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THE EFFECT OF VARYING CERTAIN PARAMETERS ON THE PERFORMANCE OF THE S.C.A.M.P. PRODUCED 5.56 MM PROJECTILE

DARCOM INTERN TRAINING CENTER

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THE EFFECT OF VARYING CERTAIN PARAMETERS ON THE PERFORMANCE OF THE S.C.A.M.P. PRODUCED 5.56 MM PROJECTILE

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This study investigates the effect of changing the boattail and the nose radius on the performance of the current 5.56 mm bullet. The results showed that elimination of the boattail had a detrimental effect on the performance while a change in the nose radius had no change on the performance of the 5.56 mm bullet.

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FOREWORD

The research discussed in this report was accomplished as part of the Product/Production Engineering Graduate Program conducted jointly by DARCOM Intern Training Center and Texas A&M University. As such, the ideas, concepts and results herein presented are those of the author and do not necessarily reflect approval or acceptance by the Department of the Army.

This report has been reviewed and is approved for release. For further information on this project contact: Professor T. F. Howie, DRXMC-ITC-PPE, Red River Army Depot, Texarkana, Texas 75501.

Approved:

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For the Commandant

James L. Arnett

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During the course of this work, the author was employed by the U. S. Army as a career intern in the DARCOM Product/Production Engineering Graduate Program. He is grateful to the U. S. Army for the opportunity to participate in this program.

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CHAPTER I

INTRODUCTION

The U. S. Army Developement And Readiness Command is now in the process of undertaking an adventurous program in the field of small arms ammunition production. The program, known as S.C.A.M.P. (Small Calibre Ammunition Modernization Program) constitutes a manufacturing process for the high volume, computerized, highly automated small calibre ammunition, notably the 5.56 mm ball projectile as used in the Army's M16A1 rifle. The prototype of this process is located at the Frankford Arsenal in Philadelphia, Penn. The main topic of this study concerned itself with the bullet submodule. A number of separate operations go into the manufacture of a projectile. These operations form various physical dimensions, and shapes of the projectile. These include the ogive, which simply stated is the nose cone of the bullet, the boattail, the tapered rear portion of the projectile, and the nose radius. This is a high performance projectile with a free flight velocity in excess of twice the speed of sound (Mach 2) as fired from the M16A1 rifle. Specifically the problem was to determine the effects of the three aforementioned bullet parameters (ogive, boattail, and nose radius) on the accuracy and performance of the bullet under the limitations of the SCAMP process. The probable effects of the rotation rate of the projectile were also investigated under the same accuracy and performance criteria under the same limitations.

The solution was achieved through test firings of the projectiles. A number of lots of bullets of different shapes were made. The bullets were fired in order to substantiate that any change in the performance was indeed attributed to the change in any of the parameters. The parameters were varied one at a time, and compared to the control lot. The test firings were conducted at the aeroballistics testing facilities at Twin Cities Arsenal. This testing facility can change within certain tolerances, various bullet parameters, fire, and evaluate the results of the test firings through the use of a computer facility.

This project could have great consequences on the success of the SCAMP program. The possible reduction in production processes, such as the possible elimination of the boattail or slackening of point diameter tolerance, can be of great importance to the ultimate success of this program. Also this could open the way for a new means of small calibre projectile performance evaluation.

CHAPTER II

THE CURRENT STATE OF THE ART

The study of aeroballistics, or the science of free flight, high speed projectiles, is actively pursued today. Many agencies have carried out, and are in the process of carrying out elaborate tests on many of the U. S. Army's armament projectiles. These projectiles range from the small rocket-like fleshettes to the largest artillery shells. As already stated in the introduction, this study concerned itself solely with the performance of the M193 ball round as used in the M16A1 rifle.

Although tests have been carried out on many other kinds of projectiles, and have therefore been published, there is, however, not much published material on the 5.56 mm projectile. More specifically there is no published material on the effects of ogive, nose radius, or boattail, or spin rate. There is, however, some material that can be useful in this study. The first is the developement of a program entitled SPIN-73 [6]*. This program calculates various aerodynamic

*Numbers in brackets refer to numbered references in the list of references at the end of this paper.

coefficients, and stability canstants. It is an empirical program that uses past laboratory data as a tool in the developement of curve fitting techniques. This program also uses the aerodynamic formulae available for calculation of the aerodynamic coefficients as a function of the Mach number. All these coefficients are outputs of the program, and the characteristics of the projectiles are program inputs. (Dimensions, moments of inertia about the longitudinal and transverse axis etc.) There is, however, a range for each of these parameters for which the program is valid. These were determined by the previous project, and are the only restrictions to the input data. Its disadvantage is that for small calibre ammunition, the program neglects the effects from rifling marks. These effects cannot be disregarded with respect to this author's problem.

While this program is a useful aid for the bullet designer, it by no means gives a clear cut solution to this author's problem. The most current work being done is at the Ballistics Research Laboratories (BRL) at Aberdeen Proving Ground, Maryland. The research has concerned itself mainly with the ogive and the boattail of the M193 [2]. These bullet parameters have been modified to improve the performance, and subsequent free flight (spark photography) studies have been performed. These results served as a starting point for this study. However, the reader must remember that the main goal of this paper is to determine the critical effectiveness of the aforementioned parameters on the performance of the 5.56 mm bullet; the final goal of the project being the possible elimination of certain features.

This projectile analysis is quite involved, and therefore for the sake of clarity, the many aspects of the project are discussed in their own subsequent chapters. The remaining chapters of this report cover the following topics: Chapter III covers the manufacturing process, Chapter IV covers alternate designs and their evaluation, and finally Chapter V contains conclusions and recommendations.

CHAPTER III

THE 5.56 MM PROJECTILE

The SCAMP Bullet Submodule

The manufacture of the Army's 5.56 mm bullet is a complex operation. The finished bullet is shown in Figure 1 on page 26. The critical dimension in this drawing is the overall length of the projectile. Both the cartridge and the bullet are made in a number of steps. The bullet itself is of a bi-metal construction. It consists of a center lead antimony core (Figure 3 page 28) which comprises the largest volume and mass of the projectile. Surrounding this lead core is a copper jacket (Figure 2 page 27). This copper jacket is the part of the completed bullet where all of the final exterior aerodynamics are "imprinted".

This jacket is produced by a number of steps. The jacket starts as a cup. This cup is then exposed to a number of stamping operations until it reaches its final shape. The reader should note that the final ogive and nose radius have been formed by the end of this operation. The lead core (already by this time having been made) is then rammed into the jacket, and since lead-antimony is a soft alloy, the core conforms to the interior shape of the jacket. At this point the bullet travels onwards, and the boattail is formed, as well as the rear crimping of the jacket, and the knurling of the cannelure.

All these operations are done at a very high speed, and they must be done with a good deal of accuracy. All of the dimensions allow tolerances only in one direction, with all save one (the width of the knurled portion) allowing a deviation to the smaller.

Limitations Of Design Changes

The M16A1 rifle is the current standard Army weapon. The current SCAMP project will produce the current 5.56 mm projectile for this weapon. The reader must then ask himself the following question. Now that the SCAMP project has advanced this far why change the bullet now? This is a very good question. However, one can study changes in the design that could be accomodated for by the current process without causing a complete redesign of the process or the rifle itself.

Let the reader consider the parameters of the bullet itself that affect the performance of the projectile. These are the ogive, nose radius, boattail, and spin rate. Obviously all are affected by the manufacturing process, and subsequently any change in the aforementioned parameters requires a change in the manufacturing process of the gun or the bullet. However, some changes are not as drastic as others with respect to the SCAMP process and gun production. The features that do not drastically change the manufacturing process are the boattail and the nose radius. The boattail can be eliminated or modified quite readily because as stated before, the formation of the boattail is done in a separate section of the submodule. One can change the angle, and vary the length of the boattail without altering the overall length of the projectile. This was done in an effort to determine the effect of changing or eliminating the boattail on the performance of the projectile. The nose radius can also be varied without changing the overall length of the bullet. If the reader refers to Figure 1 on page 26, he will note that the nose is quite blunt, and could almost be considered a flat nose. If the nose were pointed at the reader, the head of the projectile would appear as a small circle. Therefore this paper studied the effect of changing the diameter of this circle. In the terms of the aerodynamisist, this diameter is known as the MaPlat diameter.

If the other parameters (ogive and spin rate) were changed, the rifle would have to be changed also. Work is being done in this area by the people at BRL, who are recommending a change in the rifle. Obviously the change in spin rate requires a change in the rifling, and therefore the spin rate cannot be changed indiscriminately. By changing the spin rate of the bullet, one can also affect the stability of the projectile from over stable to under stable. This will result in an inferior projectile. The ogive cannot be changed because of the effect of necessitating a complete redesign of the rifle. Researchers at BRL have studied the performance of an improved M16A1 projectile, the BRL-2, which had a larger fineness ratio. Not only would the rifle have to be modified, but the SCAMP process would have to be highly modified to accomodate production of the longer projectile. A shorter projectile (smaller fineness ratio) would adversely affect the performance [2].

The report therefore concerned itself mainly with the varying of the two parameters of nose radius (MaPlat diameter) and boattail, as these parameters can readily be applied to the SCAMP process. Subsequent chapters familiarize the reader with a background of aerodynamic testing and the final problem solution.

CHAPTER IV

ALTERNATE DESIGNS AND EVALUATION

Types of Aerodynamic Testing

The preceding chapter discussed the problem of arbitrarily changing bullet parameters. The two parameters that were investigated were the MaPlat diameter and the boattail. Therefore, this study had to first determine the type of testing methodology that could have been implemented to determine the effects of the boattail and point diameter. There are various techniques that could be used. These techniques can be classified into two major types: the supersonic wind tunnel and the aeroballistics range.

The first of these methods, the supersonic wind tunnel, involves the suspension of a model in a test chamber with a full array of measuring instruments [4]. The models often contain strain gages in order to monitor deflections in the xyz directions, and complex, jeweled gimbal mountings. All this sophisticated apparatus is necessary for the measurement of various moments, and subsequently from these measurements the various aerodynamic coefficients can be determined and compared. While this procedure lends itself to larger projectiles such as large artillery shells, this wind tunnel testing is prohibitably difficult and totally unnecessary for small calibre projectiles, especially the 5.56 mm bullet, when the other techniques are better.

The second procedure is the ballistic range. There are a number of versions of this facility. One version is called the spark range. The spark range is composed of a standard firing range with a number of high speed camera locations placed along the entire length. As the projectile travels down the range, it triggers a flash and camera at all of the stations. Therefore with the additional use of mirrors, and recording devices, an accurate record of the bullet's position at a number of points during its flight in all three reference planes can be made [4]. From these, the motion of the bullet can be determined, and subsequently the same aerodynamic coefficients can be calculated and compared. The data reduction of such an experimental technique is quite involved, and a more satisfactory method of determining the effects of the boattail or MaPlat diameter is available.

The Experimental Procedure

After repeated conversations with Mr. Frank Dietsch of the SCAMP office at Frankford Arsenal, a method for the solution of the problem was formulated. A lot of each type of bullet was manufactured and these lots were fired. In order to arrive at a good data base, lots of 20 rounds were used. The types of bullets that were tested were as follows. Two lots of 20 bullets of the standard 5.56 mm M193 ball projectile (Figure 1 page 26) and two lots of 20 bullets of a "model" which is the same as the standard 5.56 mm except there is no cannelure, were made (Figure 4 page 29). A lot of 20 of the type without a boattail (Figure 5 page 30) and a lot of 20 rounds of the type with 1/2 a boattail (Figure 6 page 31) were also made. Finally, in addition to these, a lot of 20 with a sharp point (small MaPlat diameter) and a lot of 20 with a blunt point (large MaPlat diameter) were manufactured. These bullets still retained the original boattail while only changing the point diameter. However, all of these modified bullets had no cannelure in order to expedite manufacture.

The performance criteria analysed was the accuracy as measured from the center of the target at a range of 200 yards, and the time of flight over a distance of 597 feet. The facilities for the measurement of these criteria was set up at Twin Cities Arsenal. The results appear in Tables 5 through 12 in the Appendixes of this paper. The reader will note that in some of the tests a lot of exactly 20 rounds was sometimes not met, especially in the time of flight test where some of the bullets failed to trip the timing devices. In all subsequent calculations the actual sample size was used.

Data Evaluation

At this point the author would like to present two assumptions. The first assumption is that the time of flight and the radius from the center of the target are normally distributed random variables. According to a great number of test firings that have been carried out at Twin Cities in coordination with the SCAMP program, this assumption of normality is an acceptable one. Secondly, for the purpose of hypothesis testing, an α error of .01 (again acceptable) was utilised in all computations. With these two assumptions, analysis of the data took the form of a series of tests of hypothesis.

Because of the nature of changing only <u>one</u> parameter at a time from the standard round, any change in the mean radius or mean time of flight could be directly attributable to the change in the parameter. Design evaluations took the form of a series of comparisons using each measured performance criterion. Since this involved a comparison of two normally distributed populations about two parameters namely μ_x and μ_y or σ_x and σ_y, the author referred to the text <u>Engineering Statistics</u> for formulae [1].

First the accuracy was analysed. The first comparison was between the standard 5.56 mm round and the bullet without the cannelure forthwith referred to as the "model". This comparison was necessary because it was to have been determined if this was an accurate model of the actual bullet, as all subsequent modifications were compared to this "model" and those modifications do not have a cannelure. As the true population standard deviation was unknown, all the hypothesis testing of the population means took the form of a "t" test. There are, however, two "t" tests. One involves the assumption that the standard deviations are equal, and the other assumes that the standard deviations are unequal. Therefore, it was determined first if the std deviations were equal. In other words, the hypothesis that was tested is given by:

$$H_o: \sigma_{std} = \sigma_{\text{"model"}} \quad \text{vs} \quad H_1: \sigma_{std} \neq \sigma_{\text{"model"}}$$

This was a "two-sided" F test, and was tested at a significance level of .01. The results are shown in Table 1 on page 16. As can be seen the hypothesis that the two std deviations were equal was accepted. Furthermore, the hypothesis that the mean of the "model" was less than or equal to the mean of the standard bullet was tested. The reason a one sided test was used in this case was because rejection of the null hypothesis was desired only if the mean of the challenger (in this case the "model") was greater than that of the standard 5.56 mm. The observant reader understands this because rejection was desired if the "model's" accuracy was less than that of the M193 projectile, which occured only if the "model's" mean radius was greater than that of the standard. The results of this test are presented also in Table 1 on page 16. As can be seen from the table, the null hypothesis was accepted, and it was concluded that the lack of a cannelure had no adverse effect on the accuracy of the bullet, and the "model" was indeed a good one. Table 2 on page 17 tabulated the results of comparing the other bullets (no boattail, ½ boattail, sharp point, blunt point) against the "model". The convention used in the table was that the challenger was given the designation Y, and the "model" had the designation X.

The time of flight was compared in exactly the same manner as the accuracy. First, the "model" and the standard were compared. Again the "model" proved to be a good one. The reader should note, however, that the standard deviations were not equal, but if the reader would divert his attention to Table 3 on page 18 he should note that while the standard deviations were not equal it could be easily seen that the standard deviation of the "model" was far <u>less</u> than that of the standard 5.56 mm bullet. This perfectly acceptable conclusion did not affect the fact that the means were the same and the conclusion that the "model" was good was valid. The results appear in Table 3 on page 18. Table 4 on page 19 is similiar to Table 2, but in this case the performance criteria was the time of flight. The tests again were of the one-sided variety because rejection was desired if the mean of the challenger was greater than that of the "model" signifying a lower velocity, which was undesirable. Final conclusions appear in the next chapter.

TABLE 1

PERFORMANCE CRITERIA: ACCURACY

COMPARISON OF STD 5.56 MM (Y) ROUND TO "MODEL" W/O CANNELURE (X)

$\bar{X} = 1.525$ $\quad S_x = .5485$ $\quad S_x^2 = .3009$

$\bar{Y} = 1.305$ $\quad S_y = .6718$ $\quad S_y^2 = .4513$

Test #1 $\quad H_o: \sigma_x = \sigma_y$ vs $H_1: \sigma_x \neq \sigma_y$, $\alpha/2 = .005$

$F = .6667$ Acceptance Region: $.434 \leq F \leq 2.30$

Conclusion: Accept H_o.

Test #2 $\quad H_o: \mu_x \leq \mu_y$ vs $H_1: \mu_x > \mu_y$, $\alpha = .01$

$t = 1.627$ Acceptance Region: $t < 2.38$

Conclusion: Accept H_o.

TABLE 2

PERFORMANCE CRITERIA: ACCURACY

COMPARISON OF "MODEL" (X)
TO CHALLENGER (Y) (α=.01)

Challenger	H_o	Test Statistic	Acceptance Region	Decision
Sharp point	$\sigma_x=\sigma_y$	1.415	$.384 \le F \le 3.11$	Accept
" "	$\mu_y \le \mu_x$	3.40σ	$t > -2.398$	Aceept
Blunt Point	$\sigma_x=\sigma_y$	.6783	$.384 \le F \le 3.11$	Accept
" "	$\mu_y \le \mu_x$	3.014	$t > -2.398$	Accept
No boattail	$\sigma_x=\sigma_y$	.0759	$.384 \le F \le 3.11$	Reject
" "	$\mu_y \le \mu_x$	-7.119	$t' > -2.518$	Reject
½ boattail	$\sigma_x=\sigma_y$	.1437	$.384 \le F \le 3.11$	Reject
" "	$\mu_y \le \mu_x$	-5.785	$t' > -2.518$	Reject

TABLE 3

PERFORMANCE CRITERIA: TIME OF FLIGHT

COMPARISON OF STD 5.56 MM (Y)
ROUND TO "MODEL" W/O CANNELURE (X)

$\bar{X} = 208315$	$S_x = 1401.14$	$S_x^2 = 1963189$
$\bar{Y} = 209078$	$S_y = 2692.28$	$S_y^2 = 7248372$

Test #1 $\quad H_o: \sigma_x = \sigma_y$ vs $H_1: \sigma_x \neq \sigma_y, \alpha/2 = .005$

$F = 3.692$ Acceptance Region: $.4347 \leq F \leq 2.30$

Conclusion: Reject H_o.

Test #2 $\quad H_o: \sigma_x \leq \sigma_y$ vs $H_1: \sigma_x > \sigma_y$, $\alpha = .01$

t' = positive Acceptance Region $t' < -t_{\alpha,\nu}$

Conclusion: accept H_o.

TABLE 4

PERFORMANCE CRITERIA: TIME OF FLIGHT

COMPARISON OF "MODEL" (X)
TO CHALLENGER (Y) (α=.01)

Challenger	H_o	Test Statistic	Acceptance Region	Decision
No boattail	$\sigma_x=\sigma_y$	.2891	$.360 \leq F \leq 3.44$	Reject
" "	$\mu_y \leq \mu_x$	-5.849	$t' > -2.518$	Reject
½ boattail	$\sigma_x=\sigma_y$	1.293	$.392 \leq F \leq 3.20$	Accept
" "	$\mu_y \leq \mu_x$	-5.732	$t > -3.92$	Reject
Sharp point	$\sigma_x=\sigma_y$	1.419	$.384 \leq F \leq 3.02$	Accept
" "	$\mu_y \leq \mu_x$	-1.618	$t > -2.39$	Accept
Blunt point	$\sigma_x=\sigma_y$	1.187	$.384 \leq F \leq 3.02$	Accept
" "	$\mu_y \leq \mu_x$	-2.302	$t > -2.39$	Accept

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

As was reported in the preceding chapter the conclusion that the "model" was an accurate representation of the standard 5.56 mm was reached by the appropriate hypothesis tests. This was true for both performance criteria of accuracy and time of flight. The conclusion was a very important one as it provided a means of direct comparison with the other bullet types, which have no cannelure. This direct comparison was done because if one were to compare any of the other projectiles to the "model" every time only <u>one</u> item had been changed, whether it was the boattail or the MaPlat diameter. Referring to Tables 2 on page 17 and 4 on page 19 further conclusions concerning the effect of the boattail and the MaPlat diameter on the performance were made.

The boattail elimination caused a very pronounced effect on both of the performance criteria. In both cases the hypothesis that the standard deviations were equal was rejected at a significance level of .01. Upon further investigation, the hypothesis that the means of the challenger was less than or equal to that of the standard was also soundly rejected at the same confidence level. The reader should then have surmised that the elimination of the boattail had a detrimental effect on both the accuracy and the time of flight (Indiectly the velocity). Referring to the ½ boattail model, the same two rejections of hypothesis were reached for the accuracy. However, for the time of flight tests, the hypothesis that the standard deviations were equal was accepted. However, upon further testing, the hypothesis that the means were equal was rejected, therefore the same conclusion that this ½ boattail model was also inferior to the standard round was reached.

This means a great deal to the SCAMP process, especially to the Bullet Submodule. From these results it could be concluded that the elimination of the boattail should not be done. If it was possible to tolerate the spread of the no boattail bullet, then it would be possible to eliminate two steps in the process, and expedite a solution to the problems inherent to the system. This author recommends that further studies be undertaken in order to determine the magnitude of the inaccuracy, and slower velocity under field conditions.

While elimination of the boattail proved to degrade the performance of the bullet, the variation of the MaPlat diameter had no effect on the accuracy or the time of flight of the projectile. Referring to Tables 2 on page 17 and 4 on page 19 again, the reader should easily observe that for both performance criteria, the hypothesis that the standard deviations were equal was accepted. Upon further testing, it was also concluded that the population means of the challengers were also less than or equal to that of the "model" for both blunt and sharp nose versions. This is important from the standpoint of the specifications of the nose diameter, and its tolerance. On an average the point diameter is .040" with the specification (Figure 1 page 26) calling for a maximum of .050". The blunt nose lot had nose diameters ranging from .040" to .065" with an average of .051". Normally a lot such as this would have been rejected as a defective lot, however, the performance is equal to that of the standard 5.56 mm projectile. Therefore, this author recommends that a change in the specification be allowed in order to reduce the rejection rate of the bullets.

APPENDIXES

GLOSSARY

Boattail- The rear tapered section of an aeroballistic body. Used on supersonic bodies for drag redution.

Cannelure- The knurled portion of a bullet, used for crimping the cartridge to the bullet.

Fineness ratio- The quotient of the length of an ogive to its base diameter.

MaPlat diameter- On blunt projectiles, the width of the circular flat on the nose of the projectile.

Ogive- The nose of any projectile, can be parabolic, conical, or spherical

FORMULAE FOR TEST STATISTICS AND THEIR ACCEPTANCE REGIONS

$\bar{X} = \sum X_i/n_x \qquad s_x^2 = \sum(\bar{X}-X_i)^2/(n_x-1)$

1. Test of the hypothesis that the standard deviations of two normal distributions are equal is given by the test statistic $F = s_x^2/s_y^2$ with an acceptance region of

$$1/F_{\alpha/2,\nu_y,\nu_x} \le F \le F_{\alpha/2,\nu_x,\nu_y}$$

2. Test of the hypothesis that the means of two normal distributions are equal, assuming the std deviations are equal but unknown is given by the test statistic

$$t = \frac{\bar{X} - \bar{Y}}{\sqrt{(1/n_x + 1/n_y)(\sum(\bar{X}-X)^2 + \sum(\bar{Y}-Y)^2)/(n_x+n_y-2)}}$$

with an acceptance region of $t < -t_{\alpha,n_x+n_y-2}$ if $H_o: \mu_y \le \mu_x$

and $t > t_{\alpha,n_x+n_y-2}$ if $H_o: \mu_y \ge \mu_x$

3. Test of the hypothesis that the means of two normal distributions are equal when the std deviations are unknown and not equal is given by the test statistic

$$t'_\nu = \frac{\bar{X} - \bar{Y}}{\sqrt{s_x^2/n_x + s_y^2/n_y}}$$ where the degree of freedom is given

by $$\nu = \frac{(s_x^2/n_x + s_y^2/n_y)^2}{(s_x^2/n_x)^2/(n_x+1) + (s_y^2/n_y)^2/(n_y+1)} - 2$$

with an acceptance region of $t' < -t_{\alpha,\nu}$ if $H_o: \mu_y \le \mu_x$

and $t' > t_{\alpha,\nu}$ if $H_o: \mu_y \ge \mu_x$

FIGURE 1

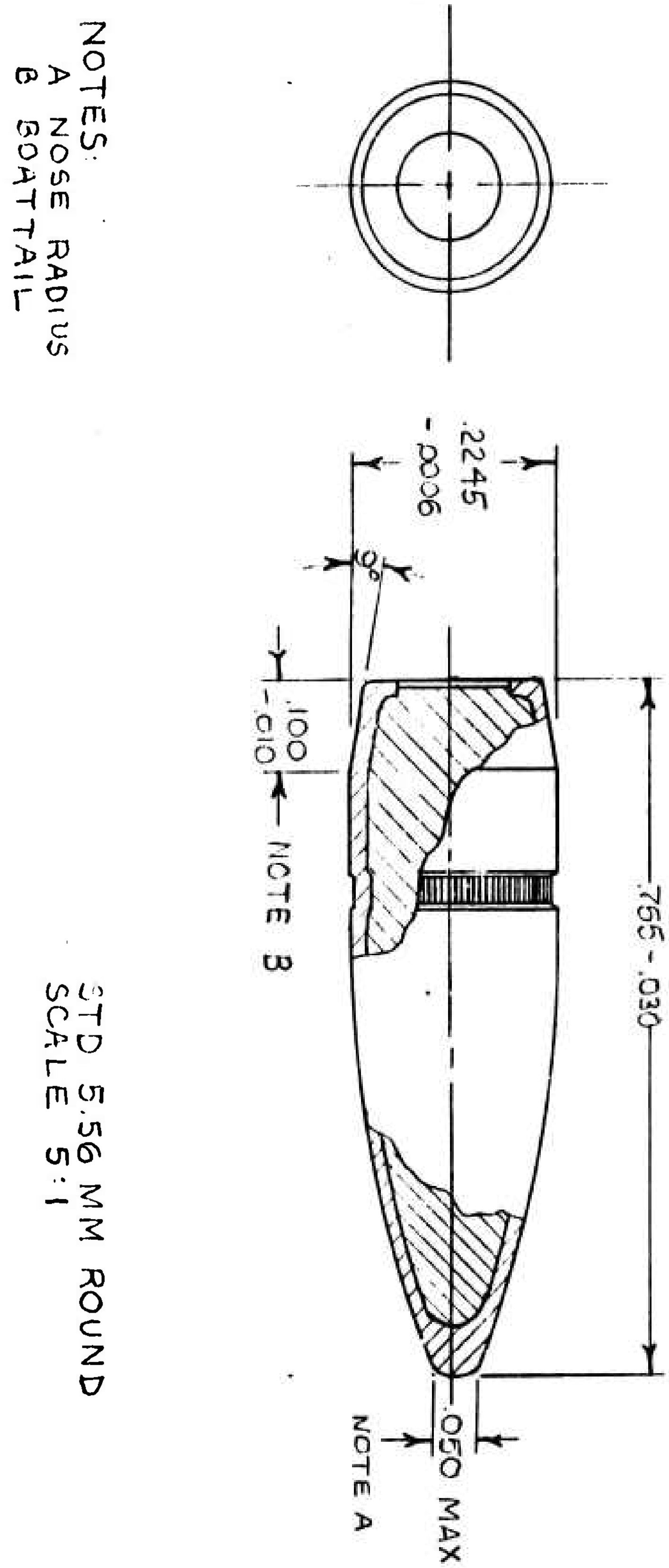
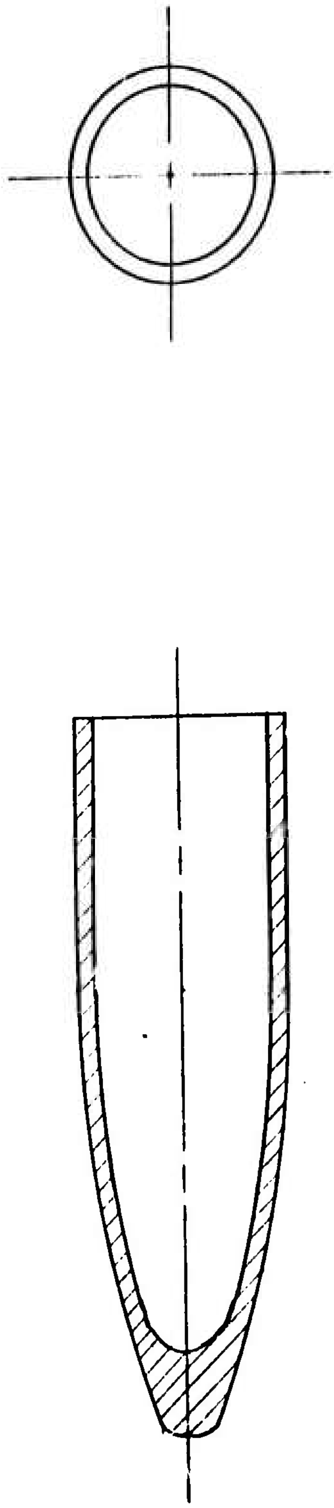
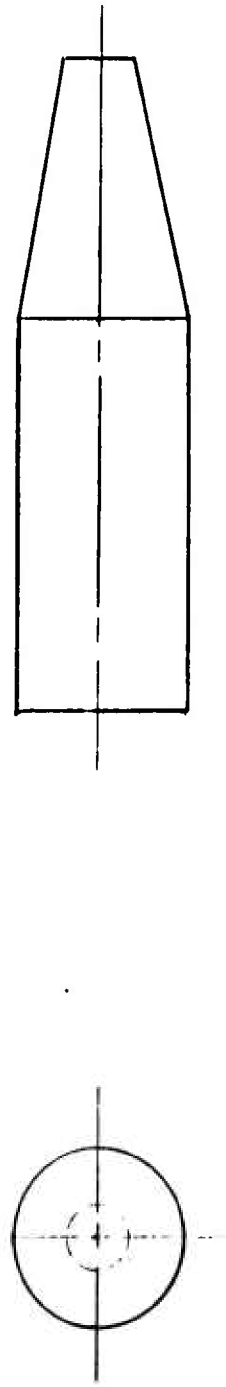

NOTES:
A NOSE RADIUS
B BOATTAIL
.2245
-.0006
10°
.100
-.010
NOTE B
.765-.030
.050 MAX
NOTE A
STD 5.56 MM ROUND
SCALE 5:1

FIGURE 2



JACKET

FIGURE 3



SLUG

FIGURE 4

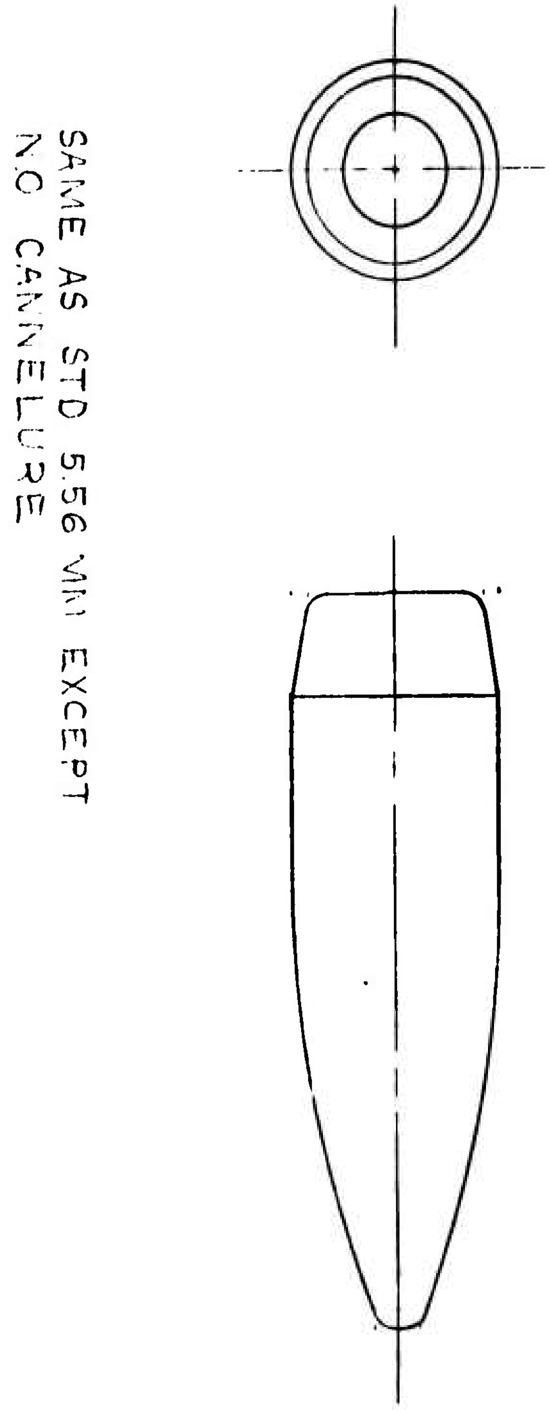
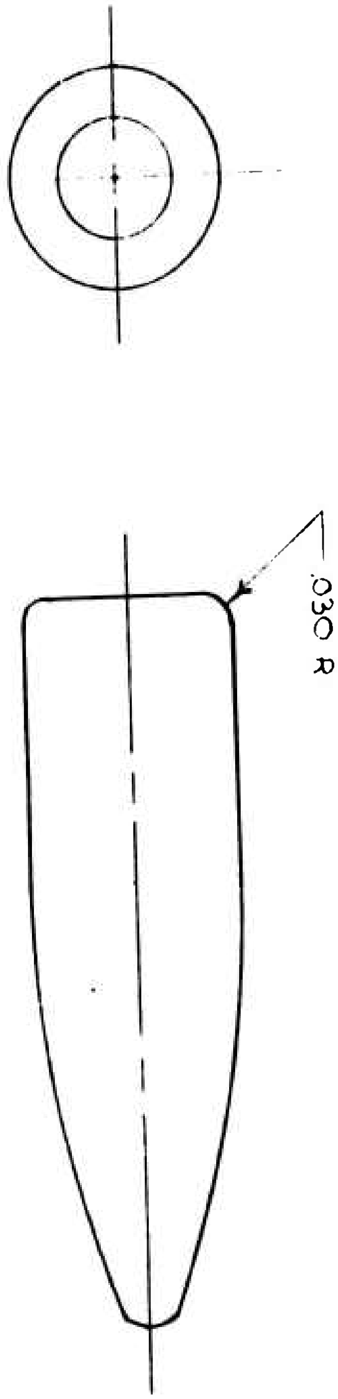
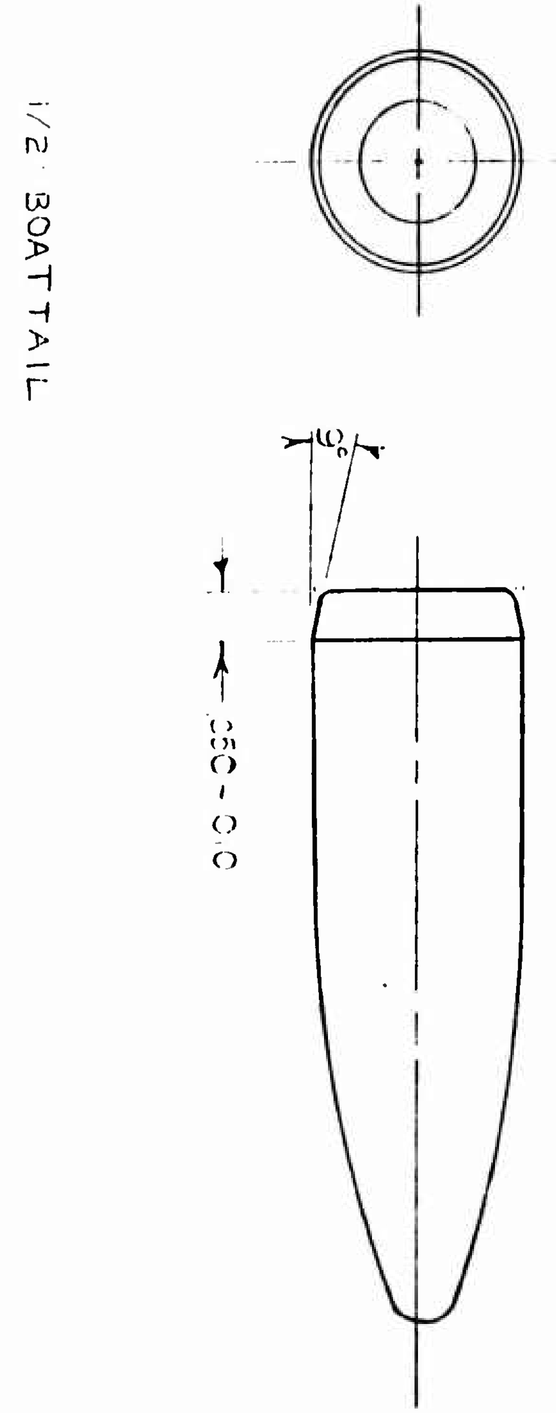


FIGURE 5



NO BOATTAIL

FIGURE 6



ACCURACY DATA

The following four tables contain the results of test firings conducted at Twin Cities Arsenal. They represent a measure of the radius from the center of the target to the hit point of the bullet. Also, the tables contain the sample mean, sample standard deviation, and the sample variance for each bullet type. The target is at a range of 200 yards.

TABLE 5

STANDARD 5.56 MM

TWO LOTS OF 20 ROUNDS

Lot #1 (inches)		Lot #2 (inches)
.41		.37
1.98		2.13
.59		1.28
1.69		1.60
1.82		.81
1.90		.48
2.93		.83
1.65		1.70
1.73		1.07
1.82		1.29
1.68	PURGED	.46
.27		.73
4.37		.59
1.37		1.59
.90		.74
.61		.71
1.91		1.86
1.26		1.26
.90		.89
1.20		.76
1.50		

$\bar{X} = 1.305 \quad S = .6718 \quad S^2 = .4513$

TABLE 6

STANDARD 5.56 MM W/O CANNELURE

TWO LOTS OF 21 ROUNDS

Lot #1 (inches)	Lot #2 (inches)
1.40	2.17
2.31	1.25
1.97	1.78
1.61	.42
1.89	2.48
1.63	1.93
1.31	.55
1.71	1.93
2.17	1.73
.97	.34
1.57	.66
.89	.60
2.34	.98
.95	1.16
2.12	1.57
1.69	2.05
1.80	.88
2.09	1.40
1.90	.74
2.73	1.16
1.57	1.60

$\overline{X} = 1.525 \quad S = .5485 \quad S^2 = .3009$

TABLE 7

5.56 MM NO BOATTAIL Radius (inches)	5.56 MM 1/2 BOATTAIL Radius (inches)
6.99	4.46
4.32	8.21
6.82	4.42
7.87	4.63
1.09	2.79
5.93	3.01
4.75	3.32
6.57	3.60
.67	3.77
4.54	2.83
5.61	2.93
3.28	3.10
3.46	2.26
7.12	2.03
4.30	2.03
2.70	3.99
6.66	1.22
3.04	3.20
5.36	2.68
3.98	4.63
$\bar{X} = 4.75$	$\bar{X} = 3.46$
$S = 1.99$	$S = 1.447$
$S^2 = 3.9601$	$S^2 = 2.094$

TABLE 8

5.56 MM SHARP POINT Radius (inches)	5.56 MM BLUNT POINT Radius (inches)
1.87	.79
.59	1.72
1.03	.67
.75	1.48
.71	1.75
2.11	.88
1.13	.45
1.84	1.39
1.19	2.06
.73	1.57
1.06	.63
1.03	1.42
1.36	.76
.70	3.15
.79	1.53
.49	.40
1.05	.76
1.28	1.95
1.10	1.14
.25	1.03
1.05	2.10
$\overline{X} = 1.05$	$\overline{X} = 1.31$
$S = .4611$	$S = .6661$
$S^2 = .2126$	$S^2 = .4436$

TIME OF FLIGHT DATA

The following four tables contain the results of a special series of tests conducted at Twin Cities Arsenal. The numbers represent chronometer time measurement of the time of flight over a distance of 597 feet for each bullet type. Also, the sample mean, sample standard deviation, and sample variance have been calculated.

TABLE 9

STANDARD 5.56 MM

TWO LOTS OF 20 ROUNDS

Lot #1	Lot #2
211594	205015
213566	205349
210258	207382
212042	206579
210983	207264
210006	206497
210650	206566
212026	207298
212191	206549
213386	207342
214029	205544
210947	207915
210779	209398
211668	206708
210633	205037
211875	206118
211284	207177
211124	205356
210487	205191
210765	207647

$\overline{X} = 209078$ $S = 2692.28$ $S^2 = 7248372$

TABLE 10

STANDARD 5.56 MM W/O CANNELURE

TWO LOTS OF 21 ROUNDS

Lot #1	Lot #2
207463	209527
207625	209508
206983	206847
207668	209624
210012	209287
208583	208046
206760	208720
210866	209560
208824	206635
205344	210818
209906	207419
206615	208604
207144	210754
208412	208016
205207	206875
206669	208483
207184	208263
208101	210730
208389	208467
209102	208420
207717	210088

$\overline{X} = 208315$ $S = 1401.14$ $S^2 = 1963189$

TABLE 11

5.56 MM NO BOATTAIL	5.56 MM 1/2 BOATTAIL
Chronograph time	Chronograph time
211753	209683
212030	210578
211523	208512
211625	208580
212874	208913
213569	212535
211143	211904
214466	210818
209868	209753
211305	208815
212431	212621
213217	210632
210279	209766
213295	211044
211860	211098
212367	210830
213861	210520
213861	211204
	211264
$\overline{X}$ = 212198	$\overline{X}$ = 210477
S = 2587.67	S = 1232.20
S^2 = 6696071	S^2 = 1518314

TABLE 12

5.56 MM SHARP POINT	5.56 MM BLUNT POINT
Chronograph time	Chronograph time
209798	207902
208069	207269
209715	208359
209524	207055
208082	209719
209052	209067
209630	210773
207482	209569
209461	208684
211144	210032
208437	208674
210151	209866
209178	211581
210299	209134
206694	207426
208345	210113
207157	210492
208255	210732
207239	210057
210041	207570
$\overline{X}$ = 208896	$\overline{X}$ = 209162
S = 1176.10	S = 1286.02
S^2 = 1383206	S^2 = 1653835

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