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A STUDY TO EXAMINE SHOTGUN PELLET PATTERN OVERLAP BETWEEN TEST FIRING DISTANCES AS A METHOD FOR DETERMINING RANGE-OF-FIRE ESTIMATES

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A STUDY TO EXAMINE SHOTGUN PELLET PATTERN OVERLAP BETWEEN TEST FIRING DISTANCES AS A METHOD FOR DETERMINING RANGE-OF-FIRE ESTIMATES

By

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ABSTRACT

A STUDY TO EXAMINE SHOTGUN PELLET PATTERN OVERLAP BETWEEN TEST FIRING DISTANCES AS A METHOD FOR DETERMINING RANGE-OF-FIRE ESTIMATES

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This study examined shotgun pellet pattern overlap between test firing distances to determine how narrow range-of-fire estimates could be made and analyzed the effect of low barrel and low shell temperature on the spread of pellet patterns.

A shotgun was fired through a series of 5 in-line paper targets placed at 15, 20, 25, 30 and 35 feet. From 100 test firings .95, .96, and .97 confidence intervals were calculated for the mean pattern diameter at each test distance. The .95 and .96 confidence intervals did not overlap between the adjacent 5 foot test distances.

Analysis of variance of the mean pellet pattern diameter at each test distance for low barrel, low shell and normal air temperature data groups showed a significant effect on pattern size caused by low shell temperature.

Dedicated to my father, Charles Gardner

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CHAPTER 1

INTRODUCTION

The purpose of this research was to develop a method for determining the degree of shotgun pellet pattern overlap between test firing distances for range-of-fire estimation. The variable nature of shotgun pellet dispersion can result in the same size pellet pattern appearing at different test firing distances. Determining the degree that pellet patterns at one test distance overlap at other test distances will indicate how narrow a range-of-fire estimate can be determined. This study examined the amount of pellet pattern overlap between targets placed at 5 foot test distance intervals. Also of concern is the effect temperature of the barrel and of the ammunition has on the spread pellet patterns. To test this effect two groups of test firings, one with a low barrel temperature and the other with a low shell temperature, were compared to a group where temperatures were not controlled.

This research was inspired by conflicting testimony given in an inquest hearing.[1] The main issue at that inquest was whether either of two shotguns had been discharged at a distance greater or less than 30 feet from a wall inside a house. The wall supported two shotgun pellet patterns allegedly caused by pellets originating from the shotguns.

The defense expert witness conducted testing which led him to the conclusion that the shotguns were fired at a distance of approximately 25 feet, but less than 30 feet. The prosecution's expert witness also tested the shotguns and formed an opinion that the weapons were discharged at a distance greater than 30 feet but less than 35 feet.

Both experts used the same distance determination method, one currently practiced by firearms examiners. Their conclusions were based on a method of visually comparing the evidence pattern to a few test patterns fired at each of several test distances. However, the test patterns of the defense expert were larger than those of the prosecution, which gave rise to the different opinions. The only notable difference in the testing was that the prosecution's testing was conducted with ambient temperature near 50 degrees F and the defense testing was done with temperature near 70 degrees F.

Currently, firearms examiners determine the distance a particular shotgun was fired by visually comparing the size of an evidence pellet pattern to the size of test patterns. A test pattern is made by shooting the firearm at a target placed at a measured distance. Different test distances are selected and the firearm is fired at targets placed at those distances. Normally, only 3 or 4 targets are fired at each selected test distance.

The test distance with targets who's pellet patterns are closest in size to the evidence pattern indicate the approximate distance-of-fire.

The testing is done with the same weapon and with shells from the same box of ammunition that produced the evidence pattern. If the same box of ammunition is not available from the crime scene then it is substituted with the same brand and shell components.[2]

Shotgun pellet patterns vary in size from one firing to the next. This variable nature results in patterns of the same size at different test distances. Consequently, any one test distance cannot be selected as a distance-of-fire without the possibility of excluding another test distance with the same pattern size. To avoid this error, distance determinations are presented as an estimated range-of-fire with upper and lower boundaries. The upper boundary is determined by selecting a test distance with pellet patterns larger in size from that of the evidence pattern. The lower boundary is selected from a test distance with pellet patterns smaller than the evidence pattern. The difference in size of the patterns selected is determined by the examiner's experience and his observations in testing.

Previous papers appearing in the forensic science literature have discussed the application of regression analysis to the distance estimation problem. The statistical methods for obtaining range-of-fire estimates and confidence intervals for those estimates were reported and tested as an objective approach. This study was conducted to shed more light on the variable nature of shotgun pellet dispersion data and the application of those methods.

CHAPTER 2

REVIEW OF LITERATURE

A review of the current forensic science literature reporting methods of shotgun distance-of-fire determination revealed four studies on statistical analysis of pellet dispersion data and two indirectly related articles.

In 1972 M. Jauhari, M. Chatterjee and P. K. Gosh of the Central Forensic Science Laboratory, Calcutta, India showed the use of in-line targets which had the effect of increasing the amount of data gained per test firing and presented two methods for estimating distance-of-fire.[3] Their study investigated the feasibility of shooting through several paper targets with one firing. To obtain test data for statistical analysis a .410 shotgun was fired 10 times through a series of 0.013 cm thick paper targets placed at 6, 9, 15, and 18 feet. To obtain questioned pellet patterns for a blind comparison the test shotgun was fired twice at 3.05 m with the same ammunition as the 10 data test firings. Another questioned pellet pattern was fired at 2.13 m with ammunition from a different lot number. This was done to test predictions of a distance-of-fire with different ammunition than was used at the crime scene.

Two methods were discussed for estimating range-of-fire, the distribution-free method and regression analysis. The distribution-free method is applied when it is not possible to assume a normal distribution of the population consisting of the size of pellet patterns at different test distances for the case at hand. This situation is present when the same weapon or the same type of ammunition as used in the crime is not available for testing. A normal distribution is assumed when the same gun and type of ammunition are available. Distribution free range-of-fire estimates are determined by using the largest and the smallest pattern diameters of each test distance. The lower end of an estimated interval is obtained from a linear interpolation between the two smallest adjacent test distance patterns. The upper end of the estimated interval is obtained from interpolation between the two largest adjacent test distance patterns.

Regression analysis was applied to the test data to calculate confidence intervals for range-of-fire estimates. The confidence intervals were calculated by multiplying the standard deviation by a numerical factor obtained from a table of specified proportions of samples of the population of test firings. When using .95 and higher confidence levels the confidence intervals may be wide spread, which may not be of practical interest. Specifying a proportion of the sampled population results in a narrower range-of-fire confidence interval without reducing the percent of the population sampled.

The results of their study showed that the target material did not significantly alter the pellet pattern at the .05 level of significance. The calculated distribution free range-of-fire limits contained the actual distance-of-fire for both types of ammunition. Regression range-of-fire confidence limits calculated for 75, 90, 95, and 99 percent of the sampled population were found to contain the actual distance-of-fire.

A report in 1975 by David Brundage adopted the use of in-line targets to reduce the number of test firings necessary for distance determinations.[4] Several test targets were set up, one behind the other, at specific distances so that one shot fired through the targets would produce several patterns that could be compared to the evidence pattern. If different pattern diameters are required more targets can be made by moving the firearm closer or further away from the targets. However, no data obtained by this method was presented.

In 1979 Steve Molnar and Thomas Nicholson conducted a study indirectly related to firearm distance testing.[5] Their study showed that 00 buck pellets tend to hold a pattern grouping in flight. The pellets formed a triangular arrangement forming single and double holes in test targets. However, no information was presented to show how consistent the pattern formation was or it's value in distance determinations.

In 1983 Kathleen Heaney and Walter Rowe of The

George Washington University, Washington, D.C. demonstrated how the number of test firings affects the width of confidence interval range-of-fire estimates.[6] In their study a shotgun was fired three times at targets placed at 10, 30 and 50 feet. Then the gun was fired five times at targets placed at 10, 20, 30, 40 and 50 feet. The gun was also fired nine times at 10, 20, 30, 40 and 50 foot targets. The pellet patterns were measured by the square root of the area of the smallest rectangle that would enclose the patterns and also by the radius of the smallest circle that would enclose the patterns. Data obtained by both the square root of the area of a rectangle and radius of a circle measurements were used to determine .95 confidence intervals for the 3, 5 and 9 test firings. The 3 test firings resulted in confidence interval widths of 23.5 ft. for the radius of a circle measurement and 49.9 ft. for the square root of the area of a rectangle measurement. The 5 test firings resulted in confidence interval width of 5.9 ft. for both measurements and the 9 test firings resulted in confidence interval widths of 3.5 and 3.0 ft., respectively.

It was determined that increasing the number of test shots from three to five resulted in a dramatic decrease in the width of the confidence interval. They reported no significant difference in the confidence interval widths by using either method of pattern measurement. Correlation coefficients greater than .99 were reported in each test set indicating a linear relationship between pattern spread and distance of fire.

In 1984 Alessandro Alfonsi, Sandro Calatri, Emidio Cerione and Piero Luchi at the University of Cagliari, Cagliari, Italy, studied the use of partial pellet patterns to determine distance-of-fire and the effects of barrel choke on pellet pattern dispersion.[7] Ten shots were fired with a full choke shotgun, ten through a half choke and ten through a cylindrical barrel gun. Five of the ten firings were with 00 buck shells and five firings were with 0 buck shells. Test distances of 5, 10, 15, 20, 30 and 40 m were selected. The pellet patterns were measured by the sum of the distance between one pellet hole and all of the remaining holes, and also by pattern diameter. The standard deviation, standard error, r value and a regression line were determined for each group of five test patterns.

Analysis of the data showed a high standard deviation for the mean values of the total distance between pellet holes and a small standard deviation for the mean values of the pattern diameters. Plotted regression lines for the cylindrical barrel gun were significantly separated from the plots of the nearly superimposed regression lines for the full and half choke barrels, using both types of ammunition. Each group tested had a correlation coefficient of .99 or higher relative to the dispersion of points pertaining to each regression line.

They concluded that you could not determine distance-of-fire with a partial pellet pattern and that lack of knowledge about the type of barrel choke can lead to completely wrong estimates on distance-of-fire.

In 1985, W. F. Rowe and S. R. Hanson of the George Washington University tested range-of-fire estimates derived by regression analysis.[8] A blind study was conducted with 10 questioned pellet patterns. Five of the patterns were fired from a 12 gauge Stevens model 77E full choke shotgun. The other five questioned patterns were fired from a 12 gauge Remington model 870 cylinder bore shotgun.

Test data was obtained by firing six shots from each gun at distances of 10, 20, 30, 40 and 50 feet. The resulting pellet patterns were measured by calculating the area of the smallest rectangle that would enclose the pattern. The data was analyzed by three methods for determining distance-of-fire. Confidence intervals were determined by weighted linear regression. Then both regression confidence intervals calculated by a factor based on a proportion of the sampled population and the distribution-free method was used, as proposed by Jauhari et al.

Regression analysis of the data was done with weighted regression confidence intervals. The standard deviation at each test distance was found to increase with range, so a weighted standard error was determined for computation of the confidence interval range-of-fire estimates. They reported that with regression analysis,

.99 confidence intervals calculated from the test data contained the actual distance-of-fire for each of the ten questioned pellet patterns. They found regression analysis to be a viable method for estimating range-of-fire. However, they found the last two methods deficient. With regression confidence intervals calculated with a numerical factor based on a proportion of the population, the upper confidence limits could not be calculated for any of the questioned patterns. The distribution-free method was applied to the same test data. The confidence limits contained the actual distance-of-fire for nine of the ten questioned patterns. However, one of the five questioned patterns, fired form the Remington gun at 14 feet, was not contained in it's confidence limit of 10.5 to 12.1 feet.

CHAPTER 3

RESEARCH DESIGN AND PROCEDURES

Collection of data

A method was applied in this study which increased the amount of pellet dispersion data with each test firing. A series of five paper targets were placed, one after another, at distances of 15, 20, 25, 30 and 35 feet. The firearm was test fired 100 times creating 100 targets at each test distance. A 5 foot interval distance between the targets was used since this was the range in distance which was involved in the inquest hearing which inspired this research and also resulted in an obvious measurable difference in pellet pattern size from one target distance to the next.

The target material used was brown wrapping paper measuring .007 inch thickness. Each target was supported by a coat hanger which was formed into a circle leaving the top hook to support the target. The target was centered on the formed wire circle and was attached to the wire by several pieces of masking tape on the back side of the paper. The targets were supported along the span of a 20 foot wooden pole (Figure 1). The narrow side of the plank was positioned upward to allow the hook end of the hanger to rest on top of the plank at each test distance.

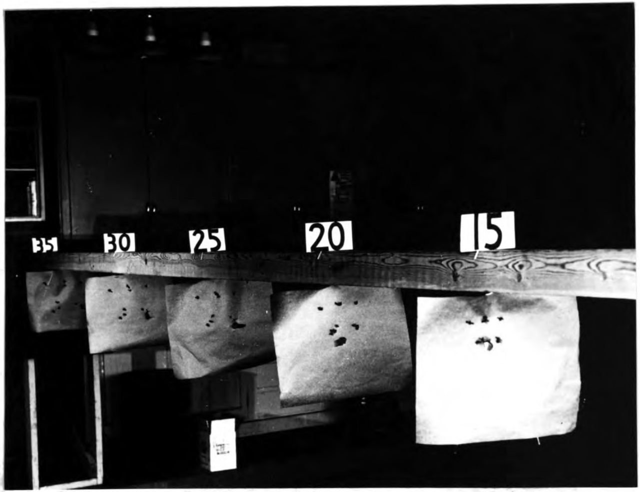


Figure 1.--In-line target support structure.

The firearm used for the test firing was a 12 gauge Remington, model 870 pump-action shotgun, cylinder bore measuring .729 inch. The barrel measured 22 inches in length.

The ammunition used was 12 gauge Winchester-Western, 00 buck, 2 3/4 inch, equivalent to 3 3/4 drams of black powder. Each shell contained 9 lead pellets, each measuring approximately .33 inch diameter, approximately 51 grains weight. All shells used in the testing were produced in the same production run, lot number (A101SC5).

The test shotgun was held stationary in a fixture while it was fired at the in-line targets (Figure 2). The muzzle of the gun could be moved up and down for target elevation alignment. Windage alignment was facilitated by moving the front of the support structure from side to side. The gun support could be adjusted forward or moved back along a support rail to vary the muzzle to target distance. After positioning the shotgun in the support structure the gun was sighted with the last target at the 35 foot distance. The gun was first test fired at a single target at the 35 foot distance to ensure proper alignment and to raise the barrel temperature up to the approximate temperature at which a particular series of tests would be conducted. The barrel of the gun was cleaned after each test firing.

To determine the effect of temperature on pellet dispersion, 20 shots were fired with a mean barrel

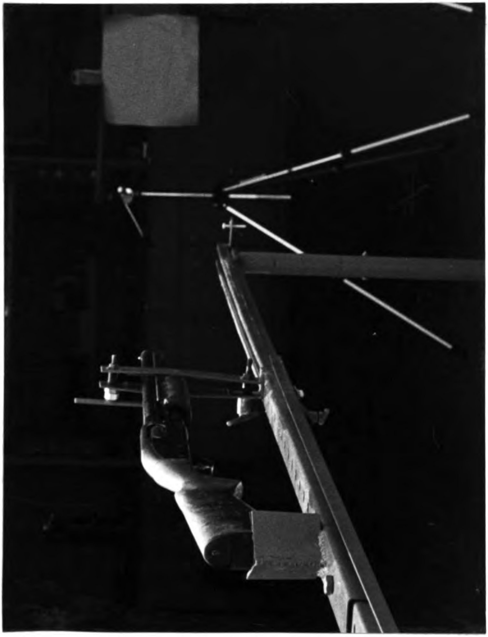


Figure 2.--Firearm support structure.

temperature of 0 degrees F, ±5 degrees and a mean shell temperature of 71 degrees F, ±17 degrees. Another 20 tests were fired with a shell temperature of +5 degrees F, and a mean gun barrel temperature of 87 degrees F, ±7 degrees.

The low gun barrel temperatures were achieved by placing liquid nitrogen into the barrel. Temperatures were measured by a calibrated secondary nitrogen-above-mercury thermometer, Fahrenheit scale ranging from -5 degrees to +125 degrees, in 1 mm increments. The thermometer was suspended midway into the gun barrel prior to each firing with the breech closed. The lowered shell temperatures were measured by the same type of thermometer on a Celsius scale ranging from -20 degrees to +110 degrees, in 1 mm increments. The bulb end was suspended in air in the freezer in which the shell temperature was lowered.

Each test pellet pattern was measured by the diameter of a circle drawn on a clear plastic overlay (Figure 3). The pattern diameter measurements were determined within .25 inch intervals. This level of discrimination was selected because of the size of the pellet hole. Measuring with .25 inch increments proved to be the most accurate in determining pattern diameters. A particular pellet pattern diameter would be determined by fitting all nine pellet holes within the closest fitting overlay circle.

Data manipulation

Tests were conducted to determine whether the

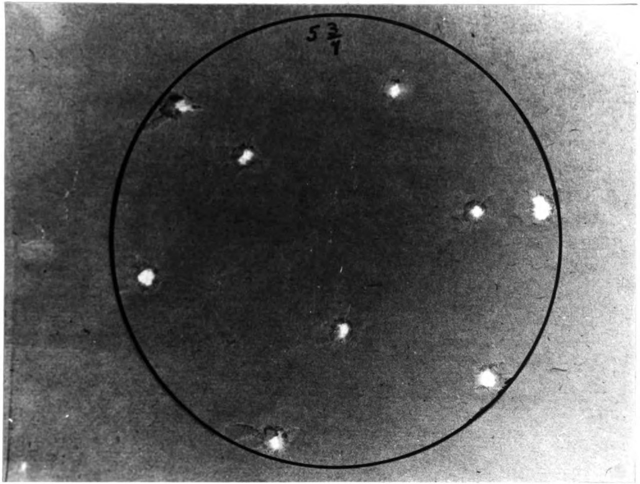


Figure 3.--Circle on clear plastic overlay positioned over pellet pattern.

target paper had any significant affect on pellet dispersion. Ten separate targets were fired at the 35 foot distance and compared statistically to 10 randomly selected targets from the total 100 targets at the 35 foot test distance. A t-test was applied to the means of each group to determine any significant difference.

To show the variability of the test data pellet patterns the standard deviation of the pellet patterns at each test distance was examined.

The data obtained from this research was examined to determine the degree of pellet pattern size overlap from one test distance to the next. Confidence intervals were calculated at .95, .90, .80, .70 and .65 confidence levels for the mean pellet pattern diameters of targets at the 5 test distances. The amount that each confidence interval extended in the next adjacent test distance confidence interval was examined.

To determine if temperature affects pellet pattern dispersion the mean pattern diameters, at each test distance, of the 20 low barrel patterns and the mean pattern diameter of the 20 low shell patterns were compared to the mean pattern diameter of the remaining 60 ambient (normal) air temperature group patterns. Analysis of variance (MANOVA) was applied to the means of each test distance, for the three temperature groups, to determine any significant difference between the temperature group means. A 1-way post hoc analysis (ANOVA) using the Scheffe technique was used to uncover the separate effects of the low temperature groups.

CHAPTER 4

ANALYSIS OF THE DATA

The primary calculations for the statistical analysis of the research data were performed by computer using the Statistical Package for the Social Sciences program (SPSS). Subsequent calculations for confidence intervals, using the data coefficients obtained by computer, and the target material t-test were done by hand.

Testing was done to determine if the target paper had a significant affect on pellet dispersion using in-line targets. A t-test was applied to the means of 10 randomly selected test targets from the 35 foot distance and 10 targets fired without intervening targets (Table 1). A .05 level of significance was chosen and 18 degrees of freedom were applied to a t-curve probability table. A value of 2.10 was obtained from the table establishing the critical region r (Figure 4). A t value of 1.42 was derived by formula from the test data. The test statistic t value of 1.42 is less than the critical region value of 2.10 and falls within the acceptable range on the t scale. Thus the difference between the two means is insignificant at the .05 level.

Figure 5 shows the standard deviation of the pellet pattern diameters about the mean of each test firing

Table 1

Pattern sizes: firings with and without intervening paper targets.
Range of Firing = 35 feet

	Pattern diameter w/targets, inches	Pattern diameter w/o targets, inches
	8.5	9.25
	8.75	9.25
	8.75	9.5
	9.5	9.5
	9.5	9.5
	9.75	9.75
	9.75	10.0
	10.25	10.5
	10.25	11.25
$\overline{X}$	9.43	9.95
S.D.	.52	.69

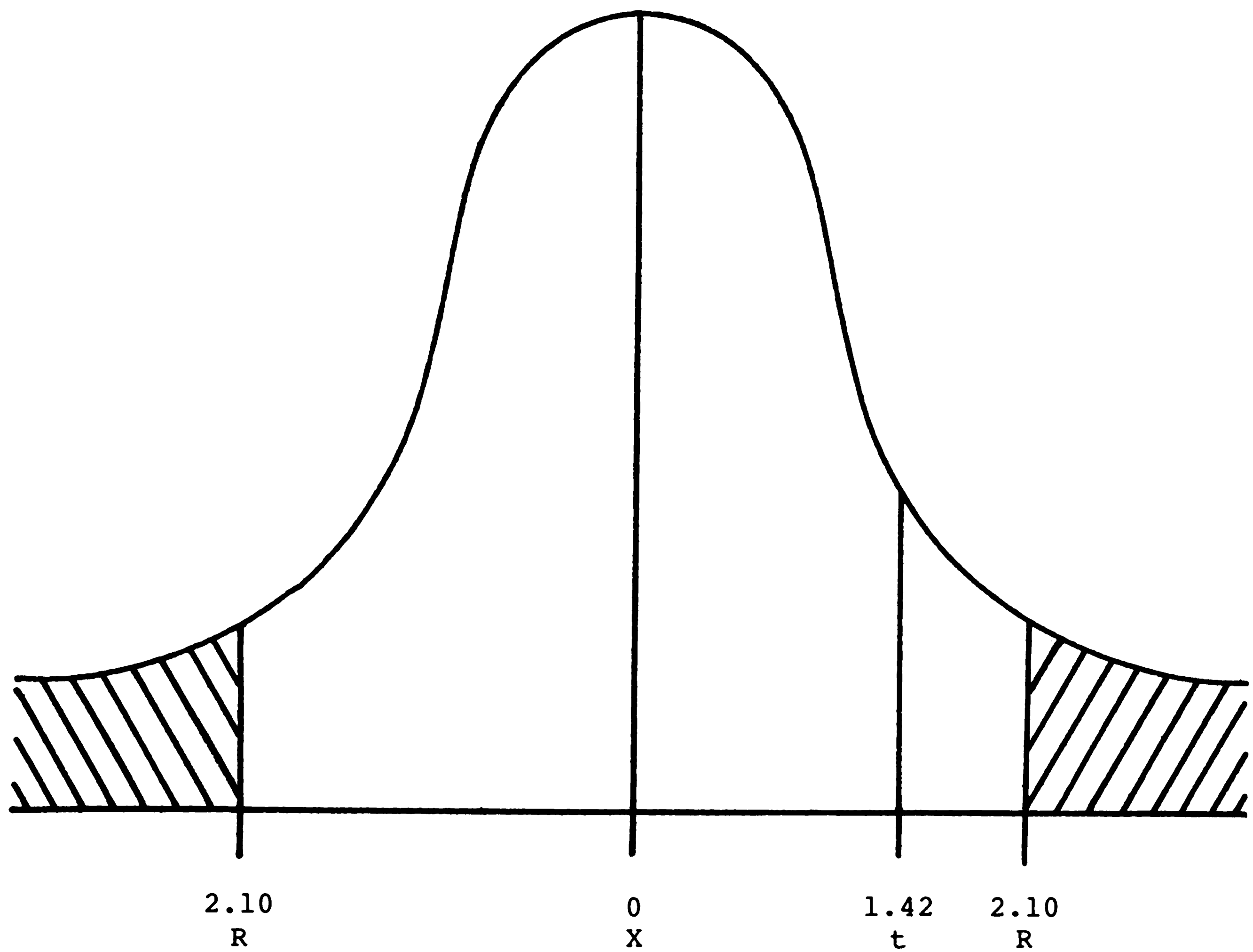


Figure 4.--Approximate sampling distribution of difference between two means showing the critical region R and test statistic t.

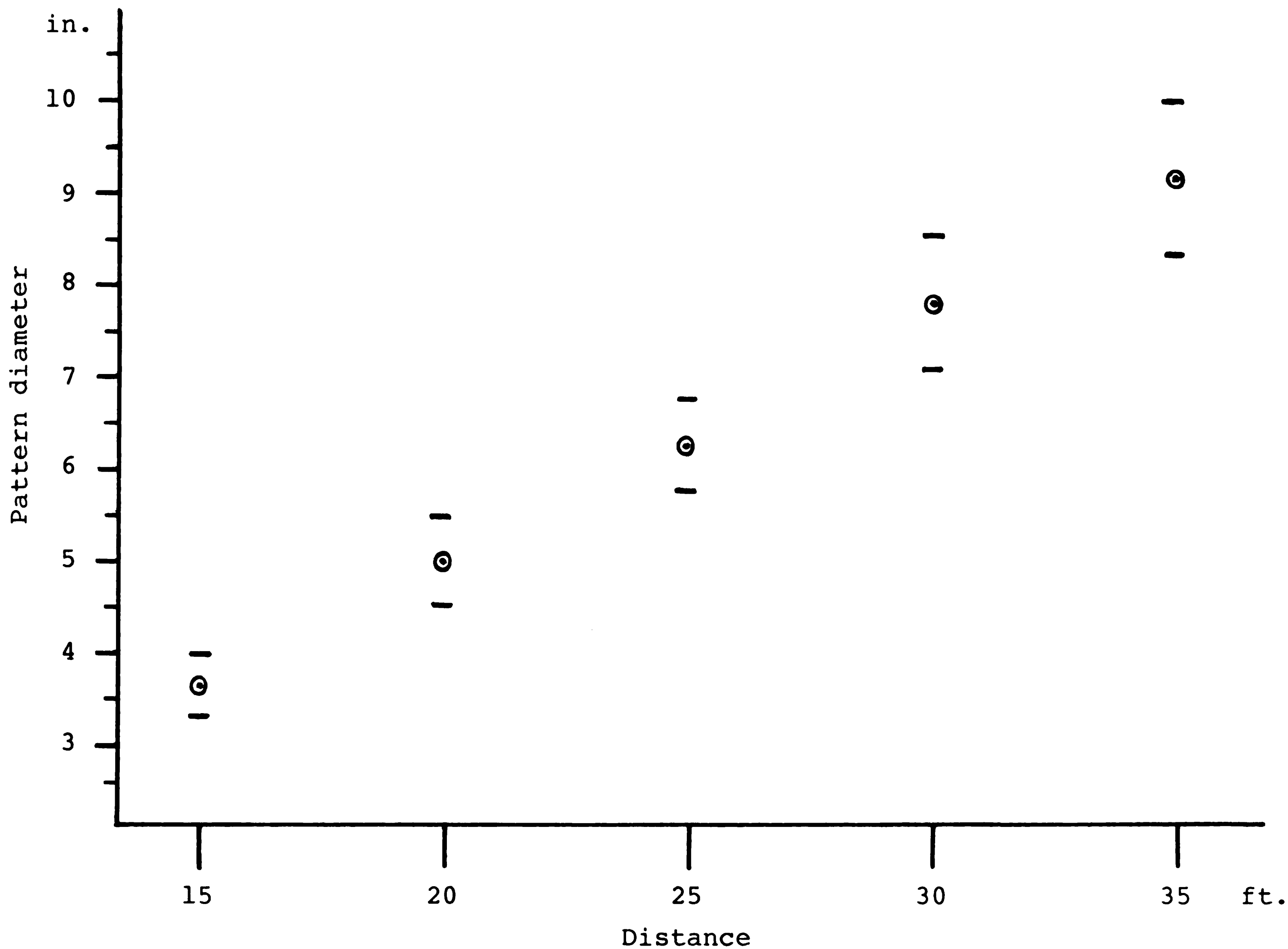


Figure 5.--Standard deviation bars for the mean of each test firing distance.

distance. The most any test pattern deviates from the means is .846 inches.

The data obtained by this research was examined to determine the amount of pellet pattern overlap between 5 foot interval test firing distances. Tables 2 through 4 show .95, .96 and .97 confidence intervals for the mean pellet pattern diameter at each test firing distance.[10] The amount of interval overlap between adjacent test distances is shown as a positive number and the separation between adjacent test distance confidence intervals, which do not overlap, is shown as a negative number in the 4th column. All of the .95 and .96 confidence intervals did not overlap between adjacent test distances. The .97 confidence intervals overlapped between 15 and 20, 20 and 25, foot test distances, however, they did not overlap between 25 and 30, 30 and 35 foot test distances. None of the confidence intervals overlapped into more than one test distance.

To determine if temperature affects pellet pattern dispersion the means of a low barrel temperature group, low shell temperature group and a normal temperature group were compared by analysis of variance (MANOVA). Table 5 shows the pellet pattern means at each test distance for the low barrel, low shell and normal temperature groups. The MANOVA revealed a significant difference between the means of each group at the .05 level of significance. To determine which test distance means were affected by

Table 2

.95 confidence intervals for mean pattern diameter at each test distance

Target Distance	Mean Pattern Diameter	.95 Confidence Interval $\bar{X} \pm Z(S.D.)$	+ or - Interval Overlap
ft.	in.	in.	in.
15	3.64	3.02 - 4.26[a]	
			-.08
20	4.96	4.34 - 5.58	
			-.14
25	6.34	5.72 - 6.96	
			-.21
30	7.79	7.17 - 8.41	
			-.21
35	9.25	8.62 - 9.87	

[a]Standard deviation S.D. = .317;
$\underline{Z}$ value = 1.96;
$\bar{X}$ = Mean at each test distance.

Table 3

.96 confidence intervals for mean pattern diameter at each test distance

Target Distance ft.	Mean Pattern Diameter in.	.96 Confidence Interval $\bar{X} \pm Z(S.D.)$ in.	+ or - Interval Overlap in.
15	3.64	2.99 - 4.29[a]	
			-.02
20	4.96	4.31 - 5.61	
			-.08
25	6.34	5.69 - 6.99	
			-.15
30	7.79	7.14 - 8.44	
			-.16
35	9.25	8.60 - 9.90	

[a] Standard deviation S.D. = .317;
Z value = 2.06;
X = Mean at each test distance.

Table 4

.97 confidence intervals for mean pattern diameter at each test distance.

Target Distance	Mean Pattern Diameter	.97 Confidence Interval $\bar{X} \pm Z(S.D.)$	+ or - Interval Overlap
ft.	in.	in.	in.
15	3.64	2.95 - 4.33[a]	
			+.06
20	4.96	4.27 - 5.65	
			+.00
25	6.34	5.65 - 7.03	
			-.07
30	7.79	7.10 - 8.48	
			-.11
35	9.25	8.59 - 9.94	

[a] Standard deviation S.D. = .317;
$\underline{Z}$ value = 2.17;
$\bar{X}$ = Mean at each test distance.

Table 5

Test distance pellet pattern means for each temperature group

Test Distance ft.	Normal Temperature Group Mean in.	Low Barrel Temperature Group Mean in.	Low Shell Temperature Group Mean in.
15	3.6917	3.6875	3.4500
20	5.0292	5.0500	4.0500
25	6.4417	6.3375	6.0500
30	7.9125	7.7625	7.4500
35	No significant difference in means		

temperature an (ANOVA) was performed on the means which revealed that temperature had a significant effect at each test distance, except at the 35 foot test distance. To uncover the separate effects of low barrel and low shell temperature, the means at each test distance for each temperature group were compared independently by a 1-way post hoc analysis of variance using the Scheffe technique. The results of the Scheffe technique revealed that the means of the low shell temperature group were significantly different from the means of the normal temperature group at the .05 level of significance. The means of the low barrel temperature group showed no significant difference from the means of the normal temperature group at the .05 level.

CHAPTER 5

DISCUSSION

At the beginning two problems were introduced, namely, to develop a method for determining the amount of shotgun pellet pattern overlap between test firing distances and to examine the affect temperature has on the spread of pellet patterns.

The data for this study was obtained by firing through a series of paper targets placed, one after another, at equally spaced test distances. The in-line target arrangement was used to increase the amount of test data for each test firing. The use of in-line targets can create a larger amount of test data with limited time and ammunition. However, the affect of the intervening targets on pellet pattern dispersion has to be examined. This was done by shooting 10 targets without any intervening screens at the furthest test distance and statistically comparing them to 10 targets from the test data randomly selected at the furthest test distance. A t-test was applied to the mean pellet patterns of each group to see if the difference in pellet dispersion, caused by the intervening targets, is statistically significant. The results of the t-test showed no significant difference between the mean pellet patterns of the two groups at the .05 level of significance.

A method was presented for determining the extent of pattern overlap at adjacent test distances. Pellet pattern dispersion varies from one firing to the next and multiple test firings result in pattern size variance at each test distance. The variance can result in an overlap of pattern size in adjacent test distances, depending on the extent of pattern variability and the spacing between the targets. The extent of pattern overlap at adjacent test distances shows how narrow a range-of-fire estimate can be made. If confidence intervals, calculated for the means of the pattern diameters at each test distance, do not extend into adjacent test distances, then a range-of-fire estimate equal to the interval between the test distance will determine how narrow range-of-fire estimates can be made. The selected confidence level reflects the probability that pellet patterns, excluded from the confidence intervals, are duplicated at adjacent test distances.

Figure 6 shows frequency distributions for the pattern diameters at each test distance. The overlapping of the boundaries of the distributions shows graphically the total extent of pattern overlap at the 5 foot test distances. It can be observed that pattern diameters of 7.25, 7.5 and 7.75 were duplicated at the 25, 30 and 35 foot test distances.

To determine the point where pattern overlap can be

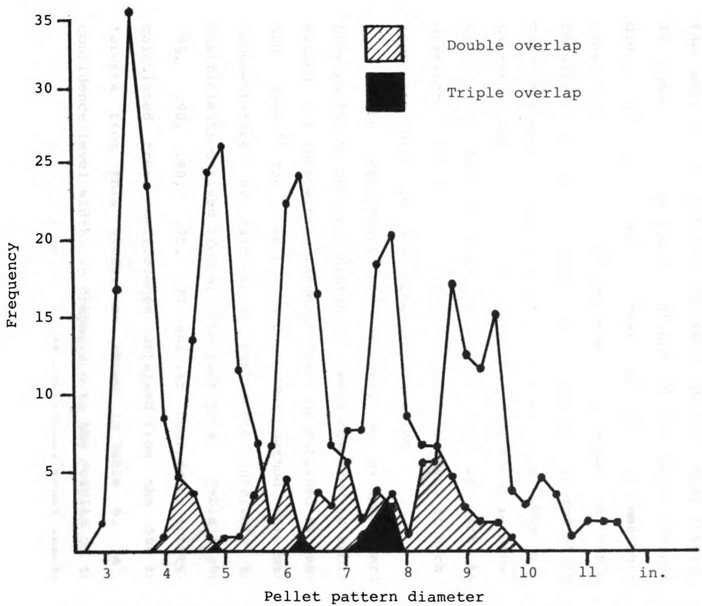
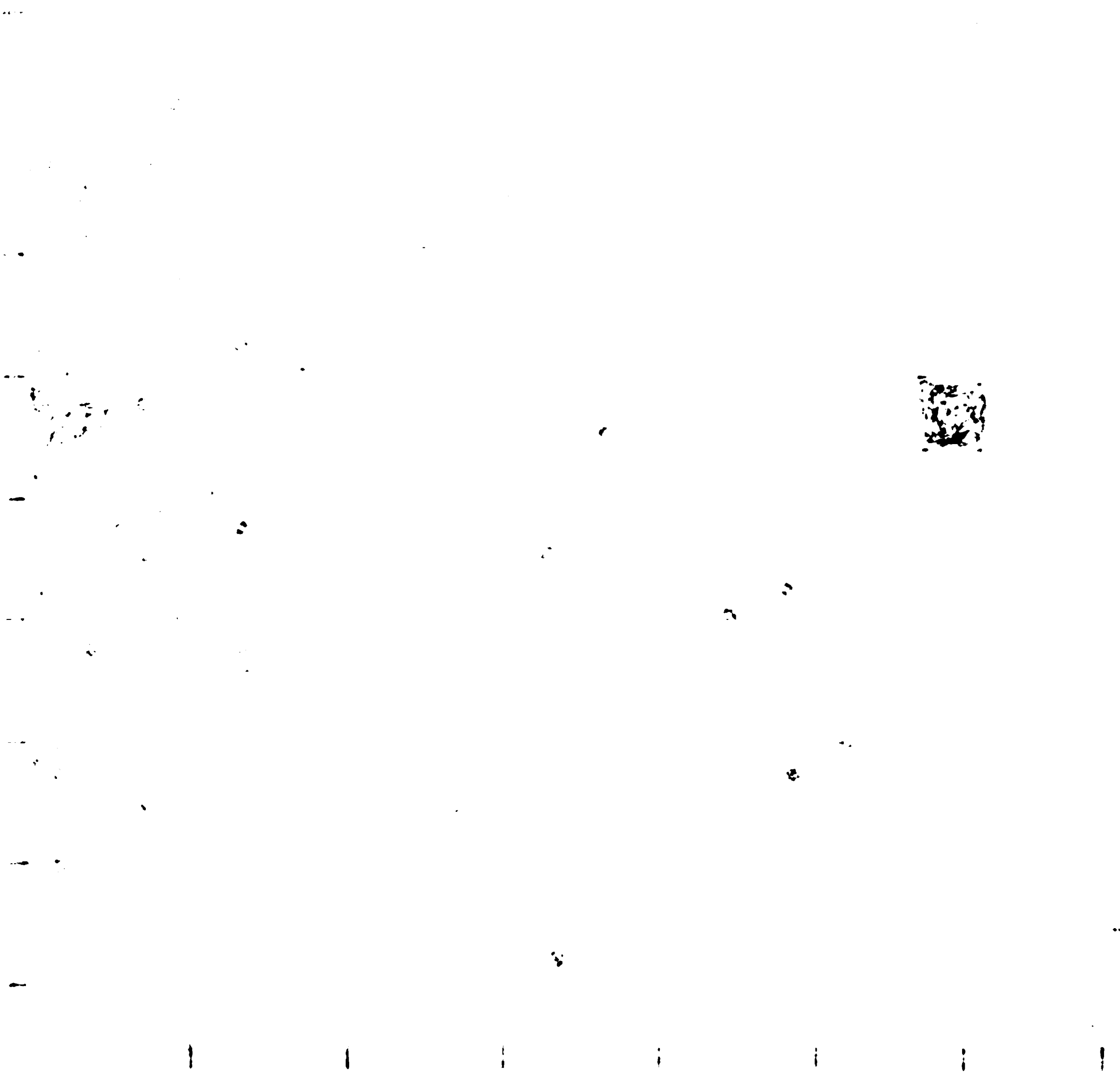


Figure 6.--Pellet pattern frequency distributions for each test distance.



eliminated between the test distances, confidence intervals were calculated at .95, .96 and .97 confidence levels for the mean pellet pattern diameters at each test distance. As shown in Tables 2 & 3, .95 and .96 confidence intervals did not overlap between each test distance. Increasing the confidence level to 97 percent, as shown in Table 4 resulted in overlap between the 15 and 20, 25 and 30 foot test distances. The standard deviation of all the pellet patterns was used to calculate the confidence intervals. Since one test firing produced targets at each test distance, the deviation of the pellet patterns at each of those test distances are necessarily related.

The results obtained by examining pattern overlap between the 5 foot test distances, were compared to another method for determining range-of-fire as outlined by Heaney and Rowe.[11] The Heaney and Rowe method determines range-of-fire by calculating confidence intervals from coefficients derived from all the test data. Table 6 shows .95, .90, .80, .75, .70 and .65 confidence intervals calculated from coefficients obtained from the 500 test targets from this study, as shown in Table 6, a .75 confidence level width. In comparison to the results of this study, as shown in Table 2, a .95 confidence level resulted in no pellet pattern overlap at the 5 foot test distances. A .96 confidence level was the highest confidence level which eliminated the overlap. Selecting a .95 confidence level with the Heaney and Rowe method results in a

Table 6

Confdidence intervals for test data.

Confidence Level %	Z Value	Confidence Interval Range $\hat{Y} \pm (ZS_e/\lvert b \rvert) \cdot (1+(1/k))^{1/2}$ ft.
95	1.96	8.48[a]
90	1.65	7.12
80	1.28	5.54
75	1.16	5.04
70	1.04	4.52
65	.93	4.04

[a]Standard error S_e = .602;
Coefficient Slope b = .2807;
Number of Pellet Patterns k = 500.
$\hat{Y}$ = Predicted distance-of-fire.
Regression intercept = -.6217.
Correlation coefficient = .965.

range-of-fire width of 8.48 feet.

The effect of temperature on the size of pellet pattern dispersion was examined by comparing the test pattern means of a low barrel temperature group and a low shell temperature group to the pattern means of a normal temperature group. The 1-way post hoc analysis of variance using the Scheffe technique revealed that low shell temperature had a significant affect, at the .05 level, on the means at each test distance, except at 35 ft. The low barrel temperature had no significant affect. In Table 5 the means of the low shell temperature group are smaller, for each test distance, than the means of the low barrel and normal temperature groups. It is hypothesized that the low shell temperature caused incomplete burning of the propellent powder resulting in a smaller pattern size resulting in a smaller mean at each test distance. At the 35 foot test distance it is suspected that the pattern variance is so great that the difference in means is less significant. The variance of the pellet pattern at each test distance can be observed in Figure 5.

In light of the results of this research it is suspected that the reason for the different range-of-fire estimates arrived at in the case which inspire this study was due, in part, to the method used. With that method selection of a range-of-fire is a result of the examiners observations in testing and his experience. A more objective approach is the statistical treatment of test data for range-of-fire estimation based on the variability experienced in testing. In this study the overlap of pellet pattern confidence intervals showed the variability experienced in the testing to arrive at a range-of-fire based on the target distance interval. If the data from the inquest hearing testing had been subjected to this type of statistical approach, subjective interpretations in analyzing the data would have been minimized and the estimated range-of-fire would have reflected the variable nature of shotgun pellet dispersion in a more objective approach. Also, analysis of the data supports temperature as a factor which should be looked at in collecting data for range-of-fire estimates. The inquest hearing data was collected at two different temperatures which may have had a significant affect on the results.

CHAPTER 6

SUMMARY

This study examined a method for determining shotgun pellet pattern overlap and analyzed the effect of low barrel and low shell temperature on the spread of pellet patterns.

The data was obtained by shooting through a series of in-line targets to increase the amount of data. Tests were done to determine if the target paper altered the pellet patterns. A t-test on the mean of a sample data group and a control group, both at the furthest target distance, showed no significant difference at the .05 level.

It was shown that the distance between test targets, where pellet pattern overlap does not occur, determines how narrow range-of-fire estimates can be made. To determine the amount of pellet pattern overlap, confidence intervals were calculated at the .95, .96 and .97 confidence levels for the mean pellet pattern at each test distance. The .95 and .96 confidence intervals did not overlap between adjacent test distances. Two of the .97 confidence intervals did not overlap between each test distance.

The results of this method were compared to a method outlined by Heaney and Rowe. Using their method range-of-fire confidence intervals were calculated from the test data at .95, .90, .80, .75, .70 and .65 confidence levels. The .75 confidence interval resulted in a 5 foot range-of-fire. The .95 confidence interval produced a 8.48 foot range-of-fire.

The affects of low barrel and low shell temperature on pellet pattern dispersion were compared to a normal temperature group. An analysis of variance determined a significant difference between the means of the low shell temperature group and the normal temperature group, except at the furthest test distance. The low barrel temperature group means were not significantly different from the means of the normal temperature group.

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