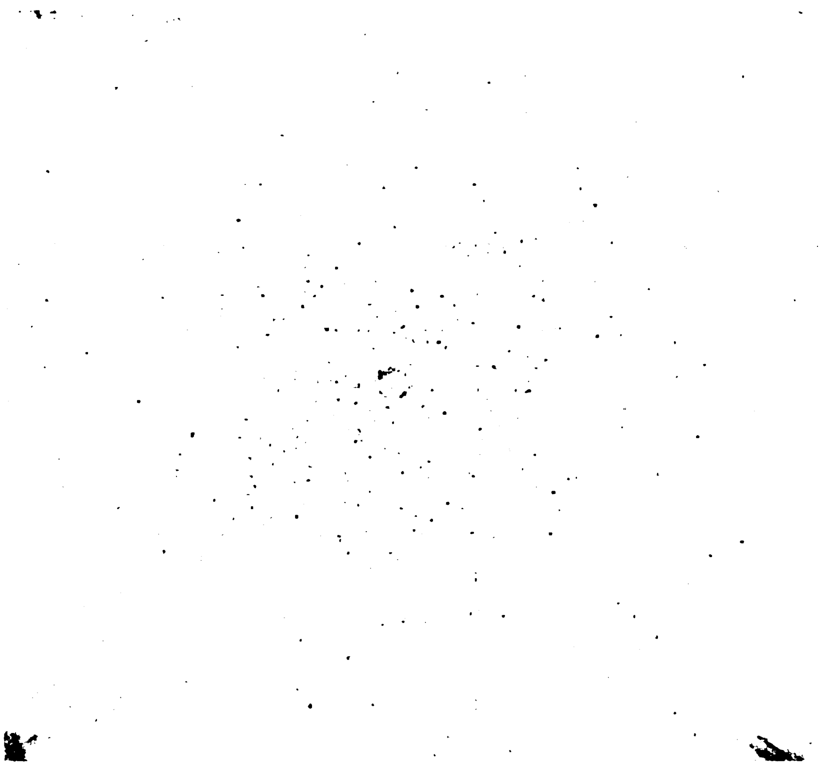

Figure 63: Week 3 – the GSR pattern on a target fired from twelve inches after being placed outside for one week.

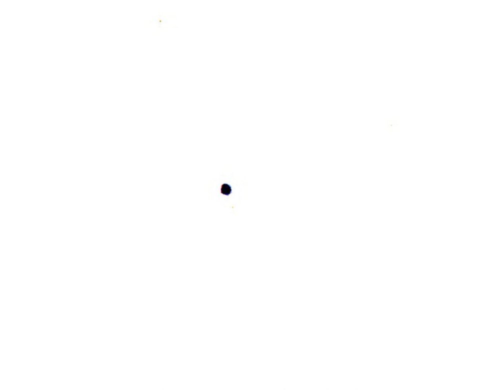

Figure 64: Week 3 – the nitrite pattern from a target fired from twelve inches after being placed outside for one week.

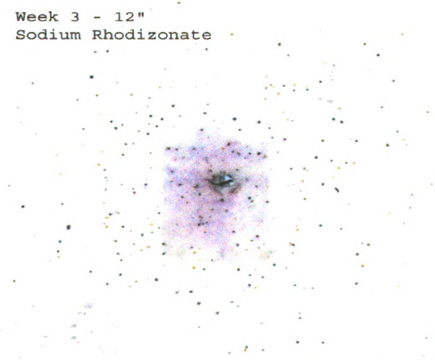

Figure 65: Week 3 - the lead pattern on a target fired from twelve inches after being placed outside for one week.

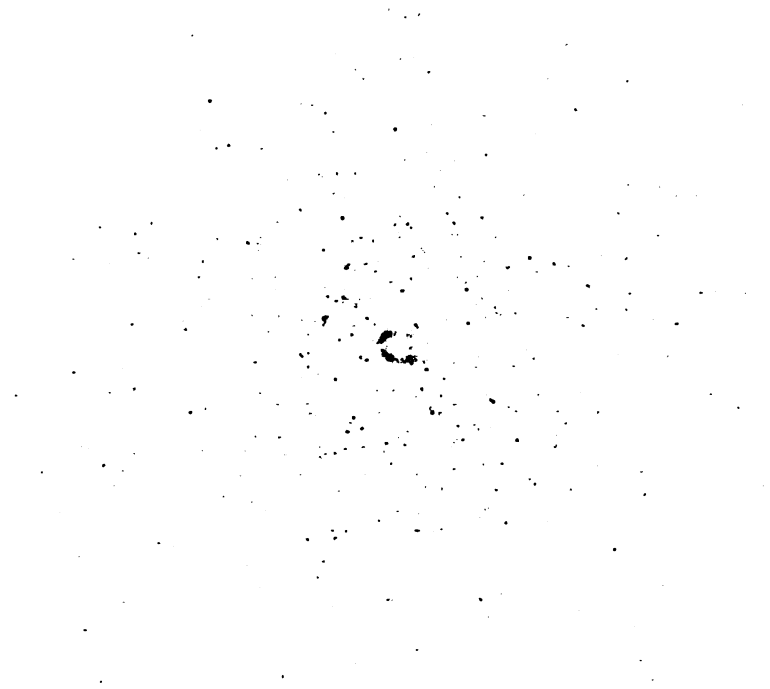

Figure 66: Week 4 – the GSR pattern on a target fired from twelve inches.

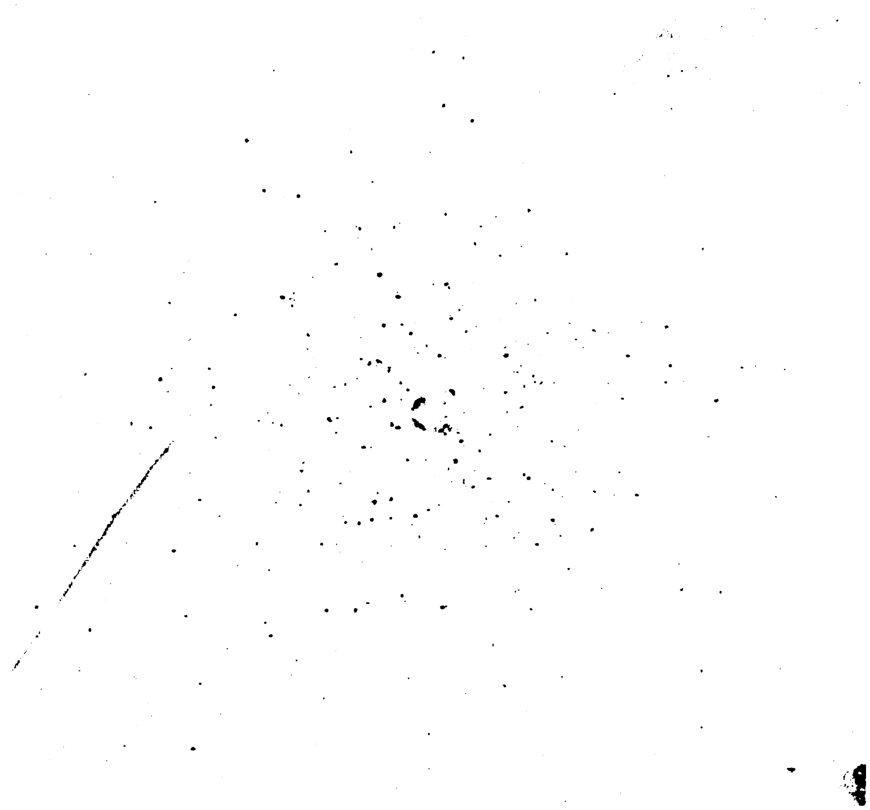

Figure 67: Week 4 – the GSR pattern on a target fired from twelve inches after being placed outside for one week.

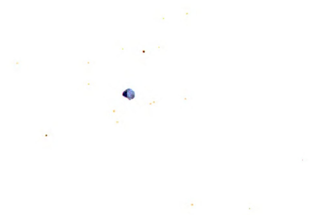

Figure 68: Week 4 – the nitrite pattern from a target fired from twelve inches after being placed outside for one week.

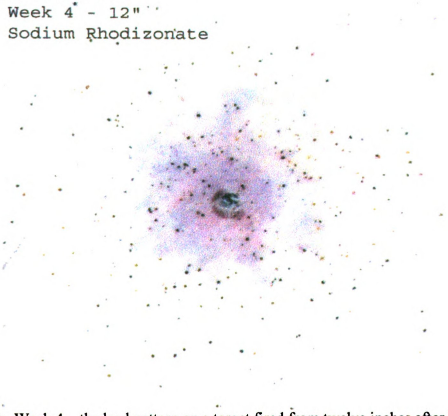

Figure 69: Week 4 – the lead pattern on a target fired from twelve inches after being placed outside for one week.

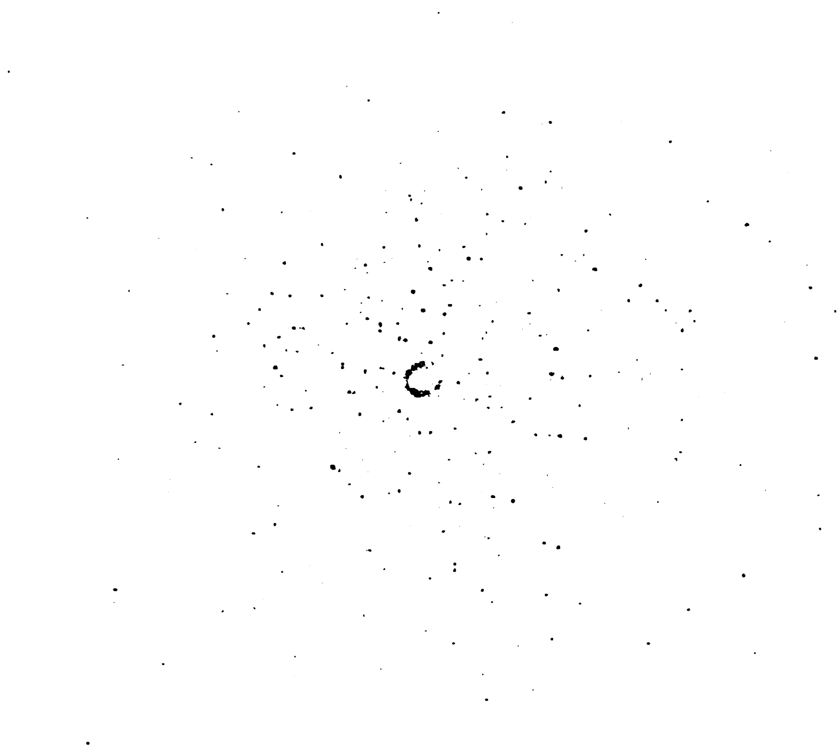

Figure 70: Week 5 – the GSR pattern on a target fired from twelve inches.

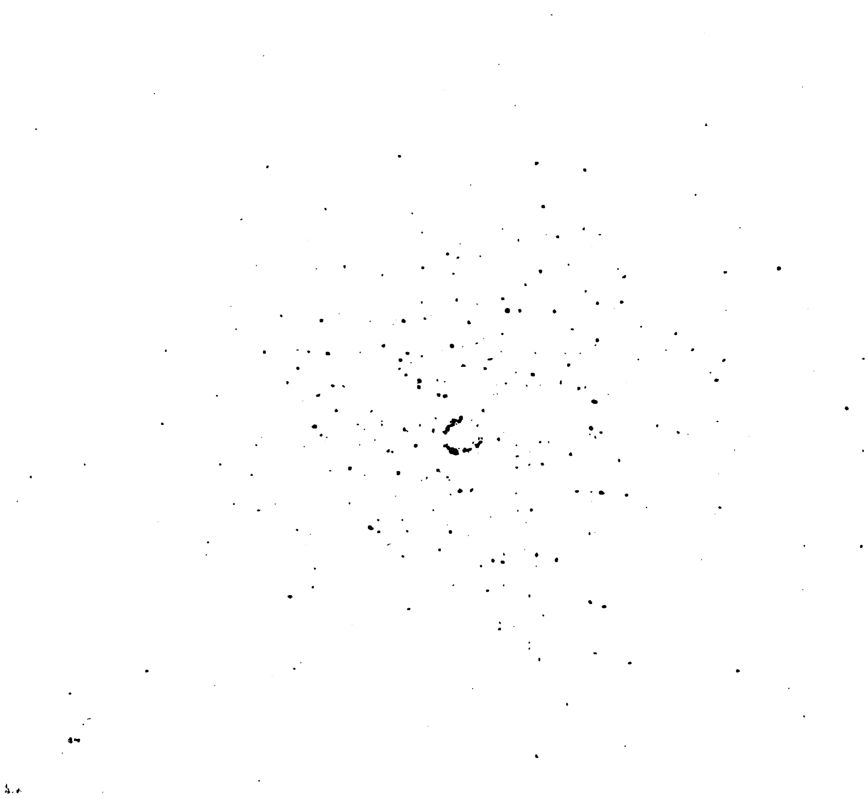

Figure 71: Week 5 – the GSR pattern on a target fired from twelve inches after being placed outside for one week.

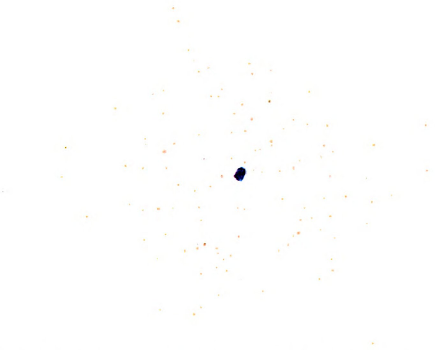

Figure 72: Week 5 – the nitrite pattern from a pattern fired from twelve inches after being placed outside for one week.

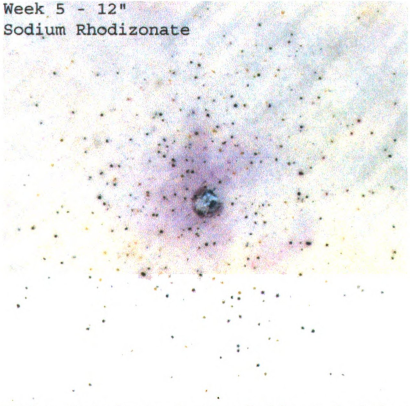

Figure 73: Week 5 – the lead pattern on a target fired from twelve inches after being placed outside for one week.

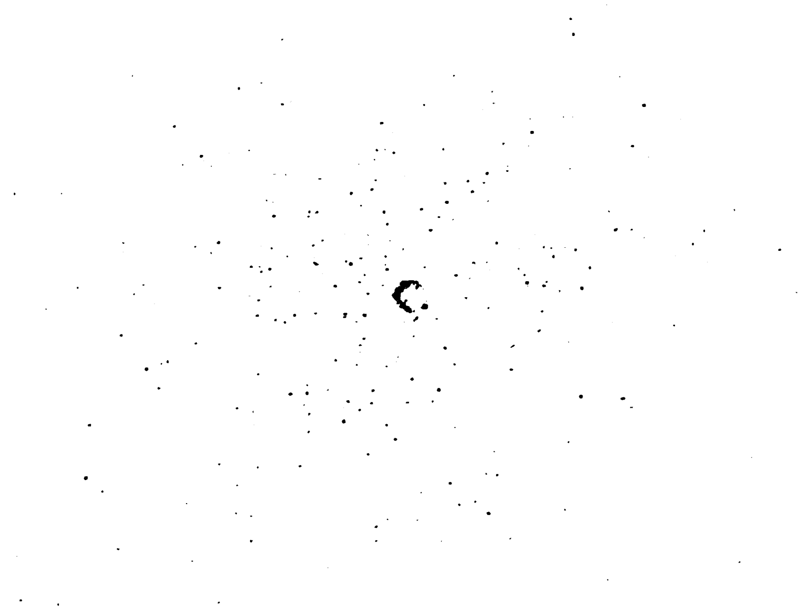

Figure 74: Week 6 – the GSR pattern on a target fired from twelve inches.

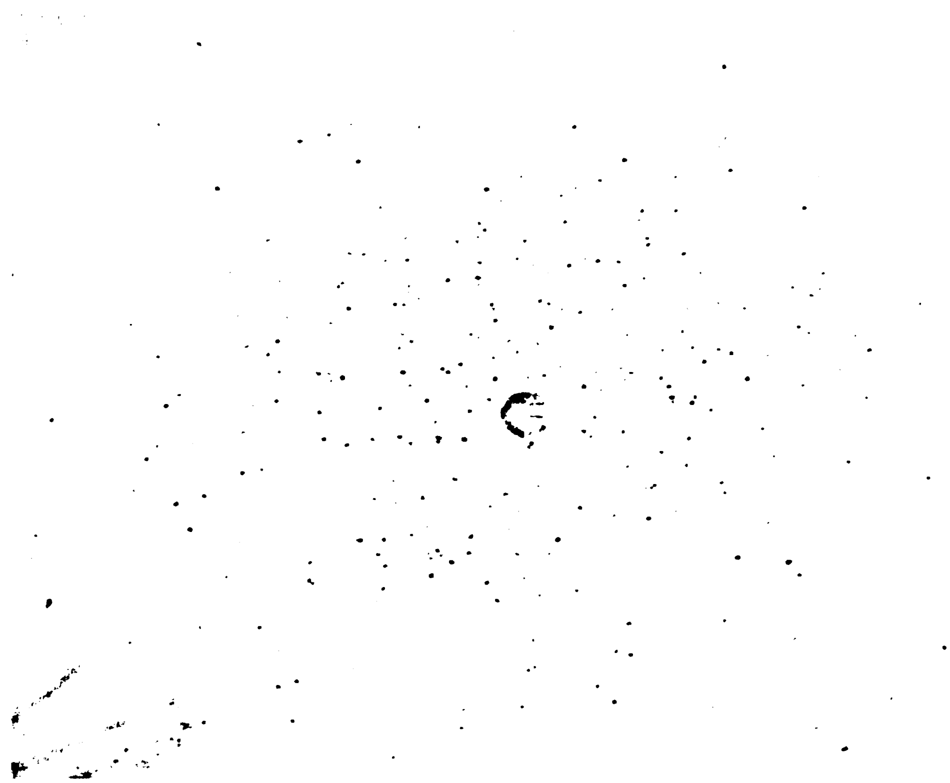

Figure 75: Week 6 – the GSR pattern on a target fired from twelve inches after being placed outside for one week.

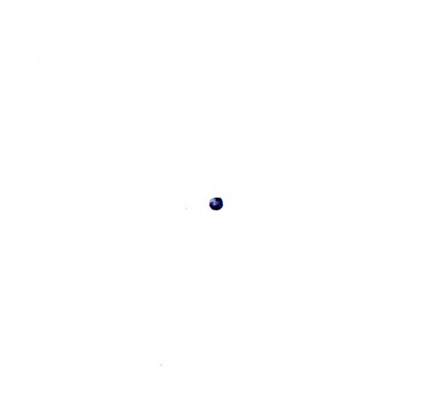

Figure 76: Week 6 – the nitrite pattern from a target fired from twelve inches after being placed outside for one week.

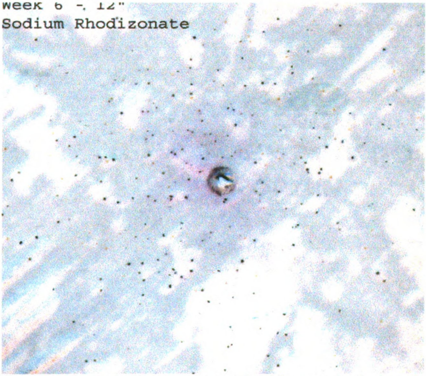

Figure 77: Week 6 – the lead pattern on a target fired from twelve inches after being placed outside for one week.

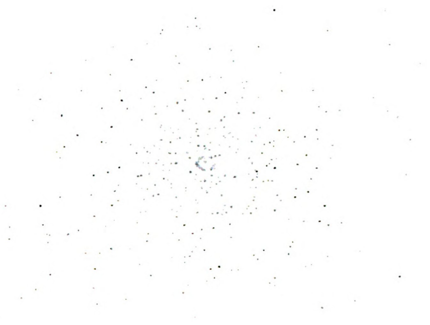

Figure 78: Week 7 – the GSR pattern on a target fired from twelve inches.

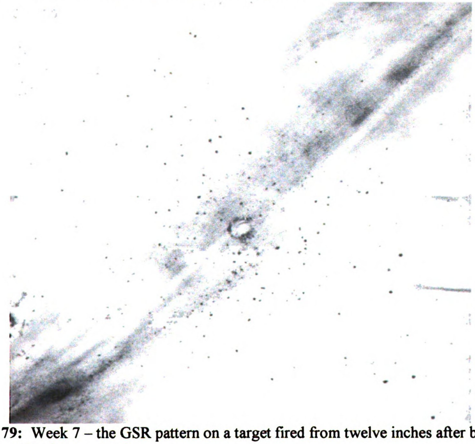

Figure 79: Week 7 – the GSR pattern on a target fired from twelve inches after being placed outside for one week.

Figure 80: Week 7 – the nitrite pattern from a pattern fired from twelve inches after being placed outside for one week.

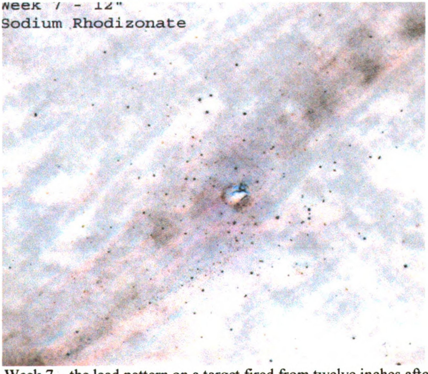

Figure 81: Week 7 – the lead pattern on a target fired from twelve inches after being placed outside for one week.

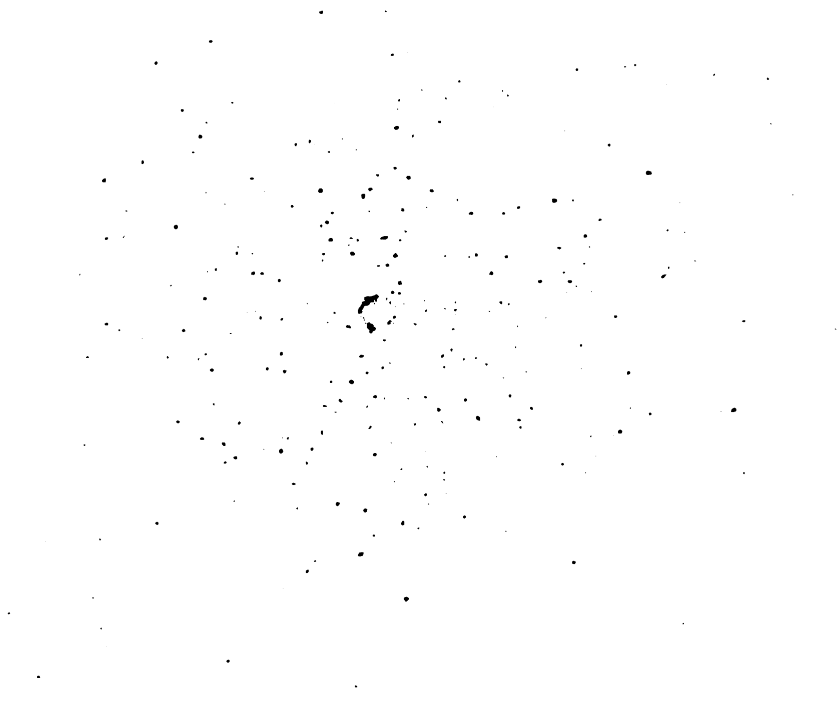

Figure 82: Week 8 – the GSR pattern on a target fired from twelve inches.

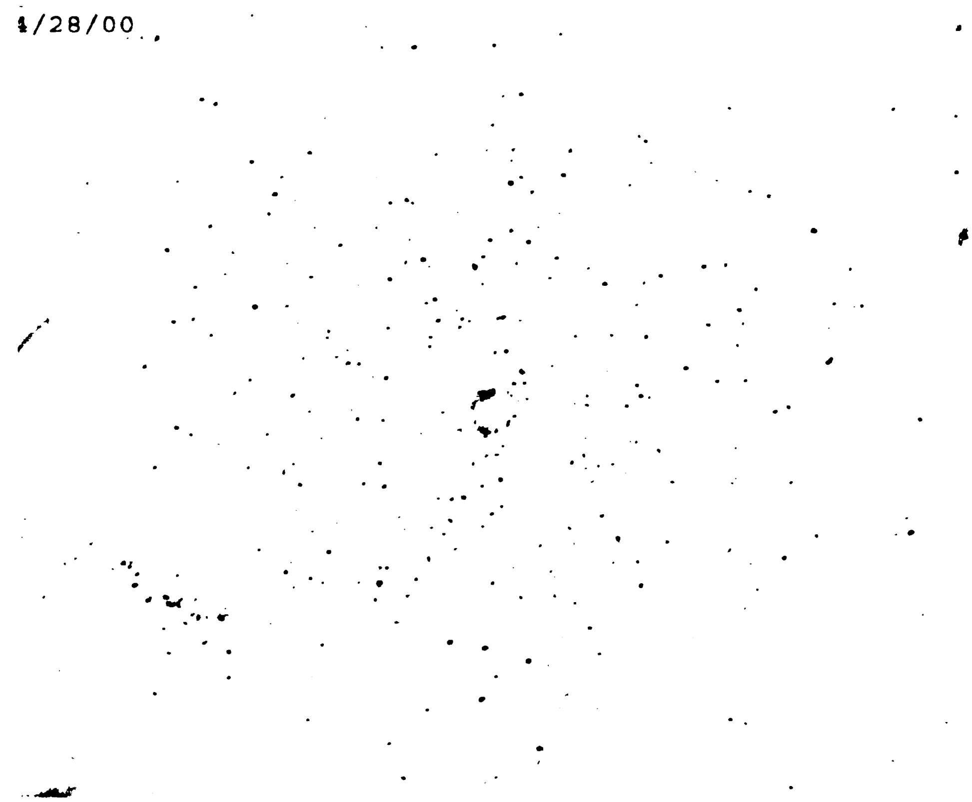

Figure 83: Week 8 – the GSR pattern on a target fired from twelve inches after being placed outside for one week.

Figure 84: Week 8 – the nitrite pattern from a target fired from twelve inches after being placed outside for one week.

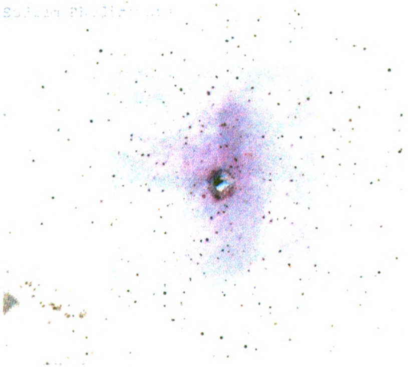

Figure 85: Week 8 – the lead pattern on a target fired from twelve inches after being placed outside for one week.

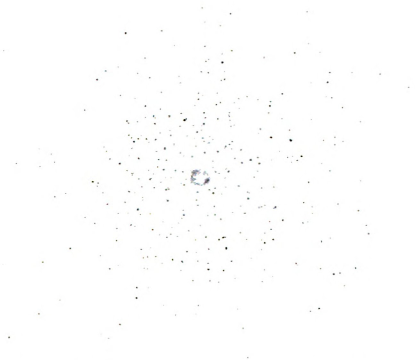

Figure 86: Week 9 – the GSR pattern on a target fired from twelve inches.

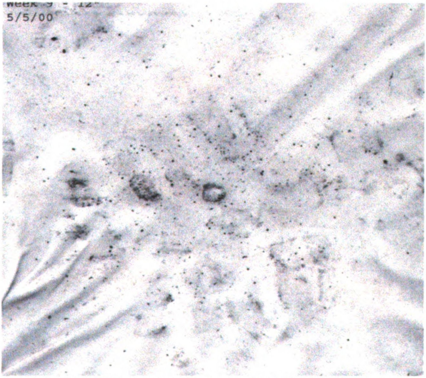

Figure 87: Week 9 – the GSR pattern on a target fired from twelve inches after being placed outside for one week.

Figure 88: Week 9 – the nitrite pattern from a target fired from twelve inches after being placed outside for one week.

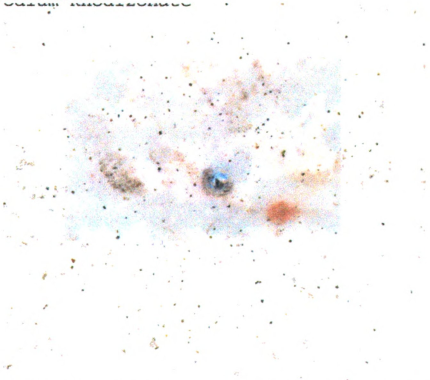

Figure 89: Week 9 – the lead pattern on a target fired from twelve inches after being placed outside for one week.

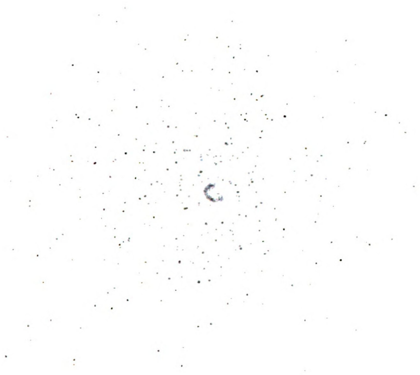

Figure 90: Week 10 – the GSR pattern on a target fired from twelve inches.

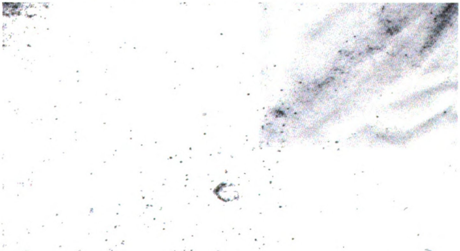

Figure 91: Week 10 – the GSR pattern on a target fired from twelve inches after being placed outside for one week.

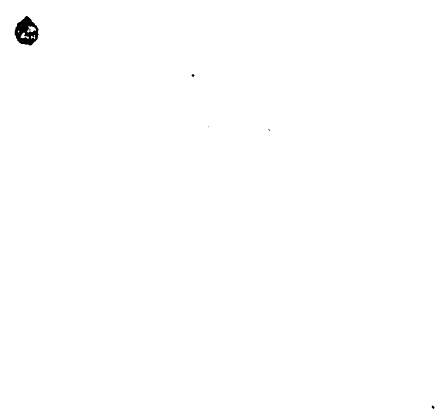

Figure 92: Week 10 – the nitrite pattern from a target fired from twelve inches after being placed outside for one week.

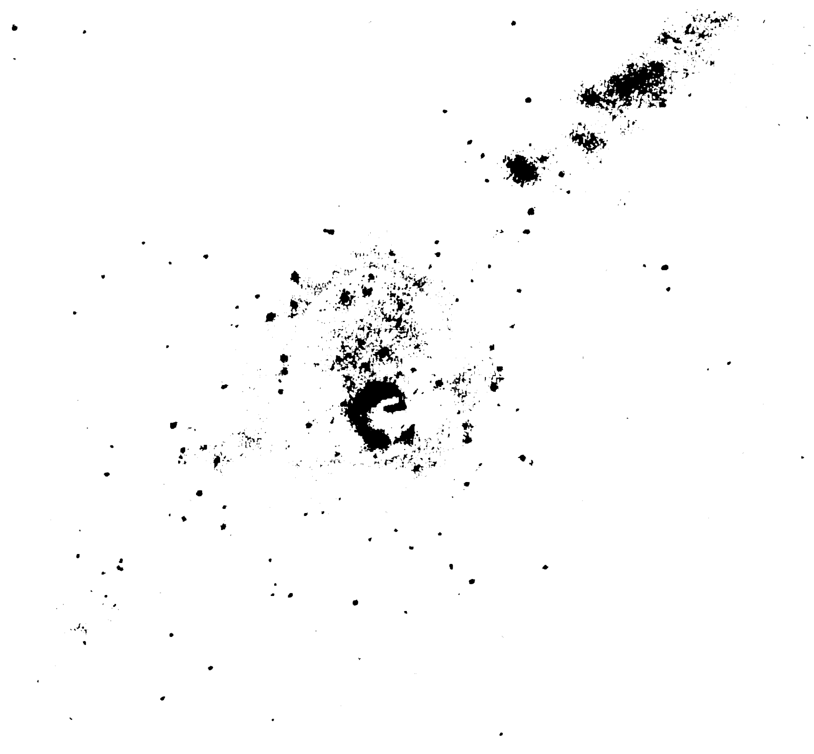

Figure 93: Week 10 – the lead pattern on a target fired from twelve inches after being placed outside for one week.

APPENDIX G

DAILY WEATHER CONDITIONS IN LANSING, MICHIGAN FROM MARCH 3, 2000 TO MAY 11, 2000

Table 27: Daily weather conditions in Lansing, Michigan from March 3, 2000 to May 11, 2000

Date	Mean Temp (⁰F)	Max. Temp (⁰F)	Min. Temp (⁰F)	Precip. (in.)	Wind speed (mph)	Max. Wind Speed (mph)	Morning	Afternoon	Night
3/3/00	31.4	46.4	17.6	none	4.6	9.21	clear, sunny	overcast	scattered clouds
3/4/00	35	53.6	23	none	7.15	16.11	mostly clear	mostly clear	mostly cloudy
3/5/00	41.7	57.2	24.8	none	2.42	6.9	clear, sunny	clear, sunny	clear
3/6/00	51.2	62.6	33.8	none	10.43	12.66	clear, sunny	clear, sunny	mostly cloudy
3/7/00	64	73.9	42.8	none	12.26	23.02	scattered clouds	partly cloudy	clear
3/8/00	66.8	78.8	55.4	none	13.17	21.87	clear, sunny	overcast	mostly cloudy
3/9/00	51	66.2	37.9	none	15.06	19.56	clear, sunny	overcast	mostly cloudy
3/10/00	25.5	28.4	23	.25 snow	8.56	11.51	snow, cloudy	Overcast	overcast
3/11/00	29.4	32	26.1	none	12.95	17.26	clear, sunny	Scattered clouds	overcast
3/12/00	30.1	42.8	21.2	none	9.29	16.11	clear, sunny	partly cloudy	mostly cloudy
3/13/00	32.9	42.8	28.4	0.01 snow	9.94	18.41	cloudy, light snow	cloudy light snow	cloudy, light rain
3/14/00	43	51.8	33.8	trace (0.01)	9.75	18.41	cloudy, misting	partly cloudy, cloudy, light rain	partly cloudy
3/15/00	48.1	60.1	42.8	misty	9.03	21.87	cloudy, misting	cloudy	scattered clouds
3/16/00	29.2	32	26.6	none	12.59	18.41	overcast	overcast	partly cloudy
3/17/00	24.8	32	21.2	none	9.36	12.66	partly cloudy	light snow, hazy	mostly cloudy
3/18/00	22.5	33.8	15.8	none	6.9	12.66	clear, sunny	Clear, sunny	clear
3/19/00	38.7	42.8	32	trace (0.01)	7.64	10.36	overcast	light rain, hazy	light rain, hazy
3/20/00	45	48.2	42.8	trace (0.01)	11.74	16.11	misty, cloudy	Misty, cloudy	misty
3/21/00	45.3	53.6	41	trace (0.01)	6.42	10.36	misty, hazy	Overcast	overcast
3/22/00	48.6	55.4	42.8	misty	5.2	8.06	misty, cloudy	Overcast	scattered clouds
3/23/00	53.2	64.4	37.4	misty	3.64	10.36	morning mist, cleared	Partly cloudy	clear

Table 27: (cont'd)

3/24/00	48.5	57.2	44.6	none	7.4	9.21	partly cloudy	Clear, sunny	scattered clouds
3/25/00	53.9	57.2	42.8	none	19.43	32.22	mostly cloudy	Partly cloudy, windy	partly cloudy
3/26/00	54.8	59	51.8	none	10.86	14.96	partly cloudy	Partly cloudy	partly cloudy
3/27/00	46.3	53.6	39.2	trace (0.01)	13.12	20.71	light rain, cloudy	Mostly cloudy	mostly cloudy
3/28/00	41.5	42.8	39.2	trace (0.01)	9.49	11.51	cloudy	Cloudy	rainy, cloudy
3/29/00	36.9	44.6	26.6	0.1	13.75	19.56	overcast	Overcast	mostly cloudy
3/30/00	37.6	51.8	24.8	none	7.37	16.11	clear, sunny	Clear, sunny	clear
3/31/00	39.2	57.9	19.4	none	4.12	16.11	partly cloudy	scattered clouds (mostly clear!)	partly cloudy
4/1/00	53.5	62.6	44.6	none	10.02	17.26	mostly cloudy	mostly cloudy	overcast
4/2/00	48.1	53.6	44.6	trace (0.01)	1.8	5.75	light rain, cloudy	misty, cloudy	partly cloudy
4/3/00	52.3	57.2	46.4	none	9.72	16.11	cloudy	cloudy	cloudy
4/4/00	36.1	46.4	26.6	trace (0.01)	14.44	21.87	cloudy, misty, windy light snow	cloudy, light snow	cloudy
4/5/00	37.8	51.8	21.2	none	10.12	21.87	partly cloudy	mostly cloudy	overcast
4/6/00	47.1	53.6	30.2	none	19.56	34.52	overcast	mostly cloudy, windy	clear
4/7/00	35.7	46.4	30.2	trace, snow	14.33	23.02	mostly cloudy	light rain, snow	snow
4/8/00	31.5	39.2	28.4	snow	13.86	20.71	snow, cloudy	partly cloudy	clear
4/9/00	35.1	48.2	19.4	snow	11.89	23.02	light snow	mostly cloudy	mostly cloudy
4/10/00	33.6	37.4	26.6	none	5.62	6.9	clear, sunny	clear, sunny	overcast
4/11/00	32.2	35.6	30.2	snow/ sleet	6.77	11.51	light snow/ sleet	light snow, haze	overcast
4/12/00	36.6	44.6	28.4	light snow	7.04	13.81	light snow, mostly cloudy	mostly cloudy	mostly cloudy

Table 27 (cont'd).

4/13/00	27	30.2	24.8	none	0.69	3.45	clear, sunny	clear, sunny	clear
4/14/00	50.4	64	41	none	9.98	13.81	partly cloudy	clear, sunny	clear
4/15/00	61.8	71.6	46.4	none	10.89	17.26	mostly cloudy	mostly cloudy	clear
4/16/00	43	48.2	39.2	none	11.81	16.11	overcast	overcast	overcast
4/17/00	43.1	53.6	37.4	trace (0.02)	12.56	18.41	light rain, cloudy	mostly cloudy	overcast
4/18/00	48.3	62.6	39.2	none	5.1	10.36	overcast	mostly cloudy	mostly cloudy
4/19/00	48.2	53.6	44.6	trace	4.94	12.66	overcast, mist	overcast, trace	light rain, hazy
4/20/00	48.7	53.6	46.4	0.5	13.29	24.17	rain	rain, t-storms	rainy, cloudy
4/21/00	41.3	45	39	trace (0.01)	12.99	23.02	misty	light rain	light rain, hazy
4/22/00	48.1	62.6	37.4	none	7.55	10.36	clear, sunny	clear, sunny	clear
4/23/00	48.9	61	33.8	none	4.7	11.51	partly cloudy	mostly cloudy	overcast
4/24/00	49.7	51.9	33.6	none	10.74	20.71	clear, sunny	clear, sunny	clear
4/25/00	45.3	57	35.6	none	10.98	18.41	clear, sunny	clear, little windy	scattered clouds
4/26/00	37.8	48.2	28.4	none	2.68	8.06	clear, sunny	clear, sunny	clear
4/27/00	40.9	62.1	34	none	6.53	12.66	clear, sunny	clear, sunny	clear
4/28/00	49.5	66.2	33.8	none	3.27	9.21	clear, sunny	partly cloudy	clear
4/29/00	52.7	62.6	37.4	none	6.33	12.66	partly cloudy	partly cloudy	partly cloudy
4/30/00	66.9	68	64.4	none	10.82	12.66	partly cloudy	partly cloudy	partly cloudy
5/1/00	52.6	57.2	46.4	0.1	6.9	12.66	partly cloudy	light rain	partly cloudy
5/2/00	46.2	64.4	37	none	3.96	6.9	clear, sunny	clear, sunny	clear
5/3/00	60.5	71.1	48.2	none	10.22	13.81	clear, sunny	clear, sunny	partly cloudy
5/4/00	60.4	79	53.6	none	10.8	18.4	mostly cloudy	mostly cloudy	mostly cloudy
5/5/00	70	81	58	none	9.7	24	sunny, clear	sunny, clear	clear
5/6/00	71	83	58	none	12.1	26	sunny, clear	partly cloudy	cloudy

Table 27 (cont'd).

5/7/00	64	81	73	trace (0.01)	11.6	25	partly cloudy	partly cloudy	partly cloudy
5/8/00	75	83	67	none	13.2	33	partly cloudy	overcast	overcast
5/9/00	66	74	58	1.37	10.5	34	cloudy, rainy	partly cloudy	rainy, cloudy
5/10/00	55	64	45	0.06	11.8	29	partly cloudy	partly cloudy	partly cloudy
5/11/00	57	65	49	trace (0.01)	11.6	32	cloudy	cloudy	cloudy

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