Spring 2015

The effects of physical flash hole deviations on factory-grade rifle ammunition

Nicolaas Martin Schrier

THE EFFECTS OF PHYSICAL FLASH HOLE DEVIATIONS ON FACTORY-GRADE RIFLE AMMUNITION

by

NICOLAAS MARTIN SCHRIER

A THESIS

Presented to the Faculty of the Graduate School of the

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

In Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE IN EXPLOSIVES ENGINEERING

2015

Approved by

Paul Worsey, Advisor

Gillian Worsey

Jason Baird

ABSTRACT

The objective of this research is to determine the effect of dimensional and positional changes of the primer flash hole on the performance of factory-grade rifle ammunition. The studied variables were flash hole diameter, offset from center, and orientation of the offset in the primer pocket. Cartridge performance was quantified by measuring muzzle velocity, chamber pressure, and target grouping size (precision).

Five different flash hole diameters were tested for both the Remington .223 and Winchester .308 calibers: 1.4mm, 2.0mm (the Fiocchi standard), 2.4mm, 2.8mm, and 3.0mm. Each diameter was tested at three offsets: centered (no offset), 0.5mm from center, and 1.0mm from center. Each of the 0.5mm and 1.0mm offsets were tested at three orientations: up (12 O'clock), side (3 O'clock), and down (6 O'clock). Every flash hole was manually drilled and each cartridge hand-loaded in order to conduct controlled testing of the flash hole variations. Testing took place in two segments with the muzzle velocity and precision measured at a private range outside Rolla, MO and chamber pressure and a second muzzle velocity measured at Fiocchi of America (Ozark, MO).

Results showed that muzzle velocity and chamber pressure varied 1-4% from the control flash hole as hole diameter, offset, and orientation changed. The precision, particularly in the 3mm diameter and centered flash hole cases resulted in improvements of up to 28%. Variations in flash hole diameter, offset, and orientation do affect cartridge performance. Alternate flash hole diameters exist that improve powder ignition consistently as well as precision. Off centered flash holes increase target grouping size and result in less consistent muzzle velocity and chamber pressure values.

ACKNOWLEDGEMENTS

I would like to thank Dr. Paul Worsey for advising me throughout this project. I would also like to thank Mark Halstead, Russell Wheeler and Fiocchi of America for their accommodation, supplied materials, and assistance with this research and its testing. I'd further like to thank Marvin Davis for the use of his facilities and rifles and for his assistance in conducting the range testing portion of this research. In addition, thank you to Jimmie Taylor DeWayne Phelps, Kevin Phelps, and Jacob Miller for your various insights and help with this project. If not for the help, knowledge, and patience of these individuals I would have never been able to complete this project. Furthermore, I'd like to thank my committee members, Dr. Jason Baird and Dr. Gillian Worsey for their knowledge and guidance in completing this work.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1 INTRODUCTION

This research is an analysis of the effects that specific physical attributes have on the performance of factory rifle ammunition. Discussed below is an overview of modern ammunition and ballistics testing as well as the reasoning and importance for this research.

Many factors determine how an ammunition cartridge will perform. Slight changes in any of these factors could affect a bullet's trajectory and precision. Knowing how a particular factor influences a cartridge will allow the cartridge to be manufactured for optimal performance. Physical and chemical variations of the cartridge's components cause these influential factors. A modern cartridge is made up of four primary components (See Figure 1.1):

- Bullet, the projectile that leaves the barrel of the gun
- Propellant/Powder, which burns causing a quick increase in pressure that launches the projectile,
- Primer, which is struck by the firing pin and ignites the powder, and the
- Case, which holds the other three components in place. The case is commonly made of brass, but can be steel or other materials. (1) (2) (3)

Figure 1.1. The four components of an ammunition cartridge.

The objective of this research is to analyze center fire (Boxer primer), factory-made rifle ammunition’s performance based on dimensional and positional changes of the flash hole. The flash hole is the physical channel at the base of the case that the primer’s energy travels through to ignite the powder within said case (1) (2) (4). Centerfire ammunition, where the primer is centered in the base of the case, can be one of two priming systems: Boxer and Berdan primers. The interior of these primers differ from each other as well as their flash hole design. Boxer priming systems use one centered flash hole whereas Berdan systems use two flash holes (1). Boxer primed systems were used for this research since it is the standard for the manufacturer involved (5).

Ammunition manufacturer Fiocchi of America solicited this research in order to potentially improve their manufacturing process as well as their product. By seeing the effects of flash hole variations on the end use of the cartridge, Fiocchi would be able to see if changes are needed. During mass production, cartridge cases continuously vibrate while the flash holes are being punched. This vibration causes common inaccuracies in the flash hole's location. Flash holes can be off center by up to 1mm in some cases (5). By determining if the flash hole's location affects the cartridge's overall performance, Fiocchi can determine whether case vibration needs to be reduced during their manufacturing process.

Another issue experienced by Fiocchi is the breaking of flash hole punches during production. Once the punch breaks, the following case in line does not receive a flash hole. This is detected by the punching equipment and the machine is shut down until the punch is replaced. This issue could potentially be resolved by using a larger diameter punch to produce the flash hole that would break less often. The effects of flash hole diameter on overall cartridge performance were also addressed by this research, in order to determine whether a flash hole punch diameter change would be viable.

Fiocchi can determine if necessary action is needed to improve the manufacturing process by discovering whether or not these variations affect cartridge performance. This research was performed in conjunction with Fiocchi to aid their continuation to improve production efficiency and product quality.

In collaboration with Fiocchi of America (Ozark, Missouri), .223 Remington and .308 Winchester rifle ammunition (depicted in Figure 1.2 and Figure 1.3) was hand assembled from parts and tested. Three factors were used to vary the flash holes. These factors were:

- Diameter – the cross sectional distance across the center of the flash hole;
- Offset – the distance that the flash hole's center was from the case base center; and
- Orientation – the direction that the offset of the flash hole was in (See Figure 1.6).

Figure 1.2. Left to right, .223 Remington and ,308 Winchester cartridges.

Figure 1.3. Case bases with fired primers. Left to right, .223 Remington and .308 Winchester.

A number of flash hole diameters with varying offsets and orientations were tested to see the effects they had on cartridge performance in these two rifle calibers. “Performance” was determined by measuring the muzzle velocity, chamber pressure, and precision of each flash hole variation.

For both the .223 and .308 calibers, Fiocchi punches a 2.0 millimeter (mm) flash hole into the center of the case base. For this research, five different flash hole diameters were chosen for comparison: 1.4mm, 2.0mm, 2.4mm, 2.8mm, and 3.0mm (Figure 1.4). These diameters were chosen because they were multiples of the area produced by a standard 2.0mm flash hole diameter (Table 1.1). Three offsets were chosen as well: Centered (or zero offset), 0.5mm off center, and 1.0mm off center (Figure 1.5). The 1.0mm offset was not used for the .223 Remington 2.4mm, 2.8mm, and 3.0mm diameters because in the small caliber the combination of the 1mm offset and these diameters exceeded the primer pocket boundary (primer pocket consistency data in APPENDIX A). A centered flash hole is centered within the case base. Furthermore, three different offset firing orientations were used for each offset flash hole cartridge. These orientations were the off center flash hole ‘up’ (12 O’Clock orientation), to the ‘side’ (3 O’Clock orientation), and 'down' (6 O'Clock orientation) (Figure 1.6). It was assumed that the 3 O'Clock and 9 O'Clock orientations would have identical effects on performance. By using variations of these three variables it was determined how flash hole diameter, offset, and offset orientation affect bullet velocity, chamber pressure, and precision.

Figure 1.4. Left to right, 1.4mm, 2.0mm, 2.4mm, 2.8mm, 3.0mm flash holes drilled in .308 Winchester cases.

Figure 1.5. Left to right, Centered, offset 0.5mm, offset 1.0mm flash holes with 2mm diameters.

Figure 1.6. Three flash hole orientations used. Numbers represent the positions of a clocks face.

Table 1.1. Selected flash hole diameters comparison based on area that diameter creates.

Diameter (mm)	Area (mm^2)	Approximate Multiple of 2mm Area
2	3.142	1
1.4	1.539	0.5
2.4	4.524	1.5
2.8	6.158	2
3	7.069	2.25

Consistent ammunition with known flash hole diameters and offsets were needed to conduct this research. Unpunched cartridge cases were acquired from Fiocchi so that the flash holes could be individually drilled. Each diameter was drilled with each off center and location variation (e.g. 2.0mm Centered or 2.8mm off center 0.5mm in the “up” orientation). Groups of 10 to 20 cases were then hand loaded for each flash hole orientation. Handloading ensured that precise load weights and bullet seating depths were used for each cartridge. This process is detailed in the Methodology section. In total over 520 .223 and 1050 .308 cartridges were hand assembled and tested during this work.

2 LITERATURE REVIEW

It is important to have a basic understanding of ballistics before continuing with this report. This section defines ballistics and its components as well as provides an overview of previous works involving flash hole alterations. It is to be noted that there is a scarcity of available published research regarding flash hole diameter and location changes. Work done by E.R. Lake with the McDonnell Aircraft Company briefly discusses the effect of flash hole size on primer function (6). This effect was further investigated by Germán A. Salazar in an article for The Rifle Journal (7). Salazar specifically discussed how the primer's flash is influenced by two different flash hole sizes. Finally, this section will discuss two phenomena that can occur in lightly loaded ammunition. The Secondary Explosion Effect (SEE) and flash-over have both been known to occur in lightly loaded cartridges (8). These phenomena could not only be related to the amount of powder in the cartridge, but also be a function of the flash hole's location. By addressing these pieces of work, the reader will acquire a necessary knowledge of ballistics to aide in fully understanding this research.

2.1 BACKGROUND

2.1.1 Ballistics Overview. Ballistics is the study of the performance of propellants and projectiles, and the laws that govern them. Two components of ballistics are interior ballistics and exterior ballistics. Interior ballistics encompasses everything that happens from cartridge ignition to the time the bullet leaves the gun. Exterior ballistics covers the bullet's flight until it comes in contact with its target (2) (9). Exterior ballistic performance is directly related to internal ballistic performance since internal ballistics dictates the starting conditions of the bullet in flight following its exit from the barrel. Changes with the flash hole take place in the realm of interior ballistics, but go on to influence the bullet's exterior ballistics.

The flash hole is the channel between the primer and the case interior, through which the primer flame passes (1) (2) (4). The diameter and location of the flash hole directly influence how the primer's energy initially interacts with the propellant. Flash hole diameter controls the surface area of propellant that the primer's energy comes in contact with, while the flash hole's location controls where in the rear of the case the primer's energy first comes into contact with the propellant.

2.1.2 Factors. This research was conducted using factory grade ammunition materials. This leads to several uncontrollable factors that affect cartridge performance. These factors could be controlled with match grade ammunition, but that was not the focus of this study. Match grade ammunition is suitable for competitive shooting. It is a combination of the most accurate powder, bullets, and cases (10).

Since the cartridge materials used in this research were factory grade, provided by Fiocchi and their suppliers, the consistency of those materials were outside the researcher's control. There are a multitude of factors that affect cartridge performance. The bullet's mass, interior case volume, and load weight and powder burn rate accuracy are some factors that can affect how the powder ignites and starts to propel the bullet out of the barrel.

Bullet mass can vary due to mass production processes. Heavier bullets (greater mass, m) require greater force (F) to move, as per Newton's second law.

$$F = m \cdot a$$

Given the same construction and materials, heavier bullets are also longer than lighter ones. Longer bullets increase the surface area in contact with the gun bore, therefore having greater friction to overcome while travelling down the barrel. This leads to lighter bullets being more likely to have higher muzzle velocities under a similar powder load (11). Different bullet masses require different loads to propel them (1) and can greatly influence the pressures produced (2). The depth to which the bullet is seated also contributes to pressure, as it influences the interior volume of the case.

Interior case volume is an important factor to cartridge performance as it dictates the volume of powder that can be loaded into that case, as well as the initial volume that the propellant gases build in. Case wall thickness directly affects the internal volume of the case. Since the outside volume of a cartridge case needs to stay within a specific size so that it can function within its intended caliber gun, a thicker walling to a case will decrease the internal volume (4). The Ideal Gas Law

$$P = n \cdot R \cdot T/V$$

shows that volume (V) and pressure (P) are inversely related. Therefore, a decrease in volume results in an increase in pressure. Increased pressure following powder ignition causes increased force on the bullet, leading to a higher bullet velocity (11). A pressure increase in the case will cause temperature increases as well (Ideal Gas Law) and increase the burn rate of the confined propellant (12).

Powder load weight and burn rate consistency directly affects cartridge performance as well. Although powder load weights may vary during factory production, they were held constant for the purposes of this research. The propellant's burn rate must remain as consistent as possible between cartridges so that a consistent chamber pressure can act on the bullet each time. This leads to consistent muzzle velocities and consistent shooting. Consistent burn rates are difficult to maintain in factory ammunition due to the mass production and shelf life. To mass produce ammunition, its components are created in individual production runs or lots. Powder burn rates therefore vary from lot to lot (1) (13). Following factory production, ammunition can be stored for a significant amount of time, possibly sitting in a warehouse without temperature control (14). This storage could also occur on the consumer's end, when ammunition is purchased in bulk. Rapid firing of cartridges also causes temperature affects as the chamber heats up from the previously fired rounds. In order to maintain consistent burn rates the new cartridge must not be subject to the heated chamber for an extended period of time. These temperature variations will affect the pressure that a cartridge generates when fired, as pressure typically increases with temperature (1).

An attempt to control these factors was made during this research. Minor variations in bullet mass, interior case volume, and powder burn rate were acceptable for this research. By normalizing the performance data against a control, the influence of these uncontrolled factors was removed.

2.2 LITERATURE REVIEW

Fiocchi themselves have not performed any previous formal research related to effects caused by differences in flash hole diameter or location. The 2mm flash hole was found to be acceptable for most calibers and was therefore adopted as the “standard”. The question has been raised within Fiocchi as to whether the flash hole’s placement affects cartridge performance in any way, but no tests have been run, leaving a divided opinion (15). The lack of previous research in this area led to this research.

Flash hole diameter effects in small caliber ammunition have been addressed in previous work. A 1970’s report by the McDonnell Aircraft Company entitled *Percussion Primers, Design Requirements* by E.R. Lake, briefly discussed differences in flash hole diameters. It is assumed that as the flash hole diameter decreases, the pressure from the deflagration product (in this case the primer) increases. The “spit”, or length at which the primer’s flash extends into the case also increases in length with smaller flash hole diameters (6). This is beneficial as greater pressures will be produced by a given powder load when it is rapidly ignited throughout by a large hot primer flash (4). Higher pressures aid in the initiation of explosive trains, giving validity to a small flash hole. However, pyrotechnic delay trains are benefited by maintaining low pressures, thus supporting a larger flash hole diameter. Ignition of an ammunition propellant is thought to fall somewhere in the middle of these two scenarios (6). This suggests that an optimum flash hole diameter exists to best assist powder ignition. However the influence of flash hole diameter on the initiation of a firing train is unknown (16).

Flash hole diameter effects on ignition were further analyzed in 2011 with an informal study comparing large and small flash holes in .308 rifle ammunition. Two types of .308 brass with small primer pockets and two different sized flash holes were compared by Salazar (7). Remington BR brass has a larger 0.080” (2.032mm) diameter flash hole compared to the Lapua Palma brass's smaller 0.062" (1.575mm) flash hole (Figure 2.1).

(2)

Figure 2.1. .308 Remington BR brass and .308 Lapua Palma brass flash hole comparison.

Salazar addresses the same assumption as mentioned earlier by Lake that a smaller flash hole would cause the primer flash to propagate more vigorously through the flash hole and therefore further into the case, similar to the way a smaller nozzle on a water hose affects water flow (7). Flow from a larger diameter to a smaller diameter causes a decrease in pressure and coinciding increase in the fluid's velocity. This is known as the Venturi effect (17). By using two different types of primers for each type of brass, a photographic comparison was made between the primer's "spit" through the flash holes. The large flash primer, a Remington 7 ½ primer, showed the Lapua Palma brass having a slightly smaller flash than the Remington BR. These results (Figure 2.2,

Figure 2.3, Figure 2.4, and Figure 2.5) were opposite to what would be expected from the water hose analogy. The small flash primer, a Wolf .223 primer, showed no discernible difference in flashes of the two types of brass (7).

Figure 2.2. Remington BR case, 0.080″ Flash Hole, Remington 7.5 Primer. (7)

Figure 2.3. Lapua Palma case, 0.062″ Flash Hole, Remington 7.5 Primer. (7)

Figure 2.4. Remington BR case, 0.080″ Flash Hole, Wolf .223 Primer. (7)

Figure 2.5. Lapua Palma case, 0.062″ Flash Hole, Wolf 223 Primer. (7)

The Salazar study suggests that flash hole diameter has a minimal, if any, effect on primer initiation. By testing five flash hole diameters, this research goes one step further than Lake and Salazar by determining if any effect that the flash hole has on the primer's "spit" in turn affects overall cartridge performance. This research will also investigate whether flash hole offsets or orientations affect powder initiation and therefore, chamber pressure, muzzle velocity, and bullet precision. This was not the focus of the previous studies.

Effects on performance caused by flash hole location have been speculated by Fiocchi and through various internet forums, but no formal research was found by this researcher. However, a flash hole's location could result in two different phenomena found in light load cartridges. Depending on how a light load cartridge is handled or how the gun is positioned, the powder may bunch directly up against the flash hole, completely away from it (against the bullet base), or anywhere in between. This will cause ignition variations (4). These phenomena are Secondary Explosion Effect (SEE) and flash-over. SEE is caused by powder that is not fully ignited, but is releasing unburnt gases (8). These gases eventually ignite causing a large pressure increase, which has been reported to cause gun damage from small bore, large capacity ammunition (1). A detonation could occur by simply cutting the charge weight by 10-15% of the full charged load for slow burning powders (4). Flash-over occurs when there is an increased surface area of propellant presented to the primer's initiating flame. Low powder volumes can settle when the cartridge is horizontal, allowing the primer flame to traverse across the large top area of the powder, igniting it simultaneously. Flash-over causes an increased burn rate within the cartridge that greatly increases the pressure (8). It is possible that a raised flash hole ("up" oriented) could cause flash-over even without a significantly low powder load. It was highly unlikely to see these phenomena in this research as the powder loads used resulted in minimum air gaps within the case.

The review of the literature suggests that the question of whether flash hole diameter and location affect cartridge performance is quite valid. It has been discussed in previous works, but not thoroughly investigated. This research intends on describing the flash holes diameter and location influence on velocity, pressure, and precision.

3 METHODOLOGY

It is important for the reader to understand the experimental processes that took place in order to obtain the results of this flash hole study. This section discusses the four steps required to obtain the results of this research: drilling of the flash hole, loading of the cartridges, testing, and data analysis. The following is a detailed overview of the materials that were needed, the equipment that was used, and the procedures that were followed for each of these steps.

3.1 FLASH HOLE DRILLING

The initial process required to complete this research was to provide the cases with flash holes. At Fiocchi, on the production lines the flash holes are punched. In this research, the flash holes were precision drilled rather than punched, so that both the diameter and location of the flash hole could be controlled. Remington .223 and Winchester .308 un-punched, flash hole-less cases were provided by Fiocchi of America in order to conduct this research. The flash holes were drilled using the following method.

Flash hole drilling took place in the machine shop of the Missouri S&T Rock Mechanics and Explosives Research Center. A Bridgeport milling machine was used to accurately drill each case individually (Figure 3.1). The cases were held in place by an aluminum block (Figure 3.2) that was anchored to the Bridgeport's bench. This block was designed to hold one case of each caliber inverted and securely so that the flash hole could be drilled into the base of the case.

Figure 3.1. Bridgeport milling machine.

Figure 3.2. Aluminum block for holding cases during drilling.

Five different flash holes comprising of one smaller (1.4mm), one standard size (2mm), and three larger (2.4mm, 2.8mm, 3mm) were drilled using black oxide high-speed-steel short length drill bits (Figure 3.3). Each drill bit diameter was equivalent to the desired flash hole diameters to be tested. The drill bit diameters and their corresponding flash hole diameters are shown in the table below (Table 3.1).

Table 3.1. Description of drill bits used for flash hole production.

Flash Hole Diameter (mm)	**Drill Bit Diameter**	**Converted Diameter (mm)**
1.4	Gauge 54	1.397
2.0	2.0mm	2.0
2.4	2.4mm	2.4
2.8	Gauge 35	2.794
3.0	3.0mm	3.0

The Bridgeport table is adjustable in all three dimensions. Left and right (x-axis) and backwards and forwards (y-axis) adjustments are electronically measureable to 0.001 inches. Up and down adjustments will be referred to as the z-axis (Figure 3.4). Adjustments along the x-axis were used to position the case to the exact degree of offset that was desired.

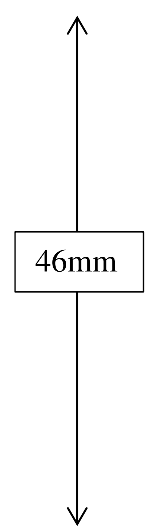

Figure 3.3. Left to right, 1.4mm, 2.0mm, 2.4mm, 2.8mm, 3.0mm drill bits used for flash hole drilling.

Figure 3.4. XYZ plane of Bridgeport bench adjustment.

3.2 DRILL SETUP

To set up the drill for drilling flash holes the table and aluminum holster was first adjusted so that the cases were centered under the drill. The aluminum block was fastened to the mill table using the bolt attachment. In order to center the drill, the case was placed into the drill's chuck right side up and then the pocket in the aluminum block was lined up with it. A coaxial indicator was used to further center the chuck within the case pocket. The indicator was fastened in the drill and lowered until it came in contact with the edge of the pocket in the aluminum block (Figure 3.5). The block and table were then adjusted along the x and y-axis until the indicator displayed that the pocket was centered under the drill. The block was then fastened into place as well as the drill's bench (Figure 3.6). The x and y coordinates of the drill were set to zero so that the centered drill position could be marked.

Figure 3.5. Centering the case well under drill using a dial indicator.

Figure 3.6. Anchored down aluminum block ready for drilling.

3.3 DRILLING

Drilling the flash holes could commence once the drill and aluminum block were in place. Each case was placed inverted into the case pocket of the aluminum block and tightened in place by the plastic side screws. The case was then drilled using the desired bit size (Figure 3.9). For offset flash holes the mill table, along with the aluminum block, was adjusted along the x-axis either 0.5mm (0.0195in) or 1mm (0.0395in) and locked in place again (Figure 3.7). Case bases were either marked in the direction of offset or aligned in the pocket so that the “L” on the cartridge base head-stamp indicated the offset direction (Figure 3.8).

Figure 3.7. Drill offset 0.0195in (0.5mm).

Figure 3.8. Stamped “L” in case base is lined up in case well to indicate flash hole offset direction.

Figure 3.9. Flash hole drilled into case.

This was performed for each category of cases so that the offset direction could be recognized once the primer was in place and the cartridge loaded, leaving the location of the flash hole obscured. Cases categorized by caliber and flash hole size and offset were then ready to be loaded.

3.4 LOADING

Cartridge loading took place at the Missouri S&T Experimental Mine, using a reloading kit. Drilled cases were kept categorized depending on their flash hole diameters and locations and separate from other configurations. Cases were loaded in groups based on their dimensions so that cases with different flash hole parameters were not mixed up. The following loading procedure was followed for each cartridge.

Prior to loading, each case was checked for burring along the edge of the flash hole and cleaned with a hand held de-priming tool if necessary. Deburred cases were then tumbled in a Hornady case tumbler containing crushed walnut shells media for a minimum time of one hour (Figure 3.10). This was done so that each case was cleaned consistently.

Figure 3.10. Cases in walnut media for tumbling.

The cases were then removed and the interior and flash holes were cleared of any walnut fragments. Any dust was cleaned off the cases using compressed air. Once cleaned, the cases were set out in a welled tray for priming. Next, the cases were greased on a foam oil pad (Figure 3.11) and then sent through the press using the sizing die.

Figure 3.11. .223 cases on grease pad.

Each case was pressed into the sizing die and then retracted (Figure 3.12 and Figure 3.13). During this retraction a primer was placed in the priming well at the bottom of the press and the case was lowered onto it (Figure 3.14). The press's lever was then pushed past neutral, which set the primer. Primer depth was visually checked to be flush with the bottom of the case.

Figure 3.12. Case in press with sizing die.

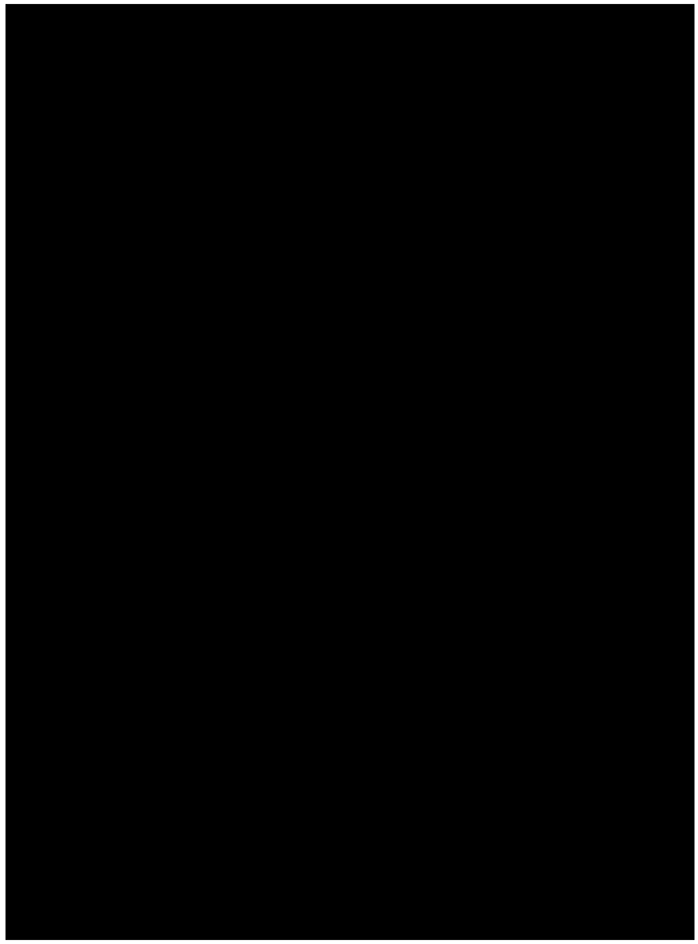

Figure 3.13. Case entering sizing die.

Figure 3.14. Priming the cartridge.

The case length was recorded for each case to ensure that it was under the recommended maximum case length for that caliber (Figure 3.15) (See APPENDIX B and C for case length data). Cases were shortened using a necking tool if they were greater than the maximum length allowed. A necking tool was used on each case to remove and imperfections from the case mouth.

Figure 3.15. Case length measurement with digital caliper.

Smokeless powder was then added to each case once they had been sized and primed. Using a powder dispenser (Figure 3.16), the powder was taken and then weighed out on a Hornady GS-1500 electronic scale (Figure 3.17). The weight was adjusted until the desired load weight was reached. This powder was then taken and poured into the primed case (Figure 3.18).

Figure 3.16. Powder dispenser and pan.

Figure 3.17. Digitally weighing powder load.

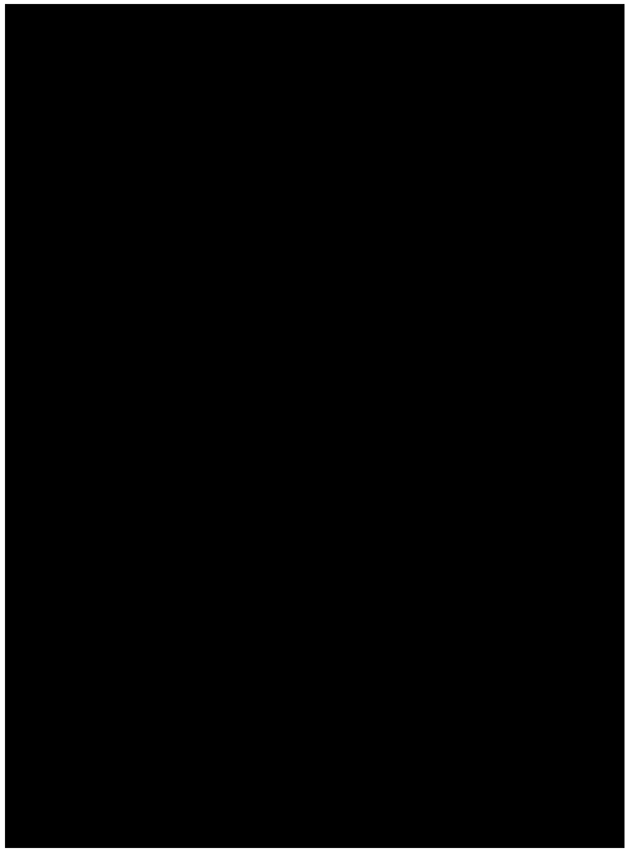

Figure 3.18. Funnel measured powder load into case.

Bullet seating took place next. The full cases were set into the press and the bullet was placed on top as the case was pressed into the seating die (Figure 3.19 and Figure 3.20). At this point the cartridge was completed. The overall length (OAL) of each cartridge was measured with a caliper and recorded to ensure that they were under the maximum OAL for that caliber (See APPENDIX B and C for OAL data). Each bullet was seated to the same depth in each cartridge for each caliber.

Figure 3.19. .308 Winchester cartridge in reloading press prior to bullet seating.

Figure 3.20. .308 Winchester cartridge being pressed in to seating die.

The specific cartridge loading materials and data were provided by Fiocchi and outlined in Table 3.2 below. The equipment used during the loading process is outlined in APPENDIX J.

Table 3.2. Cartridge loading specifications for .223 Remington and .308 Winchester calibers

Caliber	.223 Remington	.308 Winchester
Maximum Case Length	1.760”	2.015”
Maximum Overall Length	2.260”	2.810”
Powder Load Mass	1.54g or 23.7-23.8gr	2.90g or 44.7-44.8gr
Bullet Type	55gr Full Metal Jacket	150gr SST
Primer Type	CCI No. 400 Small Rifle	CCI No. 200 Large Rifle
Powder Type	WC 749	WC 749

(5)

Completed cartridges remained categorized depending on the characteristics of their flash holes. At this point, these groups of cartridges were ready for testing.

3.5 TESTING

As mentioned in the Introduction, testing was split up into two portions. The first set of testing was conducted at a private range. There, velocity measurements of 10-shot groupings were taken for each flash hole category. Targets depicting each group were saved and group sizes were measured from them. The second set of testing took place at Fiocchi of America where velocity and pressure were measured for 10-20 shot groups using Bill Wiseman and Co. pressure and velocity barrels (See APPENDIX J for equipment information) for each flash hole category. The specific procedure for each of these tests is described below.

3.5.1 Range Shooting. Shooting took place at a private range just outside of Rolla, Missouri to measure group precision and projectile velocity. The range consisted of a wooden bench and target stand. The distance from the end of the bench to the target was 100yds (Figure 3.21). A pile of rubber tires was positioned behind the wooden target stand to stop the bullets. Shot groups of ten were used for each flash hole characterization in both of the calibers. A .223 Howa 1500 bolt action rifle and a .308 Remington 788 bolt action rifle were fired from a Hyskore DLX Precision Compression Dampened shooting rest (Figure 3.22). Both guns had 24in barrels with the .308 having 1 in 9 twist rifling and the .223 having 1 in 10 twist rifling. Both rifles used a 3x9 Redfield Revolution scope.

Figure 3.21. Down range. Farthest target is at 100yds.

Figure 3.22. .223 Howa 1500 in Hyskore shooting rest.

A Prochrono digital chronograph was setup 10-20ft from the end of barrel. This was to ensure that muzzle flash did not interfere with the chronograph’s readings. This was measured as the distance between the chronograph’s first sensor and the end of the gun barrel. This distance was also held constant throughout shooting. The chronograph was mounted on a wooden stand that was leveled and clamped to a ladder (Figure 3.23). The chronograph needed to be subject to uniform light in order to get the most accurate readings. This was done by either having it in complete sunlight while using the diffusers or in overcast conditions without the diffusers. An adequate amount of light was necessary for the chronograph to function at all. The chronograph was placed so that the display faced the shooter (Figure 3.24). The rifles were sighted to ensure that they passed through the two triangular gates of the chronograph above each of the sensors. The rifles were then sighted to the center of the target down range (See APPENDIX F and G for target information).

Figure 3.23. ProChrono on ladder stand with diffusers mounted.

Figure 3.24. Chronograph and range view from shooting bench behind rifle.

A ten shot grouping was fired for each flash hole deviation set. Each of the five diameters (1.4mm, 2.0mm, 2.4mm, 2.8mm, and 3.0mm) were drilled with three different offsets (Centered, 0.5mm, and 1.0mm). The 0.5mm offset and 1.0mm offset were fired in three different orientations (up, side, and down). The cartridges were loaded into the rifle one at a time. Centered flash hole cartridges were loaded in to the chamber without concern of orientation. Off-center flash hole groups were loaded into the chamber according to their desired orientation. The cartridges were then locked into place by the bolt and the shot was fired. Velocity readings from the chronograph were recorded following each shot and the target collected after each set of ten shots (this data is available in APPENDIX D and E). After each ten shot group the rifle was removed from the shooting rest and the barrel was cleaned with a barrel snake.

Between sets, the barrel was given adequate time to cool. Daily testing ceased once the barrel became heat soaked and would not cool within a reasonable amount of time. This was to ensure that permanent damage did not occur to the rifle and that barrel temperatures remained controlled.

3.5.2 Shooting at Fiocchi. The second set of testing was performed at the Fiocchi of America facility in Ozark, Missouri. Testing there was performed in two segments with the .223 caliber being tested in May, 2014 and the .308 caliber being tested in October, 2014. Fiocchi's indoor range consists of two rooms. The first room, or recording room, contains the bench rifle (Figure 3.25) which fires through a portal in the wall leading to the second room, the range (Figure 3.27). The bench rifle has removable barrels that are thick walled so that a high volume of testing can be done at one time (APPENDIX J - Equipment). A PVC pipe surrounds the barrel and tunnels through the wall into the range. This is to reduce noise and flash in the recording room. The bench rifle contains a piezoelectric transducer connected to a desktop computer that records the chamber pressure.

Figure 3.25. Bench rifle setup in recording room at Fiocchi of America.

The range contains two velocity screens that also connect to the computer and record the bullet’s velocity (Figure 3.26).

Figure 3.26. Velocity screens in range room at Fiocchi of America.

Figure 3.27. Second velocity screen and down range view in range room at Fiocchi of America.

Progen 2K10 software was used to record and compile the data for both velocity and pressure for each flash hole orientation (See APPENDIX H and I for the Fiocchi data).

Each set of ammunition was slowly rotated end over end once prior to shooting to settle the powder uniformly (Figure 3.28). Cartridges were loaded in their desired orientation into the back of the bench rifle (Figure 3.29, Figure 3.30, and Figure 3.31). A lever then locked a piston in place behind the cartridge, securing the cartridge in the chamber (Figure 3.32 and Figure 3.33). The firing pin was then put into position through the piston and triggered. A file was saved and printed following each firing set.

Figure 3.28. .308 cartridges sandwiched in ammo wells so they could be rotated.

Figure 3.29. Empty bench rifle chamber, top view.

Figure 3.30. .308 cartridge partially loaded into bench rifle chamber, top view.

Figure 3.31. .308 cartridge loaded into bench rifle chamber, back view. The firing pin can be seen in the foreground standing up straight.

Figure 3.32. Closed chamber with firing pin in place, ready to fire, top view.

Figure 3.33. Firing pin folded up into place, ready to fire, back view.

The .223 ammunition was fired in sets of ten. The bench rifle had a pull cord trigger for these tests. The .308 ammunition was fired in twenty shot sets. The bench rifle had been updated to an electronic triggering system for the .308 cartridge testing. This allowed for the exact triggering moment to be recorded by the software (Figure 3.34, Figure 3.35, and Figure 3.36).

Figure 3.34. Progen 2K10 software ready for data acquisition.

Figure 3.35. Progen 2K10 software shot data recording.

Figure 3.36. Progen 2K10 software read out of pressure curve following a shot.

3.6 DATA ANALYSIS

Once all the data was acquired it was ready to be worked into useable information. Velocity and pressure data had outliers removed in order to clean it up. The data was then normalized using the centered 2mm data as a control value. Grouping sizes from the target data were measured using On Target shooting software.

3.6.1 Outlier Removal. Due to the volume of testing that took place for the velocity and pressure measurements, outliers occurred in the data. Outliers are data points that do not properly represent the data as a whole as they are either unreasonably high or low values. There can be several causes for outliers, including equipment malfunction, misreads, and human error causing the procedure to not be followed properly. Outliers were determined in this research using the Interquartile Range (IQR) method. Each data set representing a specific flash hole diameter and location was individually subjected to this method of outlier removal.

3.6.1.1 Interquartile Range Method. The IQR method is used to identify outliers. Using Microsoft Excel the individual data sets were analyzed. Using a sample data set (Table 3.3), the IQR method is demonstrated below.

1. Sample Velocity Data Set.

Table 3.3. Sample velocity data with outlier detection.

Velocity (fps)	Q1	Q3	IQR	Outlier?
2805	2806.2	2819.1	12.9	no
2815.8				no
2812.9				no
2828				no
2814.6				no
2817.2				no
2784.4				outlier
2817.6				no
2809.9				no
2778				outlier
2821.8				no
2820.6				no
2804.8				no
2806.6				no
2811.9				no
2779.5				outlier
2834.9				no
2818.6				no
2811.7				no
2828.9				no

2. Find first and third quartile

The first quartile (Q1) is the 25th percentile value in a ranked set of values separating the bottom 25% from the top 75%. The third quartile (Q3) is the 75th percentile value in a ranked set of values separating the top 25% from the bottom 75%. These calculations were determined in Excel using the QUARTILE.INC function. This function determines the specified quartile range for a highlighted set of data.

QUARTILE.INC(array,quartile)

The array is the data set being analyzed (column 1 in Table#) and the quartile is 1 for calculating the Q1 (column 2 in Table #) and 3 for calculating Q3 (column 3 in Table #).

3. Find IQR

The IQR is simply the difference between Q3 and Q1 (column 4 in Table 3.3).

4. Determine outliers

To determine if a value is an outlier it either had to be greater than Q3+1.5*IQR or less than Q1-1.5*IQR. Using and IF and OR function in Excel, outliers were found (column 5 in Table#).

```
=IF(OR(E2<Q1-1.5*IQR,E2>Q3+1.5*IQR),"outlier","no")
```

3.6.2 Target Measurement. Group sizes were calculated using On Target shooting software. Each target was scanned into the program to be analyzed. The caliber, hole size, and distance from target were specified for each target. The target was calibrated in the software to identify a distance scale (there is 1 inch spacing between the concentric rings on the target). Each hole was highlighted allowing the software to calculate group size, average to center, and minute of angle (MOA) values (Figure 3.37).

Figure 3.37. Scanned target for .308 Winchester 1.4mm diameter, centered flash hole 10-shot group. Bullet holes were manually identified and range, caliber, and target size data were inputted. Software calculated group sizes from these inputs.

The average to center value was used as the representative for precision in this research. It is the average of the distances between the group center and each shot making up said group. Average to center measurement was used as it includes every shot in the group but are more accommodating of outlying shots than the max spread measurement (center-to-center measurement of the two furthest bullet holes). For example in Figure

3.37, the max spread is quite large as there is one outlying bullet hole. The average to center measurement takes into account that the other nine holes in the shot group are grouped tighter to one another demonstrating better precision than the max spread value implies.

3.6.3 Data Normalization. Normalization is the process of adjusting values to a common scale. The velocity and pressure data was normalized in order to create and compare useful results. The data was normalized to the centered 2mm diameter flash hole data. The centered 2mm data was chosen as a control for normalization as it is the current standard being used by Fiocchi. The results of this normalization can be seen in section 4. Results, but how the data was normalized is described below.

The normalization process used with this research is demonstrated below using an example data set (Table 3.4). The data set below is a set of 2mm flash hole velocity readings that are being normalized to the centered, 2mm diameter flash hole (control) set of values.

1. Raw Dataset

Table 3.4. Sample data for normalization calculation.

1.4mm (fps)	**Control – 2mm (fps)**	**2.4mm (fps)**	**2.8mm (fps)**	**3.0mm (fps)**
2805	2824.3	2830.5	2857.9	2856.2
2815.8	2841.6	2811.9	2852.1	2845.8
2812.9	2843	2801.7	2855	2836.2
2828	2846.3	2826	2850.1	2818.1
2814.6	2828.9	2801	2851.8	2815
2817.2	2825.8	2841.1	2841.3	2830.4
2817.6	2837.7	2802.1	2853.3	2843.2
2809.9	2821.4	2826.3	2815.9	2834.7
2821.8	2831.3	2850.8	2850.9	2833
2820.6	2831.7	2827.3	2837.3	2837.5
2804.8	2830.8	2820.2	2850.3	2842
2806.6	2833.1	2811.2	2820.3	2822.4
2811.9	2809.6	2799.7	2849.8	2838.5
2834.9	2804.5	2827.3	2838.5	2833.3
2818.6	2852.1	2789.8	2820.6	2837.6
2811.7	2817.3	2843.8	2841.1	2832.1
2828.9	2832.8	2822	2871.2	
	2817.5	2824.9	2831.2	
		2837.4	2845.2	
		2800.8		

2. Average and Standard Deviation Calculations

The averages and standard deviations of each column in Table 3.4 were calculated using the Excel functions,

=average(array) and

=stdev.s(array) , respectively

Table 3.5 shows the calculation results for the sample data set.

Table 3.5. Average and standard deviation values for sample data set in Table 3.4. The Control-2mm average is highlighted.

AVERAGE (fps)	2816.518	2829.428	2819.79	2843.884	2834.75
SD (fps)	8.468857	12.46873	16.91287	14.10253	10.2922

3. Normalization to the Control's Average

Each value in columns of Table 3.4 was then divided by the average of column 2 (the control's average highlighted in Table 3.5). This new value was then multiplied by 100 to give a percent representation of the control average (Table 3.6).

Table 3.6. Each velocity value's percent representation of the control average.

1.4mm	**Control – 2mm**	**2.4mm**	**2.8mm**	**3.0mm**
99.13665	99.81877	100.0379	101.0063	100.9462
99.51836	100.4302	99.38052	100.8013	100.5786
99.41586	100.4797	99.02002	100.9038	100.2393
99.94954	100.5963	99.87885	100.7306	99.59964
99.47594	99.98135	98.99528	100.7907	99.49008
99.56784	99.87178	100.4125	100.4196	100.0344
99.58197	100.2924	99.03416	100.8437	100.4867
99.30983	99.71628	99.88946	99.52189	100.1863
99.73041	100.0662	100.7554	100.7589	100.1263
99.688	100.0803	99.9248	100.2782	100.2853
99.12958	100.0485	99.67386	100.7377	100.4443
99.1932	100.1298	99.35578	99.6774	99.75162
99.38052	99.29923	98.94934	100.72	100.3206
100.1934	99.11898	99.9248	100.3206	100.1369
99.61732	100.8013	98.59944	99.688	100.2888
99.37345	99.57137	100.508	100.4125	100.0944
99.98135	100.1192	99.73748	101.4763	
	99.57844	99.83998	100.0626	
		100.2818	100.5574	
		98.98821		

4. Normalized Averages

The averages of each column in the new set of data are then taken (Table 3.7) and plotted on a bar graph to compare against the control (Figure 3.38).

Table 3.7. Average and standard deviation calculations for percent representations in Table 5.

AVERAGE	99.54372	100	99.65937	100.5109	100.1881
SD	0.299313	0.44068	0.597749	0.498423	0.363755

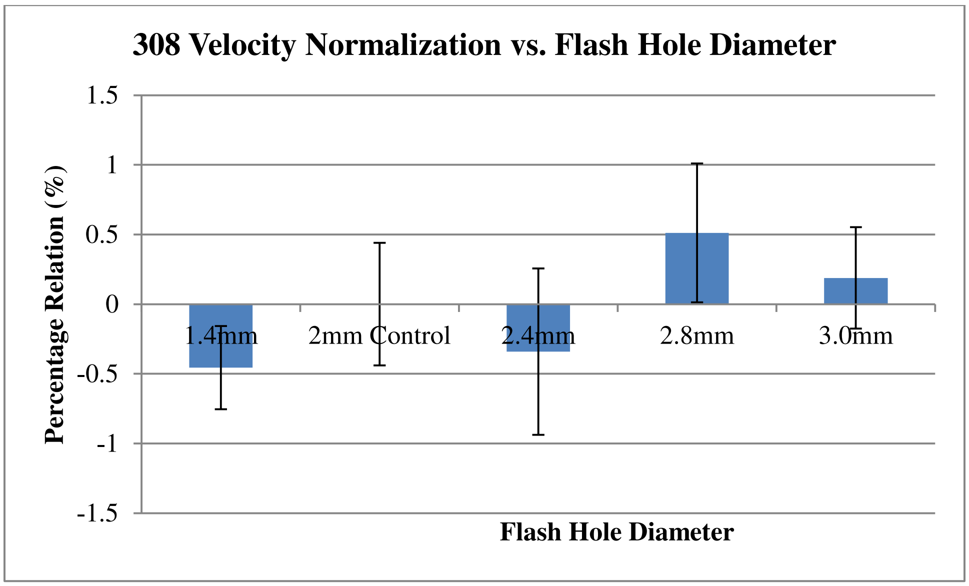

Figure 3.38. Relationship of sample velocity and flash hole diameter normalized against the 2mm diameter control.

The error bars in Figure 3.38 are the standard deviation values from Table 3.7 for each data column.

The procedures described here were used to conduct this research and acquire the data. By controlling the flash hole's diameter and location as well as loading each cartridge identically, it was possible to obtain comparable data. Testing was performed to obtain velocity, pressure, and group size measurements to make up the various datasets of each cartridges flash hole specifications. Useable data was acquired by removing outliers and that data was then transformed into understandable results through normalization. These results can be seen in the next section.

4 RESULTS

This section discusses the compilation of the data into useful results. It highlights the discovered trends seen in the measured velocities, pressures, and group sizes. By normalizing the data to the control (2mm diameter, centered flash hole), the influences of uncontrollable factors were removed from the data values. This gives a more detailed representation of how the flash hole's size, offset, and orientation affected cartridge performance.

Each column in the following bar graphs represents the average value of that column's data as a comparative percentage. The error bars are one standard deviation above and below that average point.

Also, the Fiocchi velocity and pressure data were measured simultaneously from the same set of cartridges for each flash hole variation. This is seen in the following bar graphs as the velocity and pressure plots follow similar trends.

It is important to note the y-axis scales for each plot. Each plot's control value is set at the 0% mark. Any deviation from that control is depicted as a positive or negative percentage difference from that control. Each plot's y-axis scale was determined to visibly enhance the slight differences in the plotted columns and is not intended to skew any interpretation of the results.

The effect of flash hole diameter, offset, and orientation are individually presented in this section. The results for the .223 Remington and .308 Winchester calibers are plotted separately for each set of measurements. The results are described as:

- Range Velocity: the velocity measurements from testing at the private range outside of Rolla. Plotted y-axis scale of -5% to +3.5%.
- Fiocchi Velocity: the velocity measurements from testing at Fiocchi of America. Plotted y-axis scale of -2.5% to +2.5%.
- Fiocchi Pressure: the pressure measurements simultaneously taken with the Fiocchi Velocity measurements during testing at Fiocchi of America. Plotted y-axis scale of -8% to +8%.
- Range Precision: the average-to-center group size measurements taken from 10-shot targets simultaneously taken with the Range Velocity measurements during testing at the private range near Rolla. Plotted y-axis scale of -60% to +50%.

The effect of flash hole deviations for each of these result sets is discussed as follows.

4.1 FLASH HOLE DIAMETER

One of the primary purposes of this research was to determine if the flash hole diameter of a rifle cartridge affected that cartridge’s performance. Five different flash hole diameters were tested for both the Remington .223 and Winchester .308 calibers. These diameters were: 1.4mm, 2.0mm (the Fiocchi standard for .223 and .308 calibers), 2.4mm, 2.8mm, and 3.0mm. Performance of each cartridge was quantified by measuring muzzle velocity (at the private Rolla range and at Fiocchi), chamber pressure (at Fiocchi), and precision (at the Rolla range). These performance factors are represented individually in the following plots. The horizontal axis for each plot represents the five flash hole diameters. The data for these diameters was normalized to the 2mm diameter flash hole control. The normalized values for each flash hole diameter are represented as a percentage so that they can be compared to the 2mm diameter control (0%).

4.1.1 Normalized Diameter Plots. The first set of charts represents the normalized velocity data from the private range testing (range velocity) plotted against varying flash hole diameters. The control column in each chart represents the 2mm diameter, centered flash hole rifle velocities. Each other column represents the centered flash hole data for the various flash hole diameters. Figure 4.1 depicts the .223 Remington data while Figure 4.2 represents the .308 Winchester data. These plots show no diameter deviation from the 2mm control by more than ±3%.

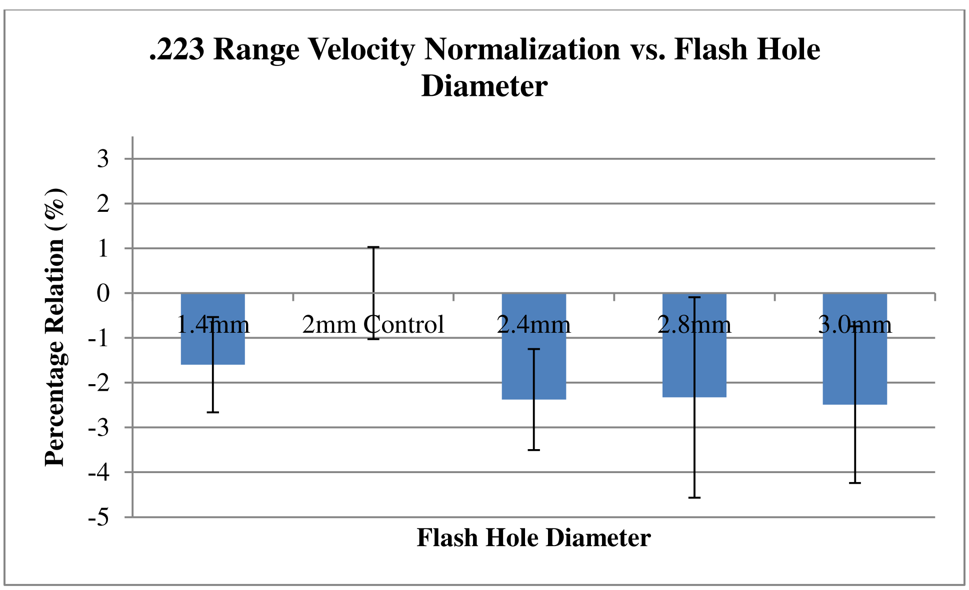

Figure 4.1. Normalized relationship of .223 Remington range velocities and flash hole diameter. The data is normalized to the 2mm diameter, centered flash hole control data.

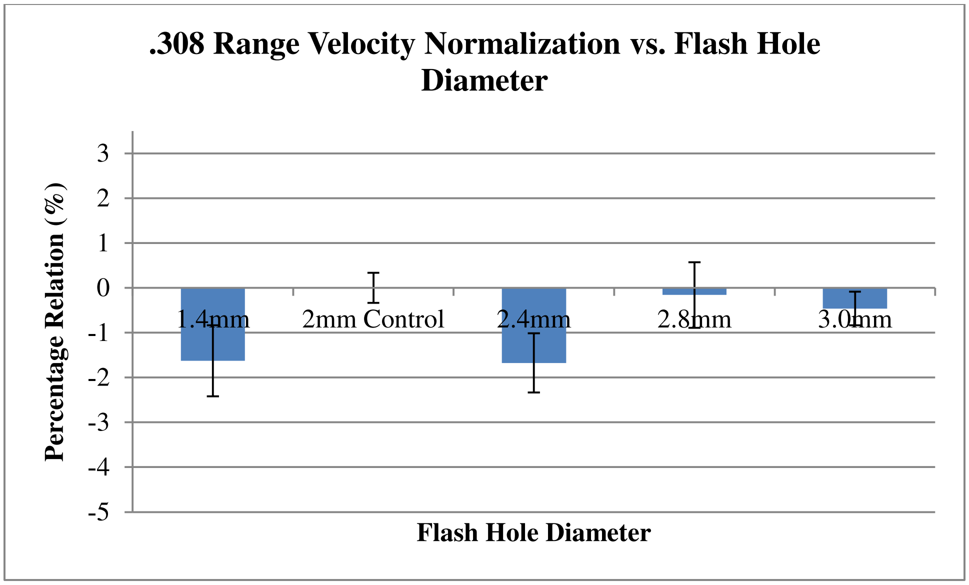

Figure 4.2. Normalized relationship of .308 Winchester range velocities and flash hole diameter. The data is normalized to the 2mm diameter, centered flash hole control data.

The second set of charts is the normalized plots of the muzzle velocities measured at the Fiocchi of America facility (Fiocchi velocity). Once again the data is normalized to the 2mm diameter, centered flash hole control. The other four columns are normalized representations of the centered flash hole velocities for their respective diameter. The .223 Remington values are displayed in Figure 4.3, whereas Figure 4.4 shows the .308 Winchester velocity results.

There is again minimal variation in these results. No variations between the flash hole diameters and the control exceed ±2%.

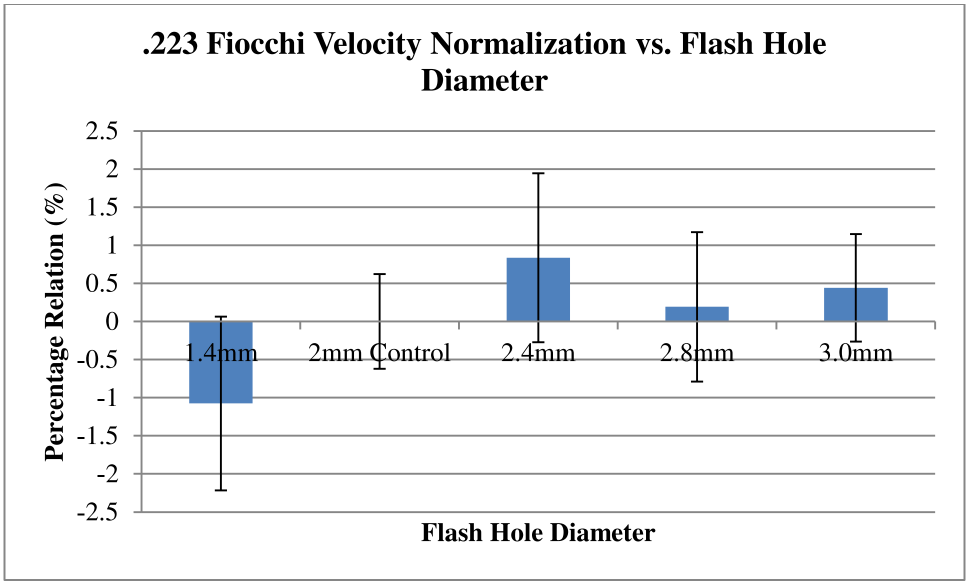

Figure 4.3. Normalized relationship of .223 Remington Fiocchi velocities and flash hole diameter. The data is normalized to the 2mm diameter, centered flash hole control data.

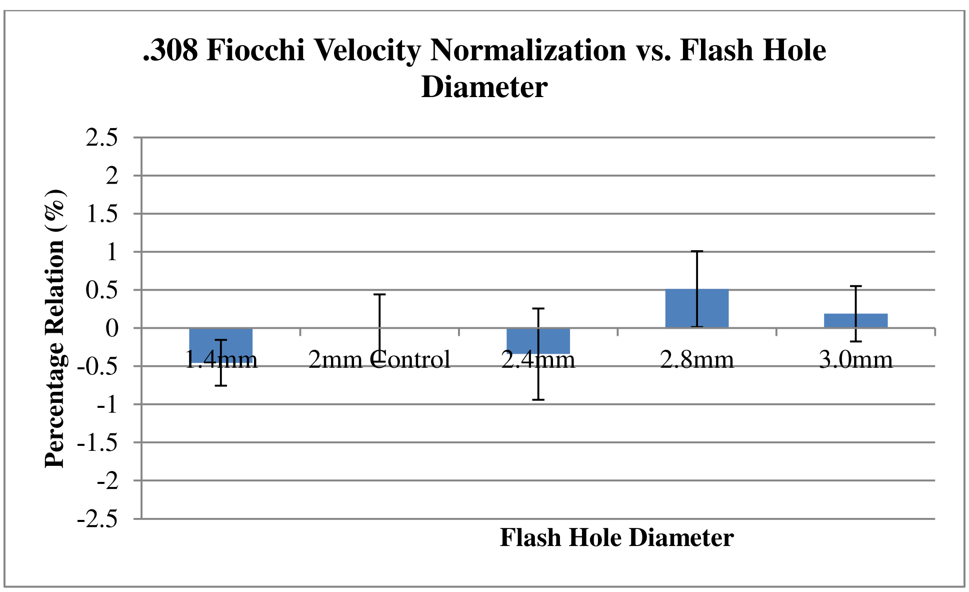

Figure 4.4. Normalized relationship of .308 Winchester Fiocchi velocities and flash hole diameter. The data is normalized to the 2mm diameter, centered flash hole control data.

Next are the normalized plots representing the influence of flash hole diameter on chamber pressure (also measured at Fiocchi). Same as the previous diameter plots, the control column is the 2mm diameter, centered flash hole data. Each diameter is normalized to the control data. Figure 4.5 and Figure 4.6 represent the .223 Remington and .308 Winchester pressure results, respectively. Any variations are within ±4% of the control for both calibers. Pressure seems to climb to a peak and then fall as flash hole diameter increases in each caliber. This peak occurs at the 2.4mm flash hole on the .223 Remington plot and at the 2.8mm flash hole on the .308 Winchester plot.

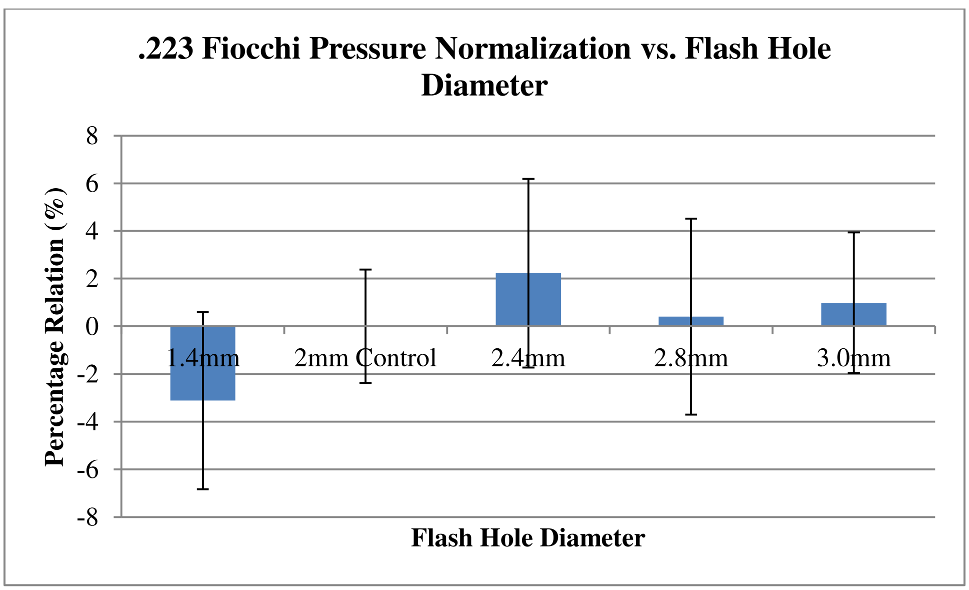

Figure 4.5. Normalized relationship of .223 Remington Fiocchi pressures and flash hole diameter. The data is normalized to the 2mm diameter, centered flash hole control data.

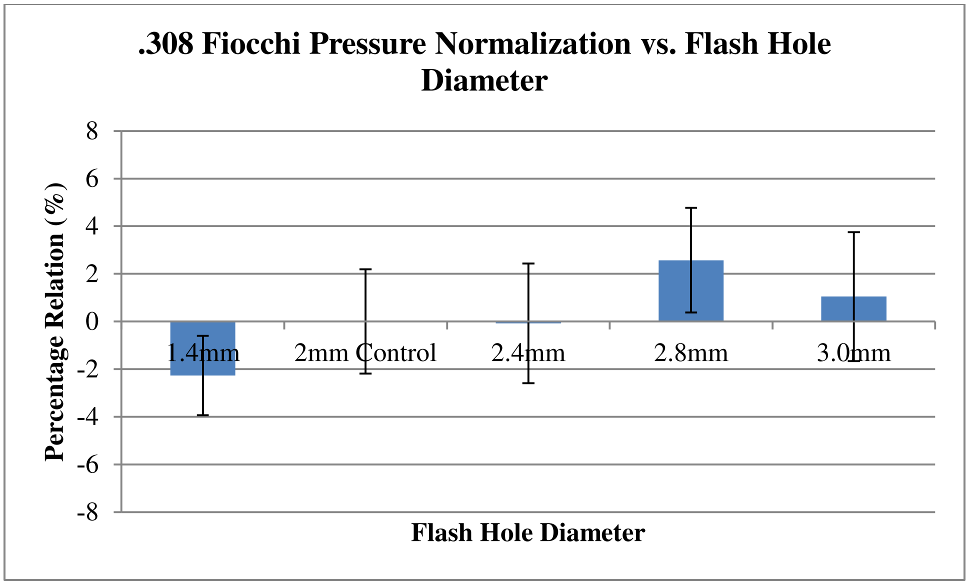

Figure 4.6. Normalized relationship of .308 Winchester Fiocchi pressures and flash hole diameter. The data is normalized to the 2mm diameter, centered flash hole control data.

The final set of diameter plots represent the normalized group sizes. This data is the average to center values for each flash hole diameter's shot group. Positive average to center values represent wider group sizes (worse precision) and negative values represent tighter groupings (better precision). The data is normalized to the 2mm diameter flash hole control. This control encompasses all of the 2mm data (every offset and orientation). The other diameter columns also include grouping data for every flash hole offset and orientation for that diameter. This allows for a larger set of data to be analyzed since there is only one centered precision value for each flash hole diameter. The following figures (Figure 4.7 and Figure 4.8) represent the precision data for the two tested calibers. Note the significant y-axis scale change from the previous plots.

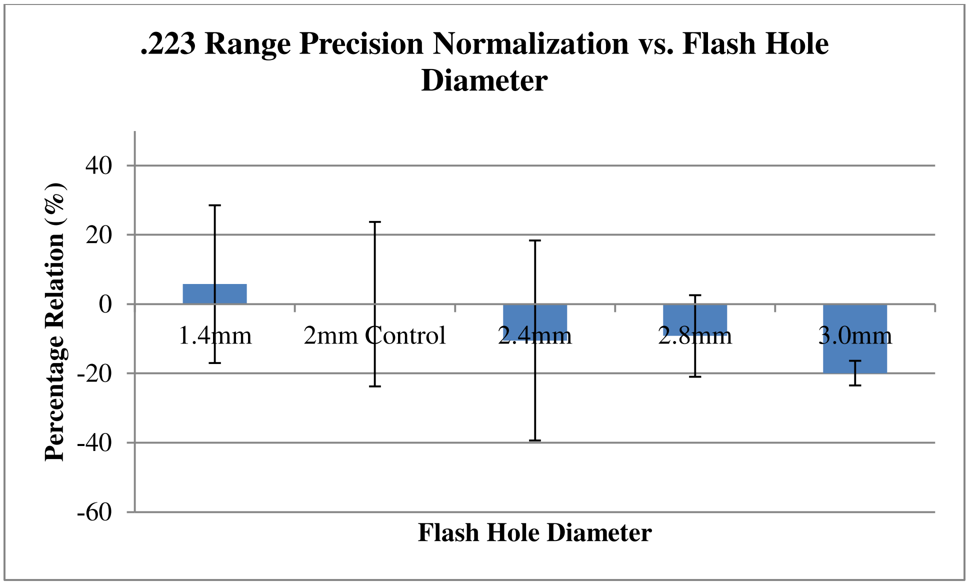

Figure 4.7. Normalized relationship of .223 Remington range precision and flash hole diameter. The data is normalized to the 2mm diameter flash hole control data.

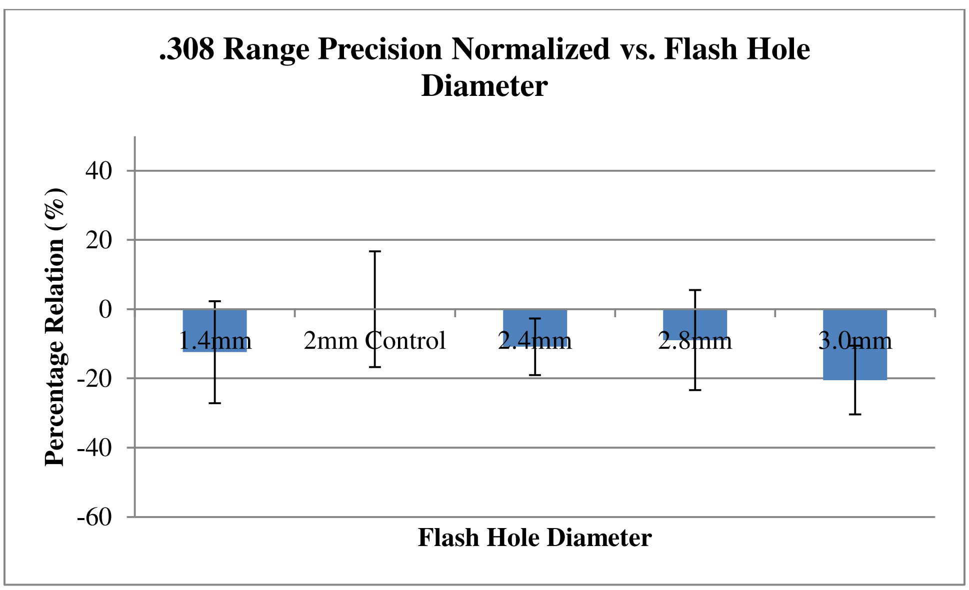

Figure 4.8. Normalized relationship of .308 Winchester range precision and flash hole diameter. The data is normalized to the 2mm diameter flash hole control data.

It is shown that as flash hole diameter increases above 2.0mm, there is a decrease in group size (i.e. an improvement in precision). Both calibers have the 3.0mm flash hole having the best precision amongst the 4 other flash hole diameters tested. The 3.0mm flash hole values for each caliber also have relatively small standard deviations compared to the other diameters. This is interesting because the standard deviations were calculated from the same number of shots for each flash hole diameter. Therefore the 3mm flash hole values are more consistent than the other flash hole diameters. This result is analyzed further in the following section.

4.2 FLASH HOLE OFFSET

Another factor investigated through this research was the affect that an off-centered flash hole has on cartridge performance. Specifically looking at the degree to which the flash hole is off center, muzzle velocity, chamber pressure, and precision data were measured and normalized. In addition to the centered flash holes, two offsets were investigated. These offsets were 0.5mm and 1.0mm off center. Once again, the normalizing control was the 2mm diameter, centered flash hole. The following plots exhibit the influence that an off center flash hole has on this research's various performance elements.

4.2.1 Normalized Offset Plots. The first chart pair (Figure 4.9 and Figure 4.10) display the normalized rifle velocity data for .223 Remington and .308 Winchester calibers. The 0.5mm column incorporates the 2mm diameter, 0.5mm offset velocities for all of the orientations (up, side, and down). The 1mm offset column was created the same way.

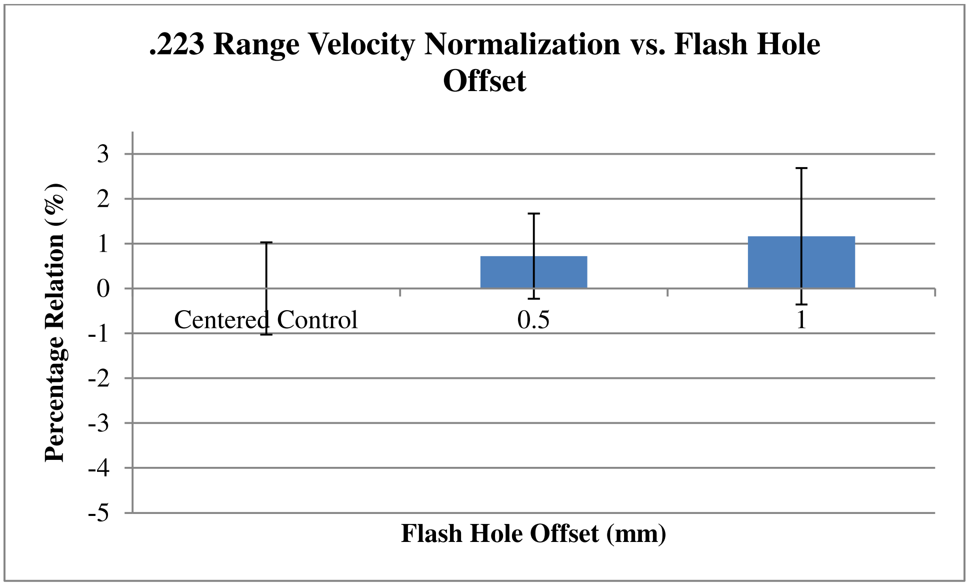

Figure 4.9. Normalized relationship of .223 Remington range velocities and flash hole offset. The data is normalized to the 2mm diameter, centered flash hole control data.

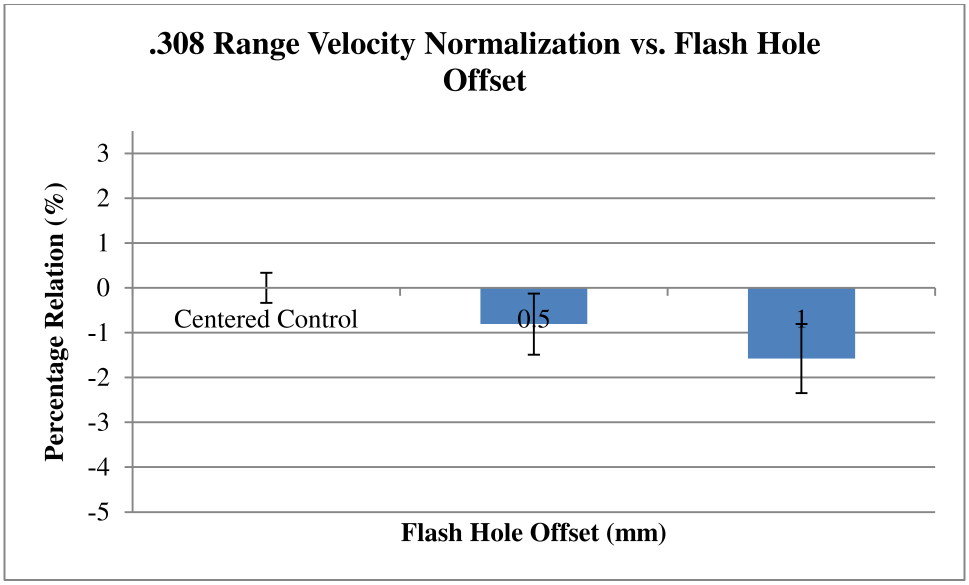

Figure 4.10. Normalized relationship of .308 Winchester range velocities and flash hole offset. The data is normalized to the 2mm diameter, centered flash hole control data.

Even though the column heights vary and seem to follow slight opposing trends between the two calibers (.223 range velocities increase as offset increases, while .308 range velocities decrease), neither plot shows a variation from the control greater than ±2%.

The lack of a trend depicting influence of offset is redisplayed in the second set of velocity charts. Figure 4.11 and Figure 4.12 portray the velocity data from Fiocchi. This data was normalized and plotted the same way as in Figure 4.9 and Figure 4.10, respectively. Variation from the normalized control is even smaller in this velocity set, with offsets being within ±1% of the control. It is to be noted that the .308 velocities once again decrease as offset increases, similar to the range velocity data.

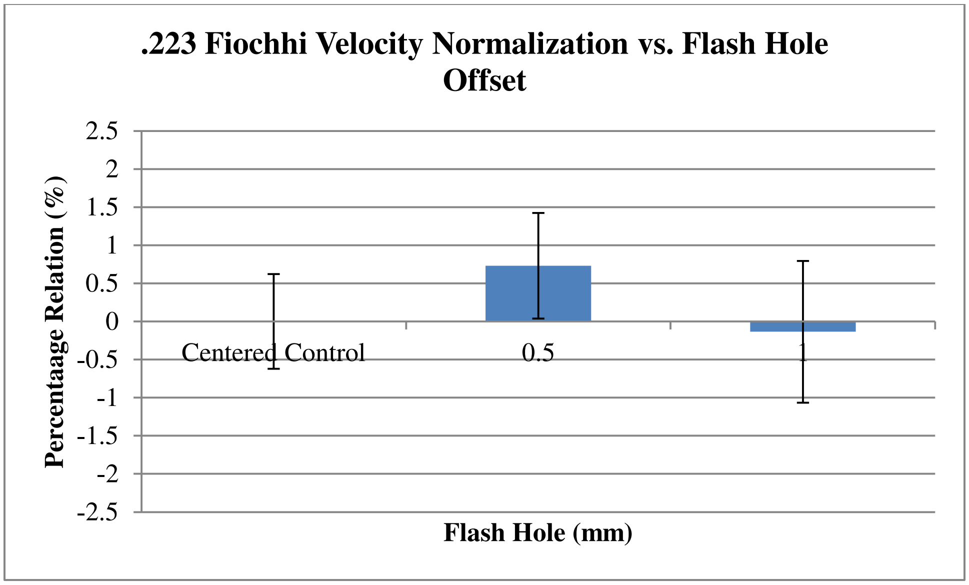

Figure 4.11. Normalized relationship of .223 Remington Fiocchi velocities and flash hole offset. The data is normalized to the 2mm diameter, centered flash hole control data.

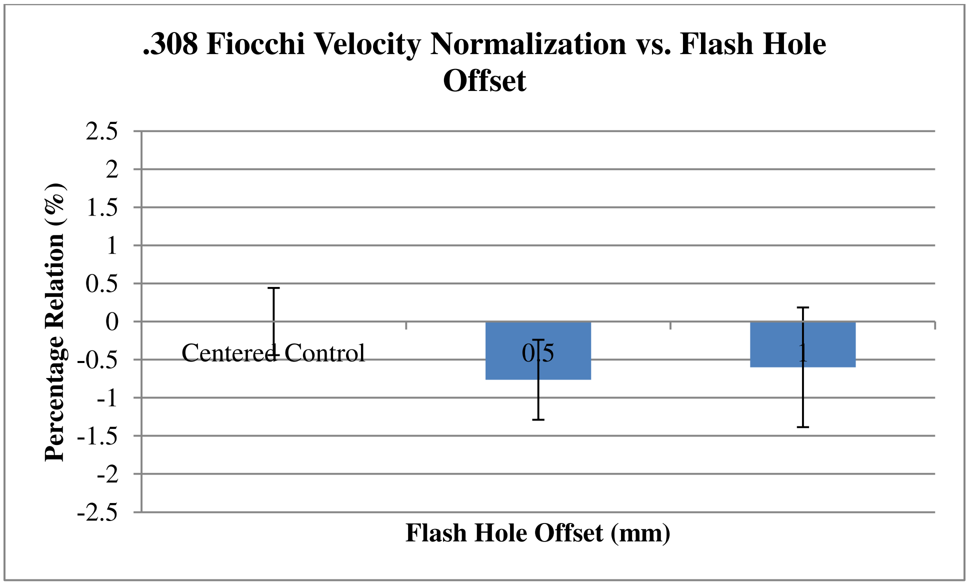

Figure 4.12. Normalized relationship of .308 Winchester Fiocchi velocities and flash hole offset. The data is normalized to the 2mm diameter, centered flash hole control data.

The next set of plots depicts the effect an offset flash hole has on pressure. The camber pressure data was again normalized against the 2mm diameter, centered flash hole values. Figure 4.13 displays the .223 Remington and Figure 4.14 displays the .308 Winchester pressure results. Each offset column value is within ±3% of the control value.

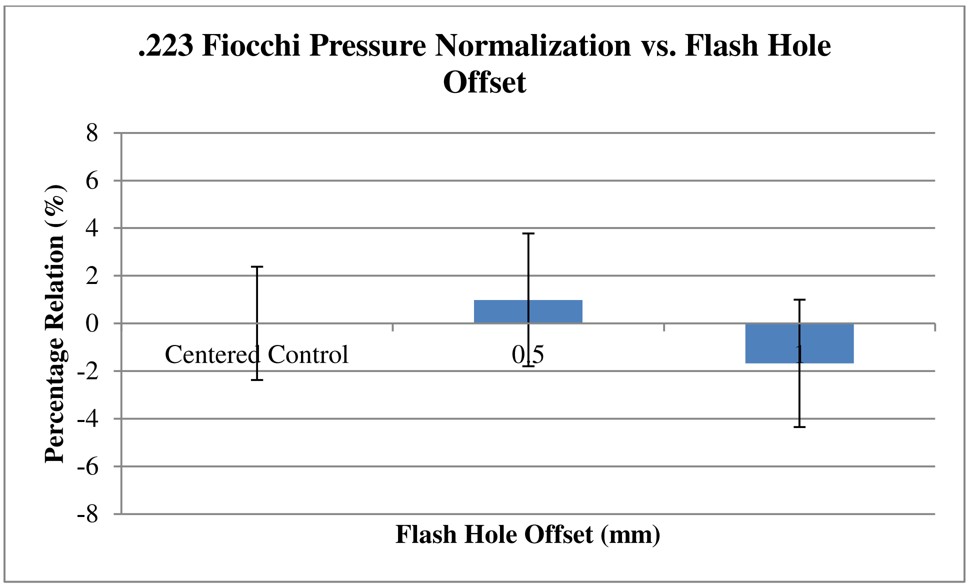

Figure 4.13. Normalized relationship of .223 Remington Fiocchi pressures and flash hole offset. The data is normalized to the 2mm diameter, centered flash hole control data.

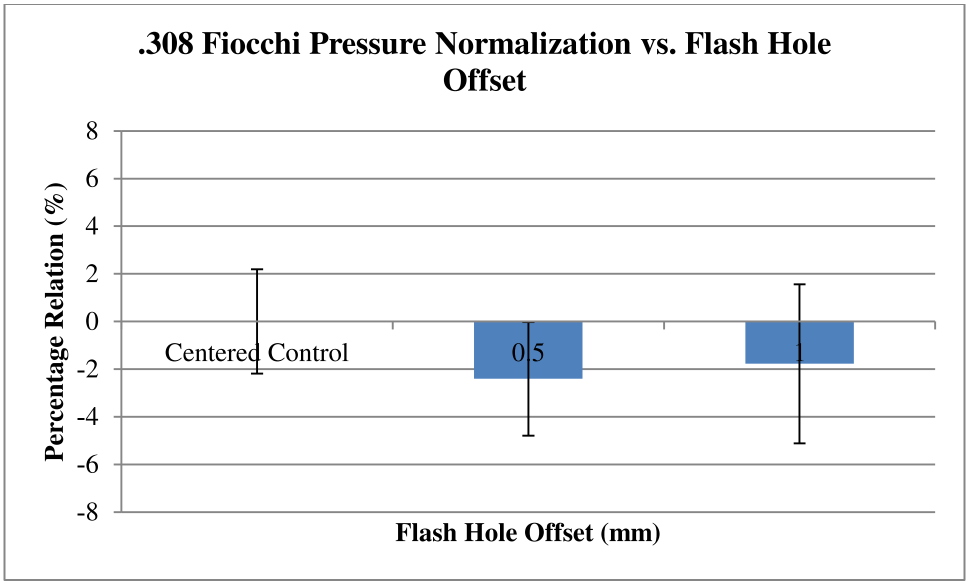

Figure 4.14. Normalized relationship of .308 Winchester Fiocchi pressures and flash hole offset. The data is normalized to the 2mm diameter, centered flash hole control data.

The relation between precision (average to center) and the degree of flash hole offset is described below in Figure 4.15 and Figure 4.16. This data was normalized to the 2mm diameter, centered flash hole data. Only one 2mm diameter, centered flash hole shot group was produced, resulting in only one precision measurement for the control. This is why the control column below does not have error bars. All three orientation's data of each offset (0.5mm and 1.0mm) were used in these figures. Once again there is a much greater difference (up to 20%) between the offset columns and the control column compared to velocity and pressure plots. That being said, the error range of each offset column is also quite large, allowing the variations to fall within one standard deviation of the control.

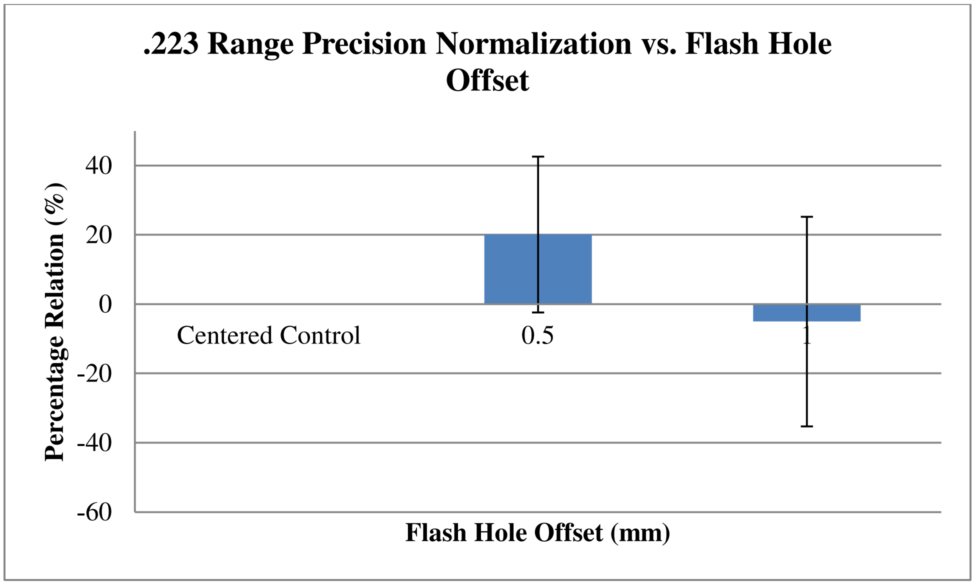

Figure 4.15. Normalized relationship of .223 Remington range precision and flash hole offset. The data is normalized to the 2mm diameter, centered flash hole control data.

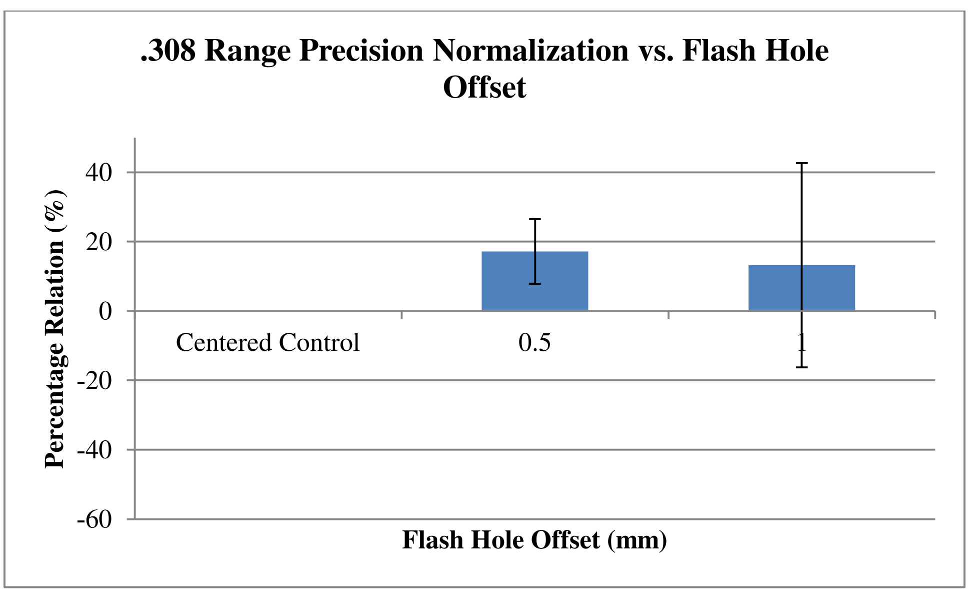

Figure 4.16. Normalized relationship of .308 Winchester range presicion and flash hole offset. The data is normalized to the 2mm diameter, centered flash hole control data.

The standard deviation spread seen in the error bars on all of the offset plots increased as offset increased. This suggests that as offset increases, a greater likelihood for pressure variations occurs. This is discussed further in the next section.

4.3 FLASH HOLE ORIENTATION

The final factor investigated was the orientation of the offset flash hole and whether it affected the cartridge's performance. The following plots present the normalized comparison between the 2mm diameter, centered flash hole control and flash holes offset to the up (12 O'clock), side (3 O'clock), and down (6 O'clock) orientations. Each orientation's data included both degrees of offset (0.5mm and 1.0mm).

4.3.1 Normalized Orientation Plots. The relation between the Rolla range velocities and flash hole orientation are presented for the .223 Remington and .308 Winchester calibers in Figure 4.17 and Figure 4.18, respectively.

Once again the range velocities for the .223 and .308 calibers have opposing trends, similar to the range velocity vs. offset plots in Figure 4.9 and Figure 4.10. Variation between the control column and the three offset orientations is less than ±2% in all cases.

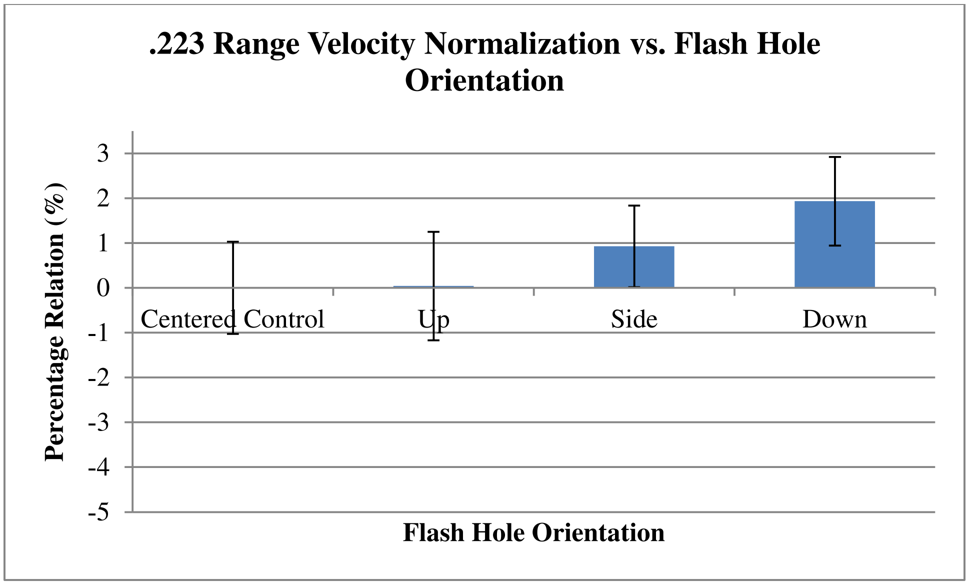

Figure 4.17. Normalized relationship of .223 Remington range velocities and flash hole orientation. The data is normalized to the 2mm diameter, centered flash hole control data.

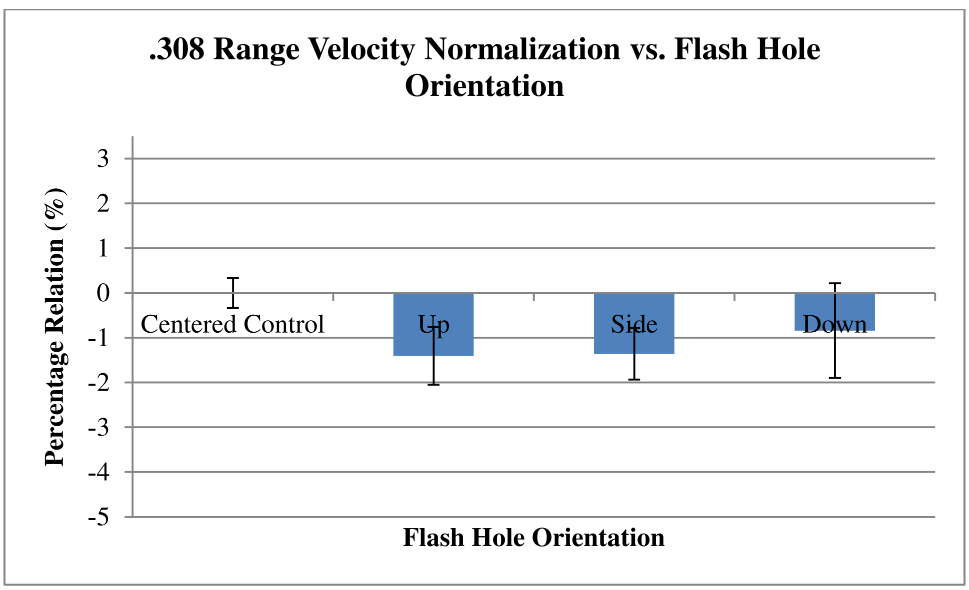

Figure 4.18. Normalized relationship of .308 Winchester range velocities and flash hole orientation. The data is normalized to the 2mm diameter, centered flash hole control data.

The normalized Fiocchi of America velocities are plotted against flash hole orientation below in Figure 4.19 and Figure 4.20. Minimal variation also appears for the velocities gathered at Fiocchi of America. These offset orientation columns deviate from the control by less than ±1% in all cases.

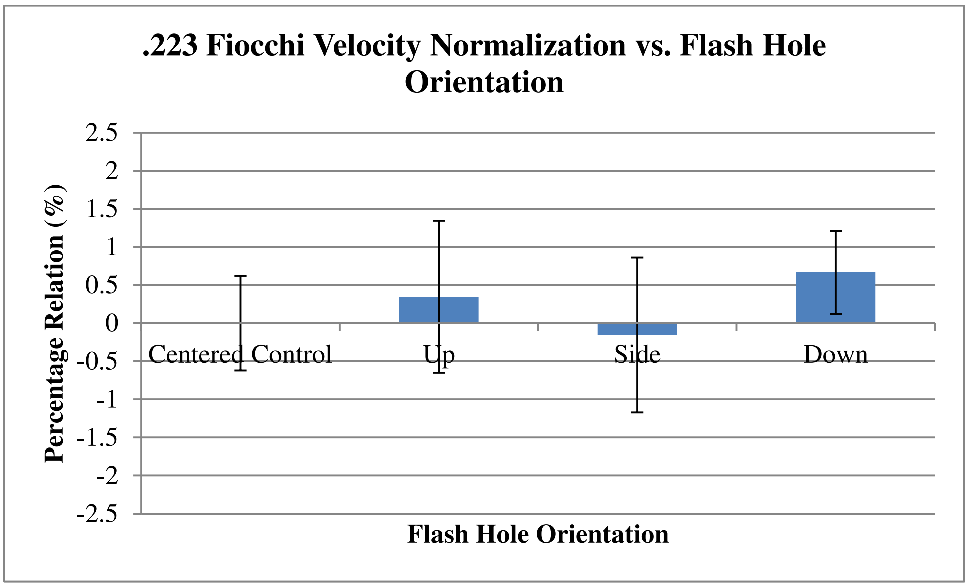

Figure 4.19. Normalized relationship of .223 Remington Fiocchi velocities and flash hole orientation. The data is normalized to the 2mm diameter, centered flash hole control data.

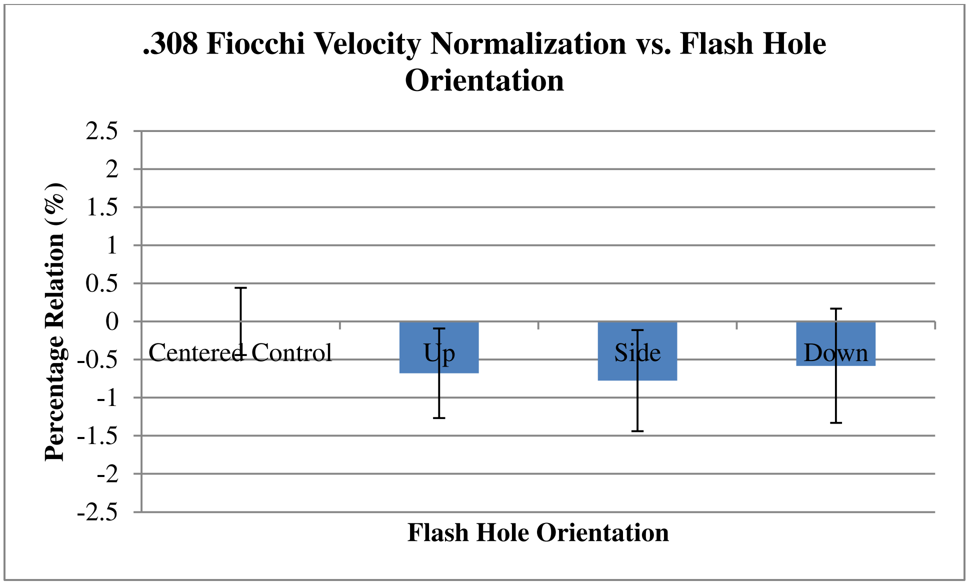

Figure 4.20. Normalized relationship of .308 Winchester Fiocchi velocities and flash hole orientation. The data is normalized to the 2mm diameter, centered flash hole control data.

The Fiocchi velocity plots above appear similar but tighter to the control than the range velocities in Figure 4.17 and Figure 4.18.

Chamber pressures normalized to the 2mm diameter, centered flash hole pressure data for each flash hole orientation are plotted in Figure 4.21 and Figure 4.22 for each the two tested calibers. The chamber pressure plots follow the same trends as the coinciding Fiocchi velocity plots. Offset orientation columns are within ±3% of the control, with error ranges spanning upwards of ±2% in each direction.

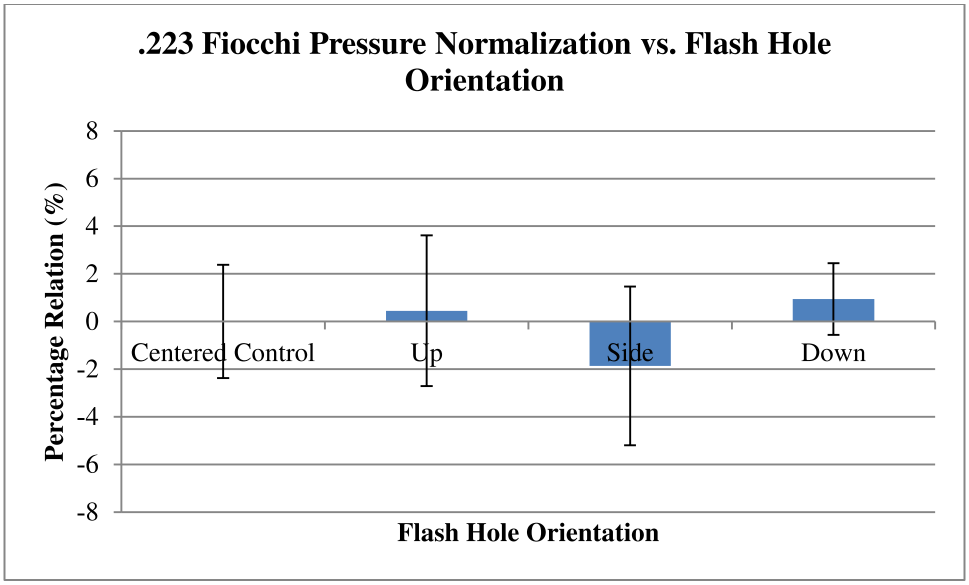

Figure 4.21. Normalized relationship of .223 Remington Fiocchi pressures and flash hole orientation. The data is normalized to the 2mm diameter, centered flash hole control data.

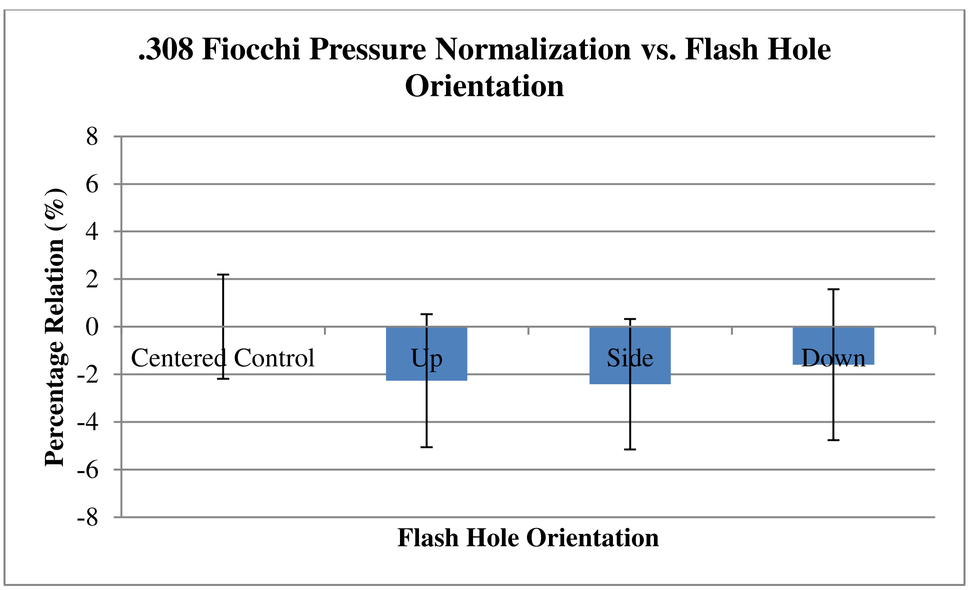

Figure 4.22. Normalized relationship of .308 Winchester Fiocchi pressures and flash hole orientation. The data is normalized to the 2mm diameter, centered flash hole control data.

Finally, range precision is plotted against flash hole orientation in Figure 4.23 and Figure 4.24.

The greatest variation caused by flash hole orientation is seen in the range precision analysis. Variations of nearly 30% compared to the control are seen in the plots below. The side orientation is consistently close (within 10%) to the control for each caliber whereas the up and down orientations have the greatest variations from the control. This is to be expected if the flash hole orientation effects are based on gravitational settling of the powder, since the side orientation would be in the same vertical location as the centered (control) flash hole. The down orientation gives consistently larger groups sizes (>20%) compared to the control. In the case of the .308 caliber, the error range is quite narrow. Therefore, the down orientation flash hole is seen to cause larger group sizes, particularly in larger calibers.

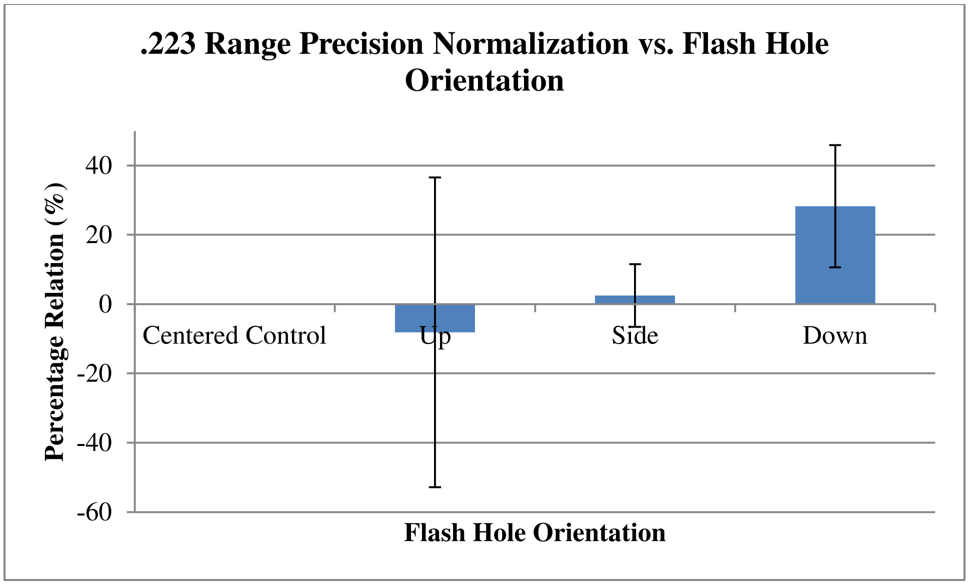

Figure 4.23. Normalized relationship of .223 Remington range precision and flash hole orientation. The data is normalized to the 2mm diameter, centered flash hole control grouping.

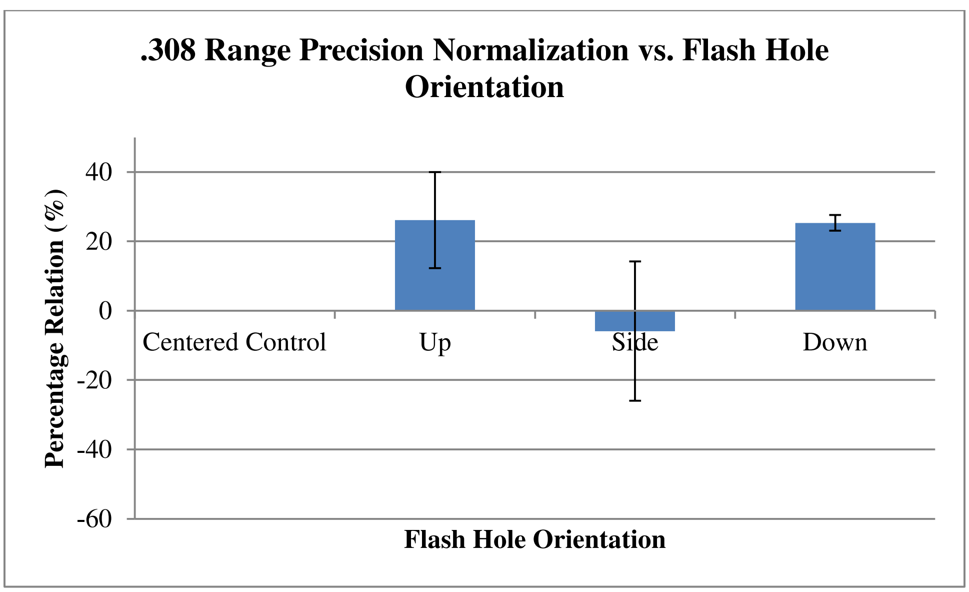

Figure 4.24. Normalized relationship of .308 Winchester range precision and flash hole orientation. The data is normalized to the 2mm diameter, centered flash hole control grouping.

5 DISCUSSIONS

The purpose of this research was to determine whether the diameter, offset, or orientation of a rifle cartridge's flash hole significantly influences the cartridge's muzzle velocity, chamber pressure, or precision. Effects that flash hole variations may have on cartridge performance could warrant changes to cartridge production by Fiocchi of America. Increasing the flash hole diameter will allow for larger punches to be used to create those flash holes. Larger punches are more durable and would require replacement less often. If cartridge performance remains constant regardless of flash hole diameter then these larger punches could be used. Flash hole offset and orientation were also investigated to determine whether the accuracy of the flash hole punch needed to be improved. By determining that flash hole offset or orientation affects cartridge performance, then case and punch vibration would need to be minimized so that the flash hole remained as centered as possible in each case. This section discusses what was learned from the testing in regards to the flash hole's influence on rifle cartridge performance. The researcher addresses the initial problems presented by Fiocchi of America and explains the various results and what conclusions they suggest. Potential future work is recommended to build on this research's results and further understand the physical components of ammunition and how those components affect cartridge performance.

5.1 FLASH HOLE DIAMETER EFFECT ON PERFORMANCE

The five different flash hole diameters tested were: 1.4mm, 2.0mm, 2.4mm, 2.8mm, and 3.0mm. These flash hole diameters were used to determine if flash hole diameter affected cartridge performance. Cartridge performance was determined by how well each flash hole diameter compared to the 2mm control flash hole diameter. Performance was measured in three different ways: muzzle velocity, chamber pressure, and precision.

Diameter had very little effect on muzzle velocity. None of the test diameters, for either the .223 or .308 caliber, exceeded 3% deviation from the 2mm diameter flash hole control for this performance variable (Table 5.1). The additional variables affecting the bullet once it separates from the case and travels down the barrel (i.e. barrel grooves, barrel length, etc.) may cause the diameter variations in the flash hole to be negligible.

Table 5.1. Deviation from control over measured performance factors as affected by flash hole diameter.

Performance Factor	Maximum deviation from control
Range Velocity	3%
Fiocchi Velocity	2%
Fiocchi Pressure	4%
Range Precision	20%

However, chamber pressure measured at Fiocchi showed a slight peak as flash hole diameter increased. For the .223 Remington caliber, pressure built as flash hole diameter increased until the 2.4mm diameter at which point pressure started to decrease again. This also occurred in the .308 Winchester data with pressure peaking at the 2.8mm flash hole diameter. This gives life to Lake's claim that some flash hole diameter between a large and small diameter, would provide the ideal ignition flame from the primer (Lake). The 2.4mm and 2.8mm diameter peaks seen in the .223 and .308 calibers, respectively, could be the ideal flash hole diameters for each caliber. Further research could be conducted to confirm these flash hole diameters provide optimal ignition from the primer.

A larger variation was discovered in the precision data, where deviations of 20% from the control were seen in both calibers. For most of the test flash hole diameters, the deviation from the control was well within the standard deviation of that data column. However, this was not the case with the 3mm flash hole diameter. For both .223 and .308 calibers, the 3mm flash hole diameter group size decreased by 20% when compared to the 2mm flash hole diameter control. This decrease was the greatest of all the other diameters and was accompanied with small standard deviations for the 3mm flash hole diameter values. Although there was a decrease in group size for flash hole diameters greater than 2mm, all but the 3mm diameter had large standard deviations. Further testing on the 3mm flash hole diameter would be required to confirm these findings.

These results suggest that flash hole diameter affects precision and chamber pressure more so than muzzle velocity. An ideal flash hole diameter may exist that provides optimal ignition resulting in slightly increased chamber pressures (up to 4%). Precision seemed to be improved by the 3mm flash hole, by upwards of 20%, with little range of error, suggesting that a larger flash hole can considerably improve shooting precision.

5.2 FLASH HOLE OFFSET EFFECTS

Along with centered flash holes, two degrees of offset flash holes were also tested. These offsets were 0.5mm from center and 1.0mm from center. By testing these two offsets in comparison to the centered flash hole data, it was determined whether off-centered flash holes affected cartridge performance, and if that effect was based on the magnitude of the offset.

Offset flash holes had a limited effect on muzzle velocity and chamber pressure. No deviation from the control greater than 3% was found, until the precision analysis (See Table 5.2). For the range measured data, the .223 Remington velocities increased slightly while the .308 Winchester velocities decreased slightly as offset increased. The .223 velocities were seen again to slightly decrease with offset increase in the Fiocchi measured velocities. Although the variation is quite small (1-2%, Table 5.2), a slight trend is visible between muzzle velocity and flash hole offset. Precision was again influenced the greatest by flash hole variation. The precision of offset flash holes was seen to vary by upwards of 20% from the centered flash hole control. However the .223 and .308 caliber data did not correlate with each other for these variations.

Table 5.2. Deviation from control over measured performance factors as affected by flash hole offset.

Performance Factor	**Maximum deviation from control**
Range Velocity	2%
Fiocchi Velocity	1%
Fiocchi Pressure	3%
Range Precision	20%

Furthermore, each plot (range velocity, Fiocchi velocity, Fiocchi pressure, and range precision) for both the .223 and .308 calibers displayed an increase in standard deviation (variations in data values) as the flash hole offset increased. Although on average offset flash holes may not significantly affect muzzle velocity, chamber pressure, or precision, as the offset increases (flash hole becomes further from center) a greater variation of values occurs.

Therefore, flash hole offset does affect consistency of muzzle velocity, chamber pressure, and precision. These variations are observed easiest with the precision results.

5.3 FLASH HOLE ORIENTATION EFFECTS

Orientation of the offset flash hole was also investigated to determine whether the direction the flash hole was from center influenced cartridge performance. The three orientations tested were: up (12 O'clock orientation), side (3 O'clock orientation), and down (6 O'clock orientation). These varying orientations were used to determine whether the effects of an offset differed depending on how the cartridge was placed inside the chamber during firing.

Once again, the greatest influence was seen in the precision results. No deviation greater than 3% occurred between the three orientations and the control for muzzle velocity or chamber pressure (Table 5.3). The .223 Remington and .308 Winchester range velocities had opposing trends as the flash hole's orientation changed. The Fiocchi velocities followed a similar trend to the range velocities, however Fiocchi's measurements appeared tighter to the control (2mm diameter, centered flash hole).

Table 5.3. Deviation from control over measured performance factors as affected by flash hole orientation.

Performance Factor	Maximum deviation from control
Range Velocity	2%
Fiocchi Velocity	1%
Fiocchi Pressure	3%
Range Precision	28%

The precision analysis displayed variations of nearly 30% compared to the centered 2mm control flash hole. However there are noticeable inconsistencies between the .223 and .308 caliber, particularly in the "up" orientation. The "side" orientation is consistently close (within 10%) to the control for each caliber. This is to be expected if the flash hole location effects are based on gravitational settling of the powder, since the "side" orientation would be in the same vertical location as the centered (control) flash hole. The "down" orientation gives consistently larger groups sizes (>20%) compared to the control. In the case of the .308 caliber, the error range is quite narrow as well, suggesting "down" oriented flash holes cause larger group sizes (worse precision) than other flash hole orientations, particularly in larger calibers.

5.4 GENERAL RESULTS

In many of these cases the .223 Remington and .308 Winchester data varied from one another (followed opposing trends, etc.). Part of this is due to the size differences between the two calibers. The .223 case has a smaller base area than the .308, meaning that the same flash hole diameter and offset would be proportionately larger compared to the .223 caliber. This can be seen in the following figures. Both Figure 5.1 and Figure 5.2 show larger ratios and larger ratio spread for the .223 Remington in comparison to the .308 Winchester.

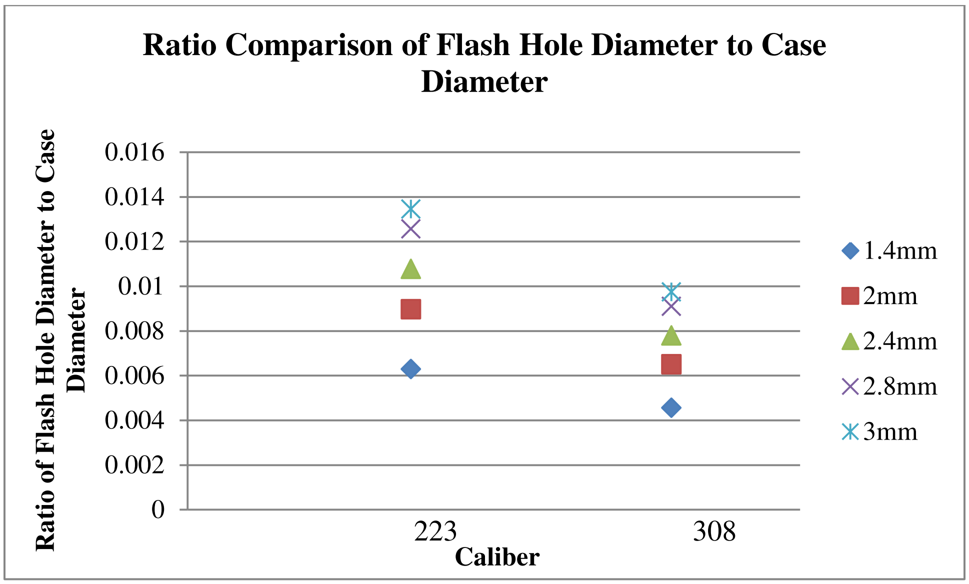

Figure 5.1. The influence of the different flash hole diameters normalized to the case diameter of each tested caliber.

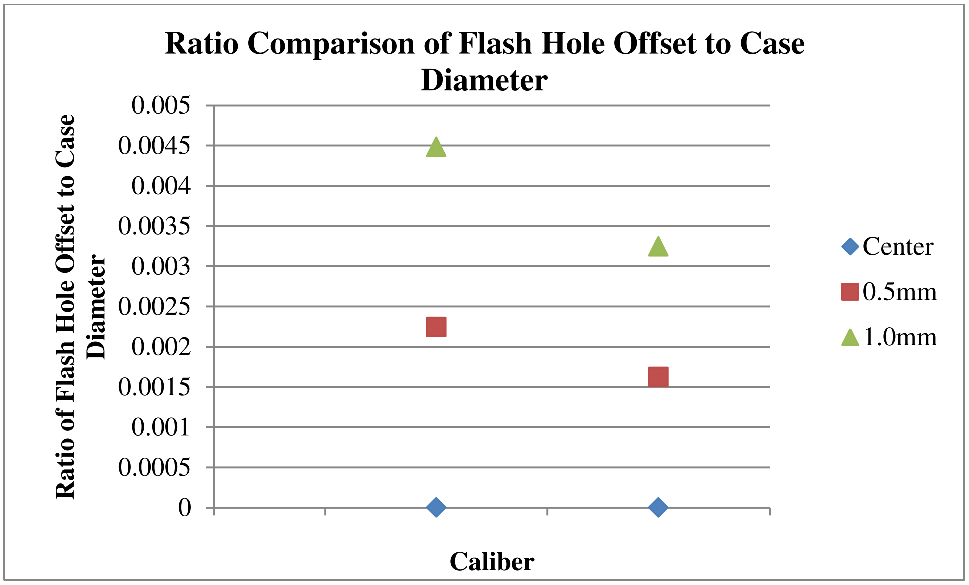

Figure 5.2. The influence of the different flash hole offset normalized to the case diameter of each tested caliber.

This shows that an equivalent change in flash hole diameter or flash hole offset will affect the smaller .223 caliber more so than the larger .308 caliber. This can account for some of the variations seen between the data sets of differing calibers.

The range velocities and Fiocchi velocities varied as well. This was due to the use of different chronograph devices to measure velocity as well as the different testing conditions (location, gun used, etc). The range testing had more variance as there was a larger number of outliers calculated compared to the Fiocchi data. The following table (

Table 5.4) shows the percentage of outliers for the two velocity measurements for each caliber.

Table 5.4. Percentage of velocity measurements that were deemed outliers in the two sets of velocity data for each caliber.

Percent of Measurements Deemed Outliers	**Range Velocity**	**Fiocchi Velocity**
.223 Remington	8.1%	4.2%
.308 Winchester	4.7%	2.6%

It is clear to see that the range velocity data had nearly twice as many outliers as Fiocchi's velocity measurements. This shows that range velocity acquisition was not as accurate as Fiocchi's system leading to variations between data sets.

5.5 FURTHER RESEARCH

As scientific research answers questions, it just as often creates more questions. In order to develop reasoning behind specific results, further research is often required. This future work becomes a more specified look at or an off chute of the original research, allowing the researcher to further their understanding of the topic or further that topic's horizons. Through this researcher's analysis of the influence of flash hole variance on cartridge performance, several questions arose which are candidates for further testing. These questions include: confirming increased precision for 3mm flash hole diameters, is there an ideal flash hole diameter to optimize powder ignition, how flash hole and powder misalignment during ignition affects performance, and what other factors related to cartridge structure are primary contributors to performance variance.

5.5.1 3mm Flash Hole Diameter vs. Precision. The results showed that the 3mm flash hole diameter presented the best precision. It may be of interest to further investigate this result. Muzzle velocity and chamber pressure are measured primarily for quality control purposes. These measurements allow manufacturers such as Fiocchi to batch test their product and ensure that they fall within a standard range. Precision and accuracy on the other hand are the primary interest of the consumer. Whether the cartridge is for competitive match shooting or hunting, precision and accuracy are what the shooter wants. The 3mm diameter flash hole rounds created the smallest group sizes on average meaning that they provide the best precision amongst the tested diameters. Increasing flash hole diameter to 3mm may cause a more consistent combustion of the powder within the cartridge leading to higher precision.

In order to test this theory further, this researcher would perform further precision tests while varying the diameter of a centered flash hole. The test diameters would consist of the standard 2mm, 3mm, and various diameters surrounding the 3mm mark (such as 2.9mm, 3.1mm, 3.2mm, and 3.5mm). The ammunition would be loaded to match grade and fired from a secure bench rifle. Match grade ammunition would allow for each cartridge to function identically, leaving any variations solely caused by flash hole deviation effects. The cartridges would be fired the same way each time using the bench rifle so that human error during firing could be reduced and the most accurate correlation between the flash hole diameter and precision observed.

5.5.2 Flash Hole Diameter vs. Optimal Ignition. Peak pressures were observed in the Fiocchi pressure measurements for certain flash hole diameters. The .223 Remington pressure data displayed a peak with a 2.4mm flash hole diameters, whereas the .308 Winchester pressures peaked with the 2.8mm flash hole diameter. These pressure peaks suggest that each caliber could have a specific flash hole diameter which allows for optimal powder ignition demonstrated by peak chamber pressure. This was also suggested by Lake in his paper discussed in section 2.2 Literature Review. Lake claimed that both large and small flash holes had beneficial tendencies and that the optimal flash hole diameter fell in between these two extremes.

Repeated pressure tests could be conducted to confirm this optimal flash hole diameter observation. The range of tested diameters could be tightened around the suspected optimal diameters (2.4mm for .223 and 2.8mm for .308) to see if a similar effect occurs. Similar to the 3mm precision tests described above, match grade ammunition would be required to ensure the most consistent primers, powder, interior case volume, and bullet mass. This would allow for the most accurate pressure readings for comparison among differing flash hole diameters.

Furthermore, it is also possible that by normalizing these optimal flash hole diameters to the cartridge caliber, particularly the internal diameter of the case or primer diameter, these optimal flash hole diameters could be easily determined. Similar to the comparisons seen in Figure 5.1 and Figure 5.2, the optimal flash hole diameter could simply be related to the caliber size.

5.5.3 Radiograph. Further research would be beneficial to investigate the SEE and flash over phenomenon mentioned in section 2.2 Literature Review. Variations of the up and down orientations were significantly greater than centered and side orientations. Lighter powder loads would only increase this effect, as an air gap would appear inside the cartridge as the powder settled. The position of this air gap when the rifle is fired could influence cartridge performance more significantly than what was found in this research.

In order to determine how off center flash holes would affect lighter loaded cartridges, a repeat of this study would be needed. It may also be beneficial to use larger calibers and/or lighter powder loads, so that an air gap within the case is more likely. For this repeat a series of cartridges with flash hole offsets and orientations, similar to the ones used in this research, would be loaded. The powder load in the new set of cartridges would be less than what was used in this research so that an air gap would be present in the cartridge. The cartridges would be loaded into the rifle chamber with the flash hole's location known. The cartridge would then be subject to a radiograph to see how the powder settled in the chamber and the location of the air gap. If possible, cartridges would be tested with the air gap in several different positions so that its effect on performance could be observed. Various powder positions could include: being evenly settled, settled towards the base of the case (so that an air gap is immediately behind the bullet), and settled to the top of the case (so that there is an air gap immediately next to the flash hole). This type of future research would allow for an understanding of how powder placement within the case affects cartridge performance.

5.5.4 Other Factors. Although some flash hole variation effects on cartridge performance were observed, most affects were within 5% of the control values (2mm center). More research is necessary to determine what the main contributing factors to performance inconsistencies are. As previously mentioned, there are many other factors that influence cartridge performance. A strong contributor is how powder burn rate changes based on the powder's storage temperature (1) (14). Variations in the burn rate directly affect chamber pressure and therefore velocity. This greatly changes the performance of the cartridge and the flight of the bullet. Determining the magnitude at which resting powder temperature affects performance would aid in understanding where overall performance deviation comes from.

6 CONCLUSIONS

Research was conducted to determine whether flash hole variance affected the performance of factory ammunition. Fiocchi of America purposed that flash hole size as well as off center flash holes could affect the quality of their consumer ammunition. Flash hole diameter, degree of offset from center, and orientation of the offset were the three factors describing flash hole variance. Cartridge performance was defined as a composition of muzzle velocity, chamber pressure, and precision. Testing was conducted in both .223 Remington and .308 Winchester calibers. Five flash hole diameters of 1.4mm, 2.0mm (currently being used by Fiocchi for .223 and .308 calibers), 2.4mm, 2.8mm, and 3.0mm were tested at three offsets: centered (no offset), 0.5mm from center, and 1.0mm from center. Each of the 0.5mm and 1.0mm offsets were tested at three orientations: up (12 O'clock), side (3 O'clock), and down (6 O'clock).

Flash holes were specifically drilled for this study, allowing for the desired size and location of the flash hole to be accurately created. Each cartridge was hand loaded to ensure identical powder weight and overall cartridge length between rounds.

Testing took place in two segments. First, range testing was performed using a .223 Howa 1500 bolt action rifle and a .308 Remington 788 bolt action rifle fired from a rifle rest. A portable chronograph was used to measure muzzle velocity, and shot group precision measurements were taken from a target 100yds down range. The second portion of testing took place at Fiocchi of America (Ozark, Missouri). The same flash hole variations were tested at Fiocchi from their calibrated barrels. A set of velocity screens measured muzzle velocity while a built in piezoelectric transducer measured chamber pressure. All four of these data sets (range and Fiocchi velocity, Fiocchi pressure, and range precision) were normalized to Fiocchi's standard 2mm diameter, centered flash hole and plotted against flash hole diameter, offset, and orientation.

Analysis of the results depicted notable relations between flash hole variance and cartridge performance. Variations from the 2mm control were primarily minimal for muzzle velocity and chamber pressure with greater variations occurring during precision analysis. Standard deviations increased with increases in variation. Flash hole diameter, offset, and orientation all have some effect on cartridge performance.

Flash hole diameter most notably affected chamber pressure and precision. The assumption made by Lake in section 2.2 Literature Review that a flash hole diameter would exist that would provide ideal ignition between the primer and the powder appears to be supported by this research. The 2.4mm flash hole diameter in the .223 Remington cartridge and the 2.8mm flash hole diameter in the .308 Winchester cartridge provided up to 4% higher chamber pressures than the other flash hole diameters. As for precision, the 3mm diameter flash holes showed up to 20% improved precision over the 2mm diameter flash hole cartridges, while maintaining a small standard deviation. This again suggests that not only an ideal flash hole diameter for providing consistent powder ignition exists, but it is larger than 2mm.

Flash hole offsets displayed varying trends in cartridge performance as well. Precision primarily decreased (larger group sizes) with an offset flash hole, with up to 20% variations from the 2mm diameter, centered control flash hole. Furthermore, every performance factor (muzzle velocity, chamber pressure, and precision) presented an increased standard deviation spread as the flash hole moved further from center. This concludes that an offset flash hole negatively affects cartridge performance consistency on all levels.

Finally, flash hole orientation changes further influenced cartridge performance. Precision decreased by up to 28%with the flash hole in the up and down orientations. The side orientation held tightest to the centered control. This reinforces the hypothesis that a relationship between the flash hole orientation and how the powder settles in the case exists, as discussed in section 2.2 Literature Review.

Each of these findings is a potential subject for future work. Other areas of future work, however, are required to determine which cartridge components other than flash hole variations are the primary contributors to performance variance. Further analysis of flash hole diameter effects on precision and powder ignition, the relationship between powder positioning within the cartridge and flash hole location, as well as the effects of temperature change on powder burn rates are key avenues of future research.

These findings suggest that Fiocchi may consider some changes to their manufacturing process. An increase in flash hole diameter may improve powder ignition as well as consistently improve precision as well as decrease machine downtime. Centered flash holes were found to have the most consistent results as well.

In final conclusion, flash hole variations were found to have several influences on the performance of factory rifle ammunition. Further work is required to understand which physical components in addition to the flash hole affect cartridge performance.

APPENDIX A.

PRIMER POCKET DATA

Summary:

The following table is a collection of .223 Remington primer pocket measurements. These measurements were done to ensure that the primer pocket did not vary significantly (few thousandths of an inch) from being centered in the case base.

Column Headings:

Outside Case Diameter (in) – the outside diameter of the case base in inches

Primer Pocket Diameter (in) – the diameter of the primer pocket in inches

Minimum Rim Width (in) – the minimum distance between the outside of the case and the primer pocket at any point around the base of the case in inches

Rim Width if Centered (in) – the rim width that a centered primer pocket would create in that cases outside diameter in inches

Degree of Offset (in) – the difference between the rim width if centered and the minimum rim width in inches

Outside Case Diameter (in)	**Primer Pocket Diameter (in)**	**Minimum Rim Width (in)**	**Rim Width if Centered (in)**	**Degree of Offset (in)**
0.371	0.171	0.099	0.100	0.001
0.371	0.172	0.099	0.100	0.001
0.372	0.171	0.099	0.101	0.002
0.372	0.171	0.098	0.101	0.003
0.372	0.171	0.099	0.101	0.002
0.372	0.171	0.099	0.101	0.002
0.371	0.171	0.097	0.100	0.003
0.372	0.171	0.098	0.101	0.003
0.372	0.171	0.097	0.101	0.004
0.373	0.171	0.099	0.101	0.002
0.372	0.171	0.099	0.101	0.002
0.371	0.171	0.097	0.100	0.003
0.372	0.171	0.099	0.101	0.002
0.371	0.171	0.098	0.100	0.002
0.372	0.171	0.097	0.101	0.004
0.372	0.171	0.099	0.101	0.002
0.372	0.171	0.099	0.101	0.002
0.371	0.171	0.098	0.100	0.002
0.371	0.171	0.097	0.100	0.003
0.371	0.171	0.097	0.100	0.003
0.371	0.172	0.098	0.100	0.002
0.372	0.171	0.099	0.101	0.002
0.372	0.171	0.099	0.101	0.002
0.372	0.171	0.100	0.101	0.001
0.372	0.171	0.099	0.101	0.002
0.371	0.171	0.098	0.100	0.002
0.371	0.171	0.100	0.100	0
0.371	0.171	0.099	0.100	0.001
0.373	0.171	0.097	0.101	0.004
0.371	0.171	0.099	0.100	0.001
0.372	0.171	0.099	0.101	0.002
0.373	0.171	0.099	0.101	0.002
0.372	0.171	0.100	0.101	0.001
0.371	0.171	0.099	0.100	0.001
0.371	0.171	0.097	0.100	0.003
0.371	0.171	0.099	0.100	0.001
0.371	0.171	0.097	0.100	0.003
0.372	0.171	0.099	0.101	0.002

0.371	0.171	0.099	0.100	0.001
0.372	0.171	0.099	0.101	0.002
0.371	0.171	0.099	0.100	0.001
0.372	0.170	0.098	0.101	0.003
0.372	0.171	0.098	0.101	0.003
0.373	0.171	0.099	0.101	0.002
0.371	0.171	0.097	0.100	0.003
0.372	0.171	0.098	0.101	0.003
0.372	0.171	0.099	0.101	0.002
0.372	0.171	0.100	0.101	0.001
0.371	0.170	0.098	0.101	0.003
0.372	0.171	0.098	0.101	0.003
0.371	0.170	0.099	0.101	0.002
0.371	0.171	0.098	0.100	0.002
0.372	0.171	0.097	0.101	0.004
0.370	0.171	0.099	0.100	0.001
0.371	0.171	0.098	0.100	0.002
0.372	0.171	0.099	0.101	0.002
0.370	0.171	0.098	0.100	0.002
0.371	0.171	0.096	0.100	0.004
0.371	0.171	0.097	0.100	0.003
0.372	0.171	0.099	0.101	0.002
0.371	0.171	0.097	0.100	0.003
0.372	0.171	0.099	0.101	0.002
0.371	0.171	0.098	0.100	0.002
0.372	0.171	0.099	0.101	0.002
0.371	0.171	0.098	0.100	0.002
0.372	0.171	0.100	0.101	0.001
0.371	0.170	0.099	0.101	0.002
0.371	0.171	0.098	0.100	0.002
0.373	0.171	0.099	0.101	0.002
0.371	0.171	0.099	0.100	0.001
0.371	0.170	0.095	0.101	0.006
0.372	0.171	0.098	0.101	0.003
0.371	0.171	0.098	0.100	0.002
0.371	0.171	0.097	0.100	0.003
0.372	0.170	0.098	0.101	0.003
0.371	0.171	0.098	0.100	0.002
0.372	0.171	0.099	0.101	0.002
0.371	0.171	0.099	0.100	0.001
0.371	0.171	0.098	0.100	0.002

0.373	0.171	0.099	0.101	0.002
0.372	0.171	0.098	0.101	0.003
0.371	0.170	0.097	0.101	0.004
0.371	0.170	0.097	0.101	0.004
0.372	0.171	0.099	0.101	0.002
0.371	0.171	0.097	0.100	0.003
0.372	0.171	0.099	0.101	0.002
0.373	0.171	0.099	0.101	0.002
0.372	0.170	0.097	0.101	0.004
0.372	0.171	0.097	0.101	0.004
0.371	0.170	0.098	0.101	0.003
0.373	0.171	0.099	0.101	0.002
0.372	0.171	0.098	0.101	0.003
0.372	0.170	0.096	0.101	0.005
0.371	0.170	0.097	0.101	0.004
0.371	0.171	0.098	0.100	0.002
0.371	0.170	0.098	0.101	0.003
0.372	0.170	0.099	0.101	0.002
0.371	0.170	0.098	0.101	0.003
0.371	0.171	0.098	0.100	0.002
0.370	0.171	0.098	0.100	0.002
0.371	0.170	0.097	0.101	0.004
0.371	0.170	0.097	0.101	0.004
0.371	0.171	0.098	0.100	0.002
0.372	0.170	0.098	0.101	0.003
0.372	0.171	0.097	0.101	0.004
0.373	0.170	0.097	0.102	0.005
0.371	0.170	0.098	0.101	0.003
0.372	0.170	0.098	0.101	0.003
0.371	0.170	0.099	0.101	0.002
0.372	0.171	0.098	0.101	0.003
0.371	0.171	0.098	0.100	0.002
0.371	0.170	0.099	0.101	0.002
0.372	0.171	0.098	0.101	0.003
0.371	0.171	0.099	0.100	0.001
0.372	0.170	0.099	0.101	0.002
0.370	0.170	0.098	0.100	0.002
0.371	0.170	0.096	0.101	0.005
0.372	0.170	0.098	0.101	0.003
0.373	0.170	0.098	0.102	0.004
0.371	0.170	0.098	0.101	0.003

0.371	0.170	0.098	0.101	0.003
0.372	0.171	0.098	0.101	0.003
0.371	0.171	0.097	0.100	0.003
0.371	0.170	0.098	0.101	0.003
0.372	0.171	0.098	0.101	0.003
0.373	0.170	0.097	0.102	0.005
0.372	0.170	0.097	0.101	0.004
0.371	0.170	0.098	0.101	0.003
0.372	0.171	0.099	0.101	0.002
0.370	0.171	0.098	0.100	0.002
0.372	0.170	0.098	0.101	0.003
0.372	0.170	0.097	0.101	0.004
0.371	0.171	0.098	0.100	0.002
0.371	0.170	0.098	0.101	0.003
0.372	0.171	0.098	0.101	0.003
0.372	0.170	0.098	0.101	0.003
0.372	0.171	0.098	0.101	0.003
0.372	0.170	0.098	0.101	0.003
0.371	0.171	0.098	0.100	0.002
0.371	0.170	0.098	0.101	0.003
0.371	0.170	0.098	0.101	0.003
0.372	0.170	0.099	0.101	0.002
0.373	0.171	0.097	0.101	0.004
0.371	0.170	0.099	0.101	0.002
0.372	0.170	0.100	0.101	0.001
0.372	0.170	0.100	0.101	0.001
0.372	0.170	0.099	0.101	0.002
0.372	0.171	0.098	0.101	0.003
0.371	0.170	0.098	0.101	0.003
0.371	0.170	0.098	0.101	0.003
0.372	0.170	0.098	0.101	0.003
0.371	0.170	0.099	0.101	0.002
0.371	0.170	0.099	0.101	0.002
0.371	0.170	0.099	0.101	0.002
0.372	0.170	0.099	0.101	0.002
0.371	0.170	0.098	0.101	0.003
0.372	0.170	0.098	0.101	0.003
0.371	0.170	0.098	0.101	0.003
0.371	0.170	0.099	0.101	0.002
0.372	0.170	0.099	0.101	0.002
0.371	0.170	0.097	0.101	0.004

0.372	0.170	0.100	0.101	0.001
0.372	0.170	0.099	0.101	0.002
0.372	0.170	0.098	0.101	0.003
0.372	0.170	0.098	0.101	0.003
0.372	0.170	0.099	0.101	0.002
0.373	0.170	0.100	0.102	0.002
0.371	0.170	0.098	0.101	0.003
0.372	0.170	0.099	0.101	0.002
0.371	0.170	0.099	0.101	0.002
0.372	0.170	0.098	0.101	0.003
0.372	0.170	0.100	0.101	0.001
0.372	0.170	0.099	0.101	0.002
0.372	0.171	0.100	0.101	0.001
0.371	0.171	0.098	0.100	0.002
0.372	0.170	0.099	0.101	0.002
0.372	0.170	0.098	0.101	0.003
0.371	0.170	0.099	0.101	0.002
0.373	0.171	0.099	0.101	0.002
0.372	0.170	0.098	0.101	0.003
0.371	0.170	0.099	0.101	0.002
0.371	0.170	0.098	0.101	0.003
0.371	0.171	0.099	0.100	0.001
0.371	0.170	0.099	0.101	0.002
0.372	0.170	0.100	0.101	0.001
0.371	0.171	0.098	0.100	0.002
0.371	0.170	0.099	0.101	0.002
0.371	0.171	0.099	0.100	0.001
0.371	0.170	0.100	0.101	0.001
0.371	0.170	0.099	0.101	0.002
0.372	0.171	0.099	0.101	0.002
0.371	0.170	0.098	0.101	0.003
0.371	0.170	0.099	0.101	0.002
0.371	0.170	0.099	0.101	0.002
0.371	0.170	0.098	0.101	0.003
0.372	0.171	0.098	0.101	0.003
0.371	0.170	0.098	0.101	0.003
0.371	0.170	0.099	0.101	0.002
0.372	0.170	0.099	0.101	0.002
0.371	0.171	0.098	0.100	0.002
0.372	0.171	0.099	0.101	0.002
0.371	0.170	0.098	0.101	0.003

0.372	0.170	0.099	0.101	0.002
0.371	0.171	0.098	0.100	0.002
0.372	0.170	0.099	0.101	0.002
0.372	0.171	0.098	0.101	0.003
0.371	0.171	0.096	0.100	0.004
0.372	0.171	0.098	0.101	0.003
0.371	0.170	0.097	0.101	0.004
0.371	0.170	0.098	0.101	0.003
0.371	0.170	0.098	0.101	0.003
0.370	0.170	0.099	0.100	0.001
0.371	0.170	0.096	0.101	0.005
0.371	0.171	0.099	0.100	0.001
0.371	0.170	0.097	0.101	0.004
0.371	0.171	0.099	0.100	0.001
0.371	0.171	0.097	0.100	0.003
0.371	0.171	0.098	0.100	0.002
0.371	0.171	0.099	0.100	0.001
0.372	0.171	0.099	0.101	0.002
0.370	0.171	0.097	0.100	0.003
0.371	0.170	0.099	0.101	0.002
0.372	0.171	0.098	0.101	0.003
0.372	0.171	0.099	0.101	0.002
0.371	0.171	0.099	0.100	0.001
0.372	0.170	0.099	0.101	0.002
0.371	0.170	0.099	0.101	0.002
0.372	0.171	0.099	0.101	0.002
0.371	0.171	0.097	0.100	0.003
0.373	0.170	0.098	0.102	0.004
0.372	0.171	0.099	0.101	0.002
0.371	0.170	0.097	0.101	0.004
0.371	0.171	0.096	0.100	0.004
0.372	0.170	0.099	0.101	0.002
0.371	0.171	0.099	0.100	0.001
0.370	0.171	0.099	0.100	0.001
0.372	0.171	0.099	0.101	0.002
0.371	0.171	0.098	0.100	0.002
0.371	0.170	0.097	0.101	0.004
0.372	0.171	0.099	0.101	0.002
0.372	0.170	0.099	0.101	0.002
0.371	0.171	0.099	0.100	0.001
0.372	0.170	0.099	0.101	0.002

0.372	0.170	0.100	0.101	0.001
0.371	0.170	0.098	0.101	0.003
0.372	0.171	0.099	0.101	0.002
0.371	0.171	0.099	0.100	0.001
0.371	0.170	0.098	0.101	0.003
0.372	0.170	0.099	0.101	0.002
0.371	0.170	0.099	0.101	0.002
0.371	0.171	0.098	0.100	0.002
0.371	0.170	0.098	0.101	0.003
0.371	0.170	0.099	0.101	0.002
0.371	0.170	0.097	0.101	0.004
0.371	0.170	0.096	0.101	0.005
0.371	0.170	0.099	0.101	0.002
0.372	0.170	0.099	0.101	0.002
0.371	0.170	0.097	0.101	0.004
0.370	0.170	0.098	0.100	0.002
0.371	0.170	0.099	0.101	0.002
0.372	0.171	0.098	0.101	0.003
0.372	0.170	0.099	0.101	0.002
0.372	0.170	0.098	0.101	0.003
0.371	0.170	0.098	0.101	0.003
0.371	0.171	0.098	0.100	0.002
0.372	0.170	0.098	0.101	0.003
0.371	0.170	0.098	0.101	0.003
0.370	0.171	0.097	0.100	0.003
0.371	0.170	0.099	0.101	0.002
0.372	0.171	0.099	0.101	0.002
0.373	0.171	0.098	0.101	0.003
0.371	0.170	0.098	0.101	0.003
0.371	0.171	0.097	0.100	0.003
0.372	0.170	0.099	0.101	0.002
0.371	0.171	0.099	0.100	0.001
0.371	0.170	0.098	0.101	0.003
0.372	0.170	0.099	0.101	0.002
0.372	0.170	0.099	0.101	0.002
0.372	0.170	0.099	0.101	0.002
0.372	0.170	0.099	0.101	0.002
0.372	0.171	0.099	0.101	0.002
0.372	0.171	0.099	0.101	0.002
0.371	0.170	0.099	0.101	0.002
0.371	0.170	0.099	0.101	0.002

0.372	0.170	0.099	0.101	0.002
0.372	0.171	0.100	0.101	0.001

APPENDIX B.

.223 REMINGTON CASE LENGTH AND OVERALL LENGTH (OAL) DATA

Summary:

The following table depicts the measured case lengths and overall lengths (OAL) of each .223 Remington case and completed cartridge. Measurements were done to ensure case length and OAL did not exceed the .223 Remington maximums of:

Case Length: 1.760”

OAL Length: 2.260”

Flash Hole Diameter (mm)	**Offset Deviation (mm)**	**Case Length (in)**	**OAL (in)**
1.4	0	1.755	2.221
1.4	0	1.7545	2.222
1.4	0	1.755	2.2195
1.4	0	1.753	2.2205
1.4	0	1.755	2.222
1.4	0	1.755	2.2195
1.4	0	1.7555	2.2195
1.4	0	1.754	2.223
1.4	0	1.7545	2.2225
1.4	0	1.755	2.222
1.4	0	1.754	2.2235
1.4	0	1.756	2.2205
1.4	0	1.7555	2.219
1.4	0	1.7555	2.219
1.4	0	1.7565	2.2255
1.4	0	1.758	2.216
1.4	0	1.755	2.2215
1.4	0	1.7565	2.2195
1.4	0	1.7545	2.2205
1.4	0	1.7555	MISSING
1.4	0	1.756	2.223
1.4	0	1.7555	2.2185
1.4	0	1.7545	2.217
1.4	0	1.7545	2.2195
1.4	0	1.7565	2.2215
1.4	0	1.7565	2.2215
1.4	0	1.7565	2.2205
1.4	0	1.755	2.214
1.4	0	1.7545	2.2195
1.4	0	1.756	2.219
1.4	0	1.757	2.2205
1.4	0	1.7545	2.216
1.4	0	1.7555	2.2175
1.4	0	1.756	2.2165
1.4	0	1.753	2.218
1.4	0	1.7565	2.224
1.4	0	1.755	2.218
1.4	0	1.7545	2.2175

1.4	0	1.7545	2.22
1.4	0	1.7545	2.2205
1.4	0	1.7565	2.2215
1.4	0	1.7555	2.222
1.4	0	1.757	2.2215
1.4	0	1.7545	2.2165
1.4	0	1.753	2.219
1.4	0.5	1.7545	2.2215
1.4	0.5	1.756	2.2235
1.4	0.5	1.7545	2.219
1.4	0.5	1.755	2.2245
1.4	0.5	1.7565	2.219
1.4	0.5	1.754	2.2225
1.4	0.5	1.754	2.2215
1.4	0.5	1.7565	2.2235
1.4	0.5	1.756	2.2255
1.4	0.5	1.7555	2.2205
1.4	0.5	1.755	2.218
1.4	0.5	1.757	2.221
1.4	0.5	1.757	2.224
1.4	0.5	1.757	2.2245
1.4	0.5	1.757	2.219
1.4	0.5	1.7575	2.221
1.4	0.5	1.7555	2.2235
1.4	0.5	1.757	2.2245
1.4	0.5	1.753	2.223
1.4	0.5	1.754	2.2175
1.4	0.5	1.754	2.218
1.4	0.5	1.7555	2.223
1.4	0.5	1.755	2.2225
1.4	0.5	1.7575	2.224
1.4	0.5	1.759	2.22
1.4	0.5	1.7575	2.225
1.4	0.5	1.756	2.2185
1.4	0.5	1.755	2.2205
1.4	0.5	1.7555	2.2225
1.4	0.5	1.7565	2.225
1.4	0.5	1.7565	2.2215
1.4	0.5	1.7555	2.219
1.4	0.5	1.756	2.222
1.4	0.5	1.7555	2.217

1.4	0.5	1.756	2.218
1.4	0.5	1.7545	2.22
1.4	0.5	1.7555	2.222
1.4	0.5	1.754	2.218
1.4	0.5	1.7555	2.222
1.4	0.5	1.7555	2.222
1.4	0.5	1.755	2.2175
1.4	0.5	1.7545	2.2205
1.4	0.5	1.7565	2.22
1.4	0.5	1.7565	2.2185
1.4	0.5	1.754	2.2175
1.4	0.5	1.756	2.217
1.4	0.5	1.755	2.2175
1.4	0.5	1.754	2.2185
1.4	0.5	1.756	2.222
1.4	0.5	1.7575	2.218
1.4	0.5	1.756	2.2195
1.4	0.5	1.755	2.216
1.4	0.5	1.754	2.2205
1.4	0.5	1.757	2.2225
1.4	0.5	1.7545	2.219
1.4	0.5	1.757	2.221
1.4	0.5	1.755	2.217
1.4	0.5	1.7545	2.223
1.4	0.5	1.7555	2.22
1.4	0.5	1.756	2.2225
1.4	0.5	1.755	2.2175
1.4	0.5	1.7555	2.22
1.4	0.5	1.7535	2.22
1.4	0.5	1.757	2.223
1.4	0.5	1.7565	2.2205
1.4	1	1.7555	2.2175
1.4	1	1.7575	2.2245
1.4	1	1.7545	2.2195
1.4	1	1.757	2.2215
1.4	1	1.7555	2.224
1.4	1	1.759	2.2235
1.4	1	1.7565	2.222
1.4	1	1.7575	2.222
1.4	1	1.754	2.218
1.4	1	1.7575	2.2195

1.4	1	1.7535	2.224
1.4	1	1.7555	2.223
1.4	1	1.7565	2.22
1.4	1	1.7545	2.2185
1.4	1	1.7575	2.22
1.4	1	1.7525	2.222
1.4	1	1.755	2.2205
1.4	1	1.7545	2.2225
1.4	1	1.7575	2.221
1.4	1	1.756	2.2255
1.4	1	1.755	2.217
1.4	1	1.7555	2.2215
1.4	1	1.7545	2.22
1.4	1	1.7535	2.2175
1.4	1	1.7555	2.222
1.4	1	1.7555	2.223
1.4	1	1.7555	2.2215
1.4	1	1.754	2.2235
1.4	1	1.7555	2.223
1.4	1	1.7555	2.2245
1.4	1	1.755	2.2205
1.4	1	1.756	2.2215
1.4	1	1.7565	2.2155
1.4	1	1.7535	2.223
1.4	1	1.754	2.221
1.4	1	1.7565	2.22
1.4	1	1.756	2.2165
1.4	1	1.754	2.222
1.4	1	1.7555	2.22
1.4	1	1.756	2.219
1.4	1	1.754	2.22
1.4	1	1.7555	2.223
1.4	1	1.7555	2.2205
1.4	1	1.754	2.224
1.4	1	1.756	2.2215
1.4	1	1.756	2.221
1.4	1	1.7565	2.219
1.4	1	1.7555	2.217
1.4	1	1.7555	2.224
1.4	1	1.756	2.217
1.4	1	1.755	2.221

1.4	1	1.7535	2.215
1.4	1	1.755	2.217
1.4	1	1.756	2.2205
1.4	1	1.7535	2.2175
1.4	1	1.755	2.2225
1.4	1	1.755	2.2225
1.4	1	1.755	2.2165
1.4	1	1.7565	2.2195
1.4	1	1.754	2.2175
1.4	1	1.7555	2.2205
1.4	1	1.755	2.223
1.4	1	1.7555	2.2205
1.4	1	1.755	2.219
1.4	1	1.7555	2.2165
2	0	1.754	2.2225
2	0	1.756	2.2185
2	0	1.7565	2.218
2	0	1.7585	2.2245
2	0	1.7555	2.222
2	0	1.754	2.2215
2	0	1.755	2.2215
2	0	1.7555	2.219
2	0	1.754	2.219
2	0	1.755	2.221
2	0	1.754	2.223
2	0	1.756	2.2225
2	0	1.7525	2.22
2	0	1.7555	2.226
2	0	1.7555	2.2235
2	0	1.755	2.2195
2	0	1.7555	2.2235
2	0	1.7555	2.2225
2	0	1.756	2.227
2	0	1.755	2.218
2	0	1.755	2.2235
2	0	1.756	2.2185
2	0	1.7545	2.224
2	0	1.7575	2.22
2	0	1.753	2.2215
2	0	1.7555	2.2205
2	0	1.7535	2.222

2	0	1.756	2.217
2	0	1.7555	2.225
2	0	1.7555	2.2185
2	0	1.756	2.219
2	0	1.7555	2.22
2	0	1.7555	2.225
2	0	1.754	2.222
2	0	1.7555	2.219
2	0	1.7575	2.2225
2	0	1.7555	2.227
2	0	1.7555	2.22
2	0	1.7555	2.2175
2	0	1.7575	2.2205
2	0	1.7565	2.2185
2	0.5	1.7555	2.22
2	0.5	1.7565	2.2205
2	0.5	1.756	2.223
2	0.5	1.754	2.2195
2	0.5	1.7555	2.2175
2	0.5	1.7555	2.222
2	0.5	1.754	2.22
2	0.5	1.757	2.2235
2	0.5	1.7545	2.2195
2	0.5	1.754	2.2215
2	0.5	1.7545	2.2185
2	0.5	1.7545	2.219
2	0.5	1.755	2.222
2	0.5	1.7555	2.2245
2	0.5	1.755	2.223
2	0.5	1.7565	2.2225
2	0.5	1.7575	2.2235
2	0.5	1.7545	2.2185
2	0.5	1.756	2.223
2	0.5	1.754	2.218
2	0.5	1.7545	2.219
2	0.5	1.7565	2.218
2	0.5	1.754	2.222
2	0.5	1.7555	2.221
2	0.5	1.756	2.2175
2	0.5	1.7545	2.224
2	0.5	1.755	2.219

2	0.5	1.755	2.218
2	0.5	1.755	2.2205
2	0.5	1.7535	2.228
2	0.5	1.755	2.2245
2	0.5	1.754	2.2235
2	0.5	1.7555	2.23
2	0.5	1.755	2.2255
2	0.5	1.7535	2.223
2	0.5	1.7535	2.2255
2	0.5	1.755	2.2255
2	0.5	1.757	2.2265
2	0.5	1.7555	2.2245
2	0.5	1.7545	2.223
2	0.5	1.7535	2.226
2	0.5	1.756	2.2285
2	0.5	1.756	2.225
2	0.5	1.7565	2.2285
2	0.5	1.7535	2.23
2	0.5	1.7525	2.2215
2	0.5	1.7535	2.229
2	0.5	1.755	2.2295
2	0.5	1.755	2.225
2	0.5	1.7535	2.2295
2	0.5	1.756	2.222
2	0.5	1.7555	2.223
2	0.5	1.7545	2.227
2	0.5	1.7535	2.2255
2	0.5	1.756	2.218
2	0.5	1.7545	2.217
2	0.5	1.7565	2.2165
2	0.5	1.757	2.224
2	0.5	1.7565	2.221
2	0.5	1.755	2.2225
2	0.5	1.7565	2.2195
2	0.5	1.7565	2.2215
2	0.5	1.7545	2.2215
2	0.5	1.755	2.22
2	1	1.7555	2.224
2	1	1.7535	2.22
2	1	1.755	2.218
2	1	1.7555	2.2215

2	1	1.756	2.218
2	1	1.756	2.2175
2	1	1.757	2.2215
2	1	1.757	2.2215
2	1	1.757	2.2225
2	1	1.755	2.2195
2	1	1.7555	2.2195
2	1	1.756	2.2215
2	1	1.7575	2.2215
2	1	1.7555	2.222
2	1	1.755	2.217
2	1	1.755	2.22
2	1	1.7555	2.2215
2	1	1.7555	2.2225
2	1	1.7555	2.217
2	1	1.756	2.221
2	1	1.7555	2.2185
2	1	1.754	2.223
2	1	1.756	2.2205
2	1	1.755	2.2205
2	1	1.7555	2.22
2	1	1.7555	2.2195
2	1	1.757	2.216
2	1	1.756	2.2185
2	1	1.7525	2.2185
2	1	1.7555	2.218
2	1	1.756	2.2215
2	1	1.756	2.2185
2	1	1.757	2.2155
2	1	1.7555	2.223
2	1	1.755	2.219
2	1	1.755	2.22
2	1	1.755	2.22
2	1	1.7565	2.2185
2	1	1.755	2.2195
2	1	1.758	2.2215
2	1	1.7555	2.219
2	1	1.756	2.217
2	1	1.756	2.219
2	1	1.7555	2.2215
2	1	1.756	2.2175

2	1	1.755	2.2145
2	1	1.7555	2.2175
2	1	1.756	2.2235
2	1	1.7575	2.2205
2	1	1.757	2.223
2	1	1.754	2.2225
2	1	1.756	2.222
2	1	1.7545	2.22
2	1	1.7555	2.219
2	1	1.756	2.2195
2	1	1.7545	2.218
2	1	1.7555	2.222
2	1	1.7555	2.2205
2	1	1.7565	2.218
2	1	1.7555	2.22
2	1	1.7535	2.2165
2	1	1.7555	2.2205
2	1	1.7585	2.2205
2	1	1.7555	2.222
2.4	0	Missing	2.185
2.4	0	Missing	2.185
2.4	0	Missing	2.2015
2.4	0	Missing	2.21
2.4	0	Missing	2.2115
2.4	0	Missing	2.217
2.4	0	Missing	2.2215
2.4	0	Missing	2.2205
2.4	0	Missing	2.2215
2.4	0	Missing	2.22
2.4	0	Missing	2.2265
2.4	0	Missing	2.2215
2.4	0	Missing	2.2195
2.4	0	Missing	2.221
2.4	0	Missing	2.2165
2.4	0	Missing	2.2225
2.4	0	Missing	2.218
2.4	0	Missing	2.2185
2.4	0	Missing	2.223
2.4	0	Missing	2.218
2.4	0	Missing	2.216
2.4	0	Missing	2.2235

2.4	0	Missing	2.2225
2.4	0	Missing	2.2175
2.4	0	Missing	2.2195
2.4	0	1.755	2.223
2.4	0	1.7535	2.2235
2.4	0	1.7545	2.2195
2.4	0	1.756	2.22
2.4	0	1.7555	2.22
2.4	0	1.755	2.22
2.4	0	1.756	2.2195
2.4	0	1.7545	2.225
2.4	0	1.7545	2.2175
2.4	0	1.755	2.221
2.4	0	1.754	2.224
2.4	0	1.755	2.2195
2.4	0	1.755	2.224
2.4	0	1.755	2.2225
2.4	0	1.7555	2.2245
2.4	0.5	1.7535	2.2225
2.4	0.5	1.754	2.221
2.4	0.5	1.7565	2.2225
2.4	0.5	1.753	2.2245
2.4	0.5	1.7565	2.2205
2.4	0.5	1.7555	2.221
2.4	0.5	1.756	2.2215
2.4	0.5	1.7555	2.223
2.4	0.5	1.7565	2.2245
2.4	0.5	1.7565	2.2235
2.4	0.5	1.7555	2.223
2.4	0.5	1.757	2.2245
2.4	0.5	1.755	2.222
2.4	0.5	1.7575	2.2245
2.4	0.5	1.758	2.2195
2.4	0.5	1.7555	2.218
2.4	0.5	1.756	2.217
2.4	0.5	1.756	2.2195
2.4	0.5	1.7565	2.224
2.4	0.5	1.755	2.224
2.4	0.5	1.7585	2.223
2.4	0.5	1.756	2.2205
2.4	0.5	1.7545	2.218

2.4	0.5	1.7565	2.224
2.4	0.5	1.7535	2.2265
2.4	0.5	1.7545	2.2215
2.4	0.5	1.7545	2.2235
2.4	0.5	1.7555	2.2225
2.4	0.5	1.759	2.222
2.4	0.5	1.754	2.223
2.4	0.5	1.755	2.2225
2.4	0.5	1.754	2.222
2.4	0.5	1.7555	2.22
2.4	0.5	1.756	2.2185
2.4	0.5	1.7555	2.2235
2.4	0.5	1.7555	2.2185
2.4	0.5	1.756	2.2215
2.4	0.5	1.7555	2.2215
2.4	0.5	1.7555	2.2225
2.4	0.5	1.7555	2.217
2.4	0.5	1.7575	2.2245
2.4	0.5	1.7565	2.2245
2.4	0.5	1.757	2.2205
2.4	0.5	1.7555	2.2195
2.4	0.5	1.754	2.2205
2.4	0.5	1.7555	2.2245
2.4	0.5	1.754	2.224
2.4	0.5	1.756	2.2225
2.4	0.5	1.754	2.222
2.4	0.5	1.7545	2.2165
2.4	0.5	1.7555	2.223
2.4	0.5	1.7545	2.2215
2.4	0.5	1.7555	2.2175
2.4	0.5	1.7555	2.222
2.4	0.5	1.7565	2.2215
2.4	0.5	1.756	2.2205
2.4	0.5	1.7565	2.219
2.4	0.5	1.7555	2.2175
2.4	0.5	1.7535	2.2175
2.4	0.5	1.7565	2.221
2.4	0.5	1.7545	2.219
2.4	0.5	1.756	2.2265
2.8	0	1.7535	2.2195
2.8	0	1.756	2.2225

2.8	0	1.7545	2.224
2.8	0	1.756	2.2255
2.8	0	1.757	2.2205
2.8	0	1.7555	2.223
2.8	0	1.756	2.223
2.8	0	1.755	2.222
2.8	0	1.7555	2.223
2.8	0	1.758	2.222
2.8	0	1.7565	2.216
2.8	0	1.7555	2.223
2.8	0	1.7565	2.2215
2.8	0	1.7555	2.2195
2.8	0	1.756	2.2185
2.8	0	1.755	2.22
2.8	0	1.753	2.22
2.8	0	1.7565	2.223
2.8	0	1.754	2.2225
2.8	0	1.757	2.218
2.8	0	1.755	2.2195
2.8	0	1.7535	2.218
2.8	0	1.756	2.22
2.8	0	1.7545	2.225
2.8	0	1.756	2.2225
2.8	0	1.757	2.221
2.8	0	1.7555	2.2195
2.8	0	1.7545	2.2235
2.8	0	1.757	2.2185
2.8	0	1.757	2.2215
2.8	0	1.7555	2.2225
2.8	0	1.756	2.2205
2.8	0	1.7545	2.2225
2.8	0	1.755	2.221
2.8	0	1.757	2.219
2.8	0	1.756	2.218
2.8	0	1.756	2.2195
2.8	0	1.7555	2.2145
2.8	0	1.7555	2.2225
2.8	0	1.756	2.2215
2.8	0.5	1.7555	2.2235
2.8	0.5	1.755	2.219
2.8	0.5	1.7545	2.22

2.8	0.5	1.757	2.2205
2.8	0.5	1.7575	2.2215
2.8	0.5	1.7545	2.219
2.8	0.5	1.754	2.218
2.8	0.5	1.7555	2.223
2.8	0.5	1.756	2.2215
2.8	0.5	1.756	2.2235
2.8	0.5	1.756	2.217
2.8	0.5	1.7555	2.2245
2.8	0.5	1.7535	2.219
2.8	0.5	1.757	2.2195
2.8	0.5	1.755	2.2195
2.8	0.5	1.7555	2.2225
2.8	0.5	1.757	2.22
2.8	0.5	1.757	2.225
2.8	0.5	1.7545	2.219
2.8	0.5	1.7555	2.2205
2.8	0.5	1.7555	2.2205
2.8	0.5	1.756	2.217
2.8	0.5	1.7545	2.22
2.8	0.5	1.7565	2.2195
2.8	0.5	1.7565	2.2255
2.8	0.5	1.7555	2.222
2.8	0.5	1.7555	2.2235
2.8	0.5	1.7545	2.2215
2.8	0.5	1.7555	2.219
2.8	0.5	1.756	2.219
2.8	0.5	1.7565	2.223
2.8	0.5	1.7555	2.2215
2.8	0.5	1.758	2.225
2.8	0.5	1.7545	2.219
2.8	0.5	1.756	2.22
2.8	0.5	1.7555	2.222
2.8	0.5	1.756	2.223
2.8	0.5	1.755	2.2195
2.8	0.5	1.7525	2.2215
2.8	0.5	1.754	2.2205
2.8	0.5	1.757	2.2235
2.8	0.5	1.7555	2.222
2.8	0.5	1.756	2.2255
2.8	0.5	1.7575	2.22

2.8	0.5	1.7555	2.223
2.8	0.5	1.755	2.219
2.8	0.5	1.755	2.2225
2.8	0.5	1.755	2.2195
2.8	0.5	1.7555	2.22
2.8	0.5	1.756	2.2235
2.8	0.5	1.755	2.2205
2.8	0.5	1.755	2.2225
2.8	0.5	1.7545	2.22
2.8	0.5	1.7555	2.2165
2.8	0.5	1.755	2.216
2.8	0.5	1.755	2.2195
2.8	0.5	1.754	2.2195
2.8	0.5	1.757	2.215
2.8	0.5	1.7555	2.22
2.8	0.5	1.757	2.217
3	0	1.756	2.2205
3	0	1.754	2.219
3	0	1.754	2.22
3	0	1.755	2.225
3	0	1.7555	2.224
3	0	1.7555	2.222
3	0	1.7555	2.223
3	0	1.757	2.2225
3	0	1.7555	2.2165
3	0	1.7535	2.219
3	0	1.7565	2.2175
3	0	1.755	2.2195
3	0	1.7555	2.221
3	0	1.756	2.2185
3	0	1.757	2.2195
3	0	1.754	2.218
3	0	1.755	2.2215
3	0	1.7555	2.219
3	0	1.7545	2.2175
3	0	1.7545	2.2185
3	0	1.7555	2.2235
3	0	1.7545	2.2205
3	0	1.7545	2.2245
3	0	1.7545	2.2215
3	0	1.7555	2.22

3	0	1.7535	2.222
3	0	1.756	2.2215
3	0	1.755	2.2195
3	0	1.7535	2.221
3	0	1.7535	2.2165
3	0	1.7555	2.225
3	0	1.7555	2.2205
3	0	1.7545	2.226
3	0	1.7555	2.225
3	0	1.755	2.219
3	0	1.752	2.223
3	0	1.7555	2.225
3	0	1.758	2.225
3	0	1.7555	2.2215
3	0	1.7565	2.2195
3	0.5	1.756	2.2195
3	0.5	1.757	2.221
3	0.5	1.756	2.223
3	0.5	1.7555	2.218
3	0.5	1.757	2.2225
3	0.5	1.7555	2.2185
3	0.5	1.756	2.223
3	0.5	1.757	2.223
3	0.5	1.754	2.223
3	0.5	1.7555	2.225
3	0.5	1.7555	2.22
3	0.5	1.755	2.219
3	0.5	1.753	2.22
3	0.5	1.755	2.2205
3	0.5	1.7545	2.2225
3	0.5	1.754	2.2195
3	0.5	1.7565	2.2225
3	0.5	1.7555	2.2185
3	0.5	1.7555	2.223
3	0.5	1.757	2.2195
3	0.5	1.753	2.2175
3	0.5	1.755	2.223
3	0.5	1.756	2.22
3	0.5	1.7555	2.2205
3	0.5	1.7555	2.2215
3	0.5	1.7555	2.225

3	0.5	1.7565	2.223
3	0.5	1.7555	2.221
3	0.5	1.7545	2.219
3	0.5	1.755	2.2175
3	0.5	1.757	2.218
3	0.5	1.7555	2.2195
3	0.5	1.754	2.2165
3	0.5	1.757	2.223
3	0.5	1.753	2.219
3	0.5	1.7555	2.2205
3	0.5	1.7555	2.223
3	0.5	1.7535	2.2245
3	0.5	1.7555	2.218
3	0.5	1.755	2.2215
3	0.5	1.7585	2.221
3	0.5	1.757	2.2195
3	0.5	1.755	2.22
3	0.5	1.7555	2.2205
3	0.5	1.7555	2.2235
3	0.5	1.757	2.2235
3	0.5	1.755	2.222
3	0.5	1.7545	2.221
3	0.5	1.7535	2.2215
3	0.5	1.7555	2.222
3	0.5	1.756	2.221
3	0.5	1.755	2.22
3	0.5	1.7565	2.219
3	0.5	1.7545	2.2245
3	0.5	1.7555	2.2275
3	0.5	1.755	2.22
3	0.5	1.756	2.2235
3	0.5	1.7555	2.223
3	0.5	1.7575	2.22
3	0.5	1.755	2.224

APPENDIX C.

.308 WINCHESTER CASE LENGTH AND OVERALL LENGTH (OAL) DATA

Summary:

The following table depicts the measured case lengths and overall lengths (OAL) of each .308 Winchester case and completed cartridge. Measurements were done to ensure case length and OAL did not exceed the .308 Winchester maximums of:

Case Length: 2.015”

OAL Length: 2.810”

Flash Hole Diameter (mm)	**Offset Deviation (mm)**	**Case Length (in)**	**OAL (in)**
1.4	0	2.0085	2.7535
1.4	0	2.0075	2.753
1.4	0	2.009	2.7545
1.4	0	2.0065	2.755
1.4	0	2.0045	2.754
1.4	0	2.0095	2.7545
1.4	0	2.009	2.7515
1.4	0	2.008	2.754
1.4	0	2.0075	2.7535
1.4	0	2.0085	2.7525
1.4	0	2.008	2.754
1.4	0	2.0065	2.7535
1.4	0	2.0095	2.754
1.4	0	2.009	2.753
1.4	0	2.007	2.753
1.4	0	2.009	2.753
1.4	0	2.0085	2.7545
1.4	0	2.009	2.7535
1.4	0	2.0095	2.7525
1.4	0	2.0085	2.754
1.4	0	2.0085	2.7535
1.4	0	2.0085	2.754
1.4	0	2.0075	2.7535
1.4	0	2.0095	2.7545
1.4	0	2.01	2.754
1.4	0	2.0095	2.754
1.4	0	2.009	2.7535
1.4	0	2.0085	2.7535
1.4	0	2.009	2.754
1.4	0	2.009	2.7535
1.4	0	2.006	2.752
1.4	0	2.0085	2.7535
1.4	0	2.0085	2.754
1.4	0	2.0095	2.7545
1.4	0	2.008	2.753
1.4	0	2.01	2.7545
1.4	0	2.0055	2.7545
1.4	0	2.0085	2.754

1.4	0	2.0095	2.7525
1.4	0	2.0085	2.752
1.4	0	2.0075	2.7525
1.4	0	2.0065	2.7545
1.4	0	2.007	2.753
1.4	0	2.0055	2.754
1.4	0	2.01	2.755
1.4	0	2.0085	2.7525
1.4	0	2.01	2.752
1.4	0	2.01	2.754
1.4	0	2.007	2.754
1.4	0	2.009	2.754
1.4	0.5	2.009	2.7535
1.4	0.5	2.007	2.754
1.4	0.5	2.008	2.753
1.4	0.5	2.01	2.7545
1.4	0.5	2.0075	2.7525
1.4	0.5	2.009	2.752
1.4	0.5	2.0065	2.7535
1.4	0.5	2.0105	2.7545
1.4	0.5	2.0095	2.754
1.4	0.5	2.0105	2.753
1.4	0.5	2.009	2.753
1.4	0.5	2.0085	2.7535
1.4	0.5	2.009	2.752
1.4	0.5	2.008	2.754
1.4	0.5	2.0095	2.7545
1.4	0.5	2.009	2.752
1.4	0.5	2.0095	2.7525
1.4	0.5	2.01	2.7535
1.4	0.5	2.011	2.753
1.4	0.5	2.01	2.753
1.4	0.5	2.0095	2.7525
1.4	0.5	2.008	2.753
1.4	0.5	2.01	2.7515
1.4	0.5	2.011	2.753
1.4	0.5	2.0095	2.7535
1.4	0.5	2.0105	2.7525
1.4	0.5	2.0105	2.7545
1.4	0.5	2.0105	2.754
1.4	0.5	2.007	2.753

1.4	0.5	2.0075	2.753
1.4	0.5	2.009	2.7535
1.4	0.5	2.01	2.7545
1.4	0.5	2.009	2.7515
1.4	0.5	2.0095	2.753
1.4	0.5	2.009	2.754
1.4	0.5	2.0085	2.753
1.4	0.5	2.0075	2.754
1.4	0.5	2.009	2.7535
1.4	0.5	2.0085	2.7535
1.4	0.5	2.0095	2.754
1.4	0.5	2.009	2.753
1.4	0.5	2.0095	2.7525
1.4	0.5	2.0075	2.754
1.4	0.5	2.009	2.754
1.4	0.5	2.007	2.7535
1.4	0.5	2.01	2.752
1.4	0.5	2.0095	2.752
1.4	0.5	2.0085	2.753
1.4	0.5	2.0095	2.754
1.4	0.5	2.0085	2.7525
1.4	0.5	2.009	2.7525
1.4	0.5	2.006	2.7525
1.4	0.5	2.0085	2.7545
1.4	0.5	2.006	2.7525
1.4	0.5	2.0085	2.7535
1.4	0.5	2.007	2.753
1.4	0.5	2.009	2.753
1.4	0.5	2.0085	2.7515
1.4	0.5	2.008	2.7525
1.4	0.5	2.0105	2.751
1.4	0.5	2.0105	2.7525
1.4	0.5	2.0085	2.752
1.4	0.5	2.0095	2.754
1.4	0.5	2.0075	2.752
1.4	0.5	2.0065	2.7545
1.4	0.5	2.0085	2.7535
1.4	0.5	2.0075	2.7545
1.4	0.5	2.0085	2.7525
1.4	0.5	2.008	2.7545
1.4	0.5	2.009	2.754

1.4	0.5	2.0085	2.754
1.4	0.5	2.0075	2.754
1.4	0.5	2.0075	2.753
1.4	0.5	2.0105	2.7535
1.4	0.5	2.0085	2.754
1.4	0.5	2.006	2.753
1.4	0.5	2.008	2.753
1.4	0.5	2.009	2.7545
1.4	0.5	2.008	2.754
1.4	0.5	2.0075	2.751
1.4	0.5	2.0095	2.7535
1.4	0.5	2.0075	2.7545
1.4	0.5	2.009	2.7535
1.4	0.5	2.007	2.7535
1.4	0.5	2.008	2.7535
1.4	0.5	2.0085	2.7545
1.4	0.5	2.0085	2.7535
1.4	0.5	2.0075	2.753
1.4	0.5	2.008	2.754
1.4	0.5	2.008	2.7545
1.4	1	2.009	2.754
1.4	1	2.008	2.752
1.4	1	2.0075	2.7525
1.4	1	2.01	2.753
1.4	1	2.007	2.7535
1.4	1	2.0075	2.7525
1.4	1	2.0085	2.752
1.4	1	2.0085	2.7545
1.4	1	2.0095	2.752
1.4	1	2.0075	2.7525
1.4	1	2.008	2.7525
1.4	1	2.009	2.7525
1.4	1	2.0065	2.7535
1.4	1	2.008	2.752
1.4	1	2.009	2.7535
1.4	1	2.008	2.7505
1.4	1	2.008	2.754
1.4	1	2.0085	2.752
1.4	1	2.008	2.7515
1.4	1	2.006	2.753
1.4	1	2.0075	2.751

1.4	1	2.008	2.7515
1.4	1	2.008	2.7515
1.4	1	2.0095	2.752
1.4	1	2.007	2.7525
1.4	1	2.0065	2.752
1.4	1	2.0095	2.7525
1.4	1	2.007	2.752
1.4	1	2.005	2.7525
1.4	1	2.008	2.753
1.4	1	2.0095	2.7525
1.4	1	2.007	2.753
1.4	1	2.0055	2.7535
1.4	1	2.008	2.7535
1.4	1	2.0085	2.7525
1.4	1	2.006	2.7535
1.4	1	2.01	2.752
1.4	1	2.009	2.7515
1.4	1	2.0085	2.7535
1.4	1	2.0085	2.7545
1.4	1	2.007	2.751
1.4	1	2.0095	2.7525
1.4	1	2.0075	2.7525
1.4	1	2.01	2.752
1.4	1	2.01	2.7525
1.4	1	2.0085	2.752
1.4	1	2.0095	2.7525
1.4	1	2.0085	2.7525
1.4	1	2.008	2.754
1.4	1	2.008	2.7515
1.4	1	2.008	2.754
1.4	1	2.0075	2.754
1.4	1	2.0085	2.7535
1.4	1	2.0075	2.754
1.4	1	2.009	2.753
1.4	1	2.0075	2.752
1.4	1	2.009	2.753
1.4	1	2.0085	2.753
1.4	1	2.01	2.754
1.4	1	2.0055	2.7525
1.4	1	2.0095	2.7535
1.4	1	2.009	2.7525

1.4	1	2.0095	2.753
1.4	1	2.008	2.751
1.4	1	2.0065	2.7525
1.4	1	2.007	2.753
1.4	1	2.008	2.7525
1.4	1	2.0095	2.7535
1.4	1	2.008	2.751
1.4	1	2.008	2.7515
1.4	1	2.0095	2.752
1.4	1	2.008	2.754
1.4	1	2.0065	2.7525
1.4	1	2.006	2.7525
1.4	1	2.0075	2.7525
1.4	1	2.0085	2.752
1.4	1	2.0075	2.751
1.4	1	2.0065	2.7525
1.4	1	2.005	2.7515
1.4	1	2.008	2.7515
1.4	1	2.0095	2.752
1.4	1	2.009	2.754
1.4	1	2.008	2.7535
1.4	1	2.0075	2.7525
2	0	2.009	2.751
2	0	2.008	2.752
2	0	2.01	2.753
2	0	2.009	2.7535
2	0	2.0085	2.753
2	0	2.0085	2.7535
2	0	2.0095	2.7535
2	0	2.011	2.7525
2	0	2.01	2.7535
2	0	2.01	2.753
2	0	2.006	2.7525
2	0	2.007	2.7535
2	0	2.0085	2.7525
2	0	2.01	2.753
2	0	2.0095	2.754
2	0	2.0055	2.752
2	0	2.009	2.7535
2	0	2.009	2.753
2	0	2.01	2.753

2	0	2.0055	2.752
2	0	2.0095	2.7535
2	0	2.0085	2.751
2	0	2.0065	2.753
2	0	2.006	2.751
2	0	2.0075	2.752
2	0	2.0105	2.7525
2	0	2.0075	2.7525
2	0	2.007	2.7545
2	0	2.0105	2.7535
2	0	2.0095	2.7545
2	0	2.0105	2.7535
2	0	2.0085	2.7535
2	0	2.0105	2.7545
2	0	2.007	2.7525
2	0	2.0105	2.754
2	0	2.01	2.753
2	0	2.01	2.7545
2	0	2.009	2.754
2	0	2.0095	2.753
2	0	2.0095	2.754
2	0	2.009	2.753
2	0	2.0105	2.7535
2	0	2.008	2.753
2	0	2.0085	2.754
2	0	2.0105	2.752
2	0	2.009	2.753
2	0	2.009	2.754
2	0	2.01	2.755
2	0	2.007	2.753
2	0	2.0105	2.753
2	0.5	2.007	2.752
2	0.5	2.01	2.754
2	0.5	2.01	2.7525
2	0.5	2.0075	2.7525
2	0.5	2.006	2.7525
2	0.5	2.0055	2.7535
2	0.5	2.0095	2.753
2	0.5	2.0095	2.7525
2	0.5	2.009	2.753
2	0.5	2.007	2.7525

2	0.5	2.0085	2.752
2	0.5	2.008	2.7525
2	0.5	2.0085	2.7535
2	0.5	2.0105	2.754
2	0.5	2.008	2.7525
2	0.5	2.006	2.7515
2	0.5	2.014	2.7525
2	0.5	2.008	2.752
2	0.5	2.01	2.7525
2	0.5	2.01	2.7535
2	0.5	2.01	2.7535
2	0.5	2.009	2.7525
2	0.5	2.008	2.7545
2	0.5	2.008	2.7535
2	0.5	2.008	2.7515
2	0.5	2.0095	2.754
2	0.5	2.008	2.754
2	0.5	2.009	2.7535
2	0.5	2.008	2.7535
2	0.5	2.009	2.753
2	0.5	2.009	2.754
2	0.5	2.0085	2.7525
2	0.5	2.008	2.7525
2	0.5	2.007	2.7545
2	0.5	2.008	2.752
2	0.5	2.006	2.752
2	0.5	2.009	2.752
2	0.5	2.0065	2.7555
2	0.5	2.0085	2.7545
2	0.5	2.011	2.752
2	0.5	2.008	2.754
2	0.5	2.0075	2.754
2	0.5	2.008	2.753
2	0.5	2.0095	2.7515
2	0.5	2.0085	2.751
2	0.5	2.009	2.7525
2	0.5	2.0075	2.7535
2	0.5	2.0085	2.7535
2	0.5	2.009	2.7555
2	0.5	2.01	2.753
2	0.5	2.0095	2.754

2	0.5	2.0085	2.7515
2	0.5	2.007	2.7525
2	0.5	2.0085	2.7525
2	0.5	2.009	2.752
2	0.5	2.008	2.7525
2	0.5	2.0085	2.753
2	0.5	2.0075	2.753
2	0.5	2.0095	2.7535
2	0.5	2.009	2.752
2	0.5	2.008	2.7525
2	0.5	2.007	2.7535
2	0.5	2.009	2.753
2	0.5	2.008	2.752
2	0.5	2.0085	2.752
2	0.5	2.0095	2.753
2	0.5	2.0085	2.753
2	0.5	2.01	2.7535
2	0.5	2.0095	2.752
2	0.5	2.01	2.7535
2	0.5	2.009	2.7535
2	0.5	2.008	2.7555
2	0.5	2.008	2.752
2	0.5	2.0075	2.754
2	0.5	2.0075	2.7535
2	0.5	2.008	2.753
2	0.5	2.0095	2.7525
2	0.5	2.008	2.753
2	0.5	2.008	2.7535
2	0.5	2.01	2.753
2	0.5	2.009	2.753
2	0.5	2.0095	2.7535
2	0.5	2.0065	2.7535
2	0.5	2.0085	2.7535
2	0.5	2.008	2.7545
2	0.5	2.0085	2.753
2	0.5	2.0085	2.7545
2	0.5	2.0065	2.7535
2	0.5	2.0095	2.7515
2	0.5	2.0095	2.754
2	1	2.009	2.753
2	1	2.007	2.753

2	1	2.0065	2.7525
2	1	2.0115	2.753
2	1	2.0055	2.753
2	1	2.0075	2.7535
2	1	2.0085	2.752
2	1	2.007	2.7515
2	1	2.009	2.753
2	1	2.009	2.753
2	1	2.0105	2.7525
2	1	2.01	2.752
2	1	2.0085	2.753
2	1	2.0065	2.754
2	1	2.0075	2.753
2	1	2.007	2.752
2	1	2.007	2.7525
2	1	2.0085	2.7515
2	1	2.009	2.753
2	1	2.008	2.752
2	1	2.009	2.753
2	1	2.0095	2.7535
2	1	2.007	2.7535
2	1	2.0105	2.754
2	1	2.0105	2.754
2	1	2.007	2.753
2	1	2.0085	2.753
2	1	2.0075	2.7535
2	1	2.0085	2.7545
2	1	2.0075	2.752
2	1	2.0085	2.7535
2	1	2.0105	2.7545
2	1	2.008	2.7525
2	1	2.0075	2.7525
2	1	2.008	2.7535
2	1	2.0075	2.7535
2	1	2.0095	2.7535
2	1	2.008	2.752
2	1	2.006	2.755
2	1	2.0085	2.754
2	1	2.007	2.7525
2	1	2.005	2.7545
2	1	2.009	2.7545

2	1	2.008	2.753
2	1	2.008	2.754
2	1	2.008	2.752
2	1	2.008	2.753
2	1	2.0085	2.754
2	1	2.009	2.752
2	1	2.0075	2.753
2	1	2.0095	2.7535
2	1	2.005	2.753
2	1	2.008	2.7545
2	1	2.0065	2.7545
2	1	2.007	2.754
2	1	2.0095	2.7565
2	1	2.0065	2.7535
2	1	2.007	2.7535
2	1	2.0095	2.754
2	1	2.01	2.7535
2	1	2.008	2.754
2	1	2.008	2.7545
2	1	2.01	2.7535
2	1	2.007	2.7555
2	1	2.007	2.753
2	1	2.0075	2.754
2	1	2.0085	2.7535
2	1	2.007	2.755
2	1	2.0085	2.7535
2	1	2.008	2.7535
2	1	2.007	2.7525
2	1	2.0095	2.754
2	1	2.007	2.754
2	1	2.0065	2.7525
2	1	2.01	2.7545
2	1	2.0065	2.753
2	1	2.0085	2.753
2	1	2.0095	2.7545
2	1	2.007	2.755
2	1	2.01	2.7525
2	1	2.0085	2.7535
2	1	2.0085	2.755
2	1	2.0105	2.754
2	1	2.008	2.753

2	1	2.009	2.7535
2	1	2.009	2.7535
2	1	2.0085	2.755
2	1	2.0085	2.7525
2	1	2.0065	2.754
2	1	2.009	2.753
2.4	0	2.0075	2.7535
2.4	0	2.009	2.7525
2.4	0	2.01	2.7525
2.4	0	2.009	2.7535
2.4	0	2.0055	2.7545
2.4	0	2.0095	2.7545
2.4	0	2.0085	2.7535
2.4	0	2.007	2.7535
2.4	0	2.01	2.7535
2.4	0	2.0085	2.753
2.4	0	2.0085	2.753
2.4	0	2.007	2.754
2.4	0	2.007	2.753
2.4	0	2.0105	2.7525
2.4	0	2.0055	2.7535
2.4	0	2.0055	2.7535
2.4	0	2.007	2.7535
2.4	0	2.0075	2.7535
2.4	0	2.009	2.753
2.4	0	2.0085	2.753
2.4	0	2.0075	2.755
2.4	0	2.008	2.753
2.4	0	2.0055	2.7535
2.4	0	2.0095	2.7535
2.4	0	2.0075	2.7525
2.4	0	2.007	2.7535
2.4	0	2.009	2.753
2.4	0	2.0085	2.7545
2.4	0	2.0085	2.7525
2.4	0	2.009	2.753
2.4	0	2.009	2.7535
2.4	0	2.0075	2.7535
2.4	0	2.0095	2.7535
2.4	0	2.0105	2.754
2.4	0	2.009	2.7525

2.4	0	2.0065	2.7525
2.4	0	2.0085	2.752
2.4	0	2.009	2.754
2.4	0	2.009	2.7535
2.4	0	2.009	2.753
2.4	0	2.0075	2.752
2.4	0	2.0085	2.754
2.4	0	2.009	2.753
2.4	0	2.0085	2.753
2.4	0	2.01	2.7525
2.4	0	2.0095	2.7545
2.4	0	2.009	2.7545
2.4	0	2.01	2.7555
2.4	0	2.009	2.7525
2.4	0	2.0085	2.7555
2.4	0.5	2.0075	2.754
2.4	0.5	2.009	2.7515
2.4	0.5	2.009	2.751
2.4	0.5	2.0065	2.7535
2.4	0.5	2.0065	2.754
2.4	0.5	2.0085	2.7535
2.4	0.5	2.0095	2.7525
2.4	0.5	2.01	2.7535
2.4	0.5	2.0085	2.752
2.4	0.5	2.007	2.752
2.4	0.5	2.005	2.754
2.4	0.5	2.009	2.7525
2.4	0.5	2.009	2.7525
2.4	0.5	2.007	2.7525
2.4	0.5	2.01	2.7535
2.4	0.5	2.009	2.751
2.4	0.5	2.009	2.753
2.4	0.5	2.0085	2.7545
2.4	0.5	2.008	2.753
2.4	0.5	2.009	2.754
2.4	0.5	2.0075	2.753
2.4	0.5	2.009	2.753
2.4	0.5	2.0075	2.753
2.4	0.5	2.005	2.7525
2.4	0.5	2.0085	2.7535
2.4	0.5	2.009	2.752

2.4	0.5	2.009	2.751
2.4	0.5	2.009	2.7525
2.4	0.5	2.006	2.7535
2.4	0.5	2.007	2.755
2.4	0.5	2.007	2.7545
2.4	0.5	2.0095	2.752
2.4	0.5	2.008	2.753
2.4	0.5	2.0085	2.7515
2.4	0.5	2.0065	2.753
2.4	0.5	2.009	2.753
2.4	0.5	2.006	2.753
2.4	0.5	2.007	2.7535
2.4	0.5	2.009	2.7545
2.4	0.5	2.0085	2.753
2.4	0.5	2.0065	2.753
2.4	0.5	2.0065	2.752
2.4	0.5	2.009	2.7525
2.4	0.5	2.006	2.7525
2.4	0.5	2.008	2.752
2.4	0.5	2.009	2.7525
2.4	0.5	2.01	2.7525
2.4	0.5	2.008	2.754
2.4	0.5	2.008	2.754
2.4	0.5	2.0075	2.753
2.4	0.5	2.0085	2.7545
2.4	0.5	2.007	2.7535
2.4	0.5	2.007	2.753
2.4	0.5	2.0085	2.754
2.4	0.5	2.007	2.755
2.4	0.5	2.008	2.7535
2.4	0.5	2.009	2.7525
2.4	0.5	2.0065	2.7545
2.4	0.5	2.0085	2.753
2.4	0.5	2.009	2.753
2.4	0.5	2.01	2.751
2.4	0.5	2.009	2.7545
2.4	0.5	2.0075	2.7545
2.4	0.5	2.0085	2.7535
2.4	0.5	2.0075	2.7525
2.4	0.5	2.009	2.754
2.4	0.5	2.008	2.754

2.4	0.5	2.007	2.753
2.4	0.5	2.01	2.7525
2.4	0.5	2.0065	2.754
2.4	0.5	2.0075	2.7545
2.4	0.5	2.0065	2.753
2.4	0.5	2.005	2.753
2.4	0.5	2.009	2.7535
2.4	0.5	2.009	2.753
2.4	0.5	2.007	2.7545
2.4	0.5	2.009	2.754
2.4	0.5	2.009	2.7535
2.4	0.5	2.0075	2.7515
2.4	0.5	2.008	2.7525
2.4	0.5	2.008	2.753
2.4	0.5	2.008	2.7525
2.4	0.5	2.009	2.7545
2.4	0.5	2.009	2.7525
2.4	0.5	2.008	2.7555
2.4	0.5	2.007	2.7545
2.4	0.5	2.009	2.753
2.4	0.5	2.0125	2.753
2.4	0.5	2.008	2.7525
2.4	0.5	2.01	2.754
2.4	1	2.0075	2.7535
2.4	1	2.005	2.754
2.4	1	2.009	2.754
2.4	1	2.0085	2.754
2.4	1	2.0085	2.7525
2.4	1	2.0085	2.7525
2.4	1	2.012	2.7525
2.4	1	2.011	2.754
2.4	1	2.009	2.7535
2.4	1	2.01	2.7525
2.4	1	2.008	2.7525
2.4	1	2.0095	2.753
2.4	1	2.0095	2.7535
2.4	1	2.0075	2.7525
2.4	1	2.0105	2.753
2.4	1	2.0055	2.753
2.4	1	2.008	2.752
2.4	1	2.009	2.7515

2.4	1	2.0065	2.7535
2.4	1	2.005	2.754
2.4	1	2.0065	2.753
2.4	1	2.01	2.753
2.4	1	2.007	2.751
2.4	1	2.008	2.754
2.4	1	2.008	2.752
2.4	1	2.0065	2.753
2.4	1	2.008	2.7545
2.4	1	2.005	2.7545
2.4	1	2.009	2.754
2.4	1	2.0065	2.753
2.4	1	2.0095	2.754
2.4	1	2.0075	2.755
2.4	1	2.0075	2.754
2.4	1	2.0055	2.754
2.4	1	2.009	2.7525
2.4	1	2.007	2.7535
2.4	1	2.0065	2.754
2.4	1	2.0095	2.7525
2.4	1	2.0095	2.753
2.4	1	2.009	2.754
2.4	1	2.0085	2.7545
2.4	1	2.009	2.754
2.4	1	2.009	2.7525
2.4	1	2.0085	2.7525
2.4	1	2.0065	2.754
2.4	1	2.009	2.754
2.4	1	2.0085	2.7535
2.4	1	2.009	2.754
2.4	1	2.008	2.7535
2.4	1	2.0095	2.752
2.4	1	2.007	2.753
2.4	1	2.008	2.7545
2.4	1	2.0065	2.7535
2.4	1	2.008	2.7535
2.4	1	2.0095	2.7535
2.4	1	2.0075	2.7525
2.4	1	2.0075	2.7535
2.4	1	2.0085	2.753
2.4	1	2.008	2.754

2.4	1	2.009	2.753
2.4	1	2.006	2.7545
2.4	1	2.009	2.7535
2.4	1	2.006	2.754
2.4	1	2.0085	2.754
2.4	1	2.008	2.7545
2.4	1	2.0075	2.754
2.4	1	2.0085	2.7555
2.4	1	2.008	2.7555
2.4	1	2.0065	2.7555
2.4	1	2.008	2.753
2.4	1	2.008	2.7545
2.4	1	2.0065	2.7545
2.4	1	2.007	2.7535
2.4	1	2.009	2.751
2.4	1	2.008	2.752
2.4	1	2.0095	2.7525
2.4	1	2.008	2.7535
2.4	1	2.007	2.753
2.4	1	2.0085	2.753
2.4	1	2.007	2.7535
2.4	1	2.0065	2.7525
2.4	1	2.008	2.7525
2.4	1	2.0095	2.752
2.4	1	2.0065	2.754
2.4	1	2.0065	2.7545
2.4	1	2.0055	2.7525
2.4	1	2.008	2.755
2.4	1	2.01	2.7515
2.4	1	2.0055	2.7535
2.4	1	2.0095	2.7525
2.8	0	2.009	2.7535
2.8	0	2.0075	2.754
2.8	0	2.0095	2.7515
2.8	0	2.009	2.7515
2.8	0	2.009	2.7515
2.8	0	2.0095	2.753
2.8	0	2.0085	2.7515
2.8	0	2.0105	2.7515
2.8	0	2.0075	2.753
2.8	0	2.0085	2.7525

2.8	0	2.0085	2.7545
2.8	0	2.0095	2.7525
2.8	0	2.01	2.754
2.8	0	2.0085	2.753
2.8	0	2.0075	2.752
2.8	0	2.0095	2.7535
2.8	0	2.0075	2.7525
2.8	0	2.009	2.7525
2.8	0	2.0065	2.751
2.8	0	2.009	2.7535
2.8	0	2.009	2.753
2.8	0	2.008	2.75
2.8	0	2.0085	2.7535
2.8	0	2.007	2.754
2.8	0	2.0095	2.7535
2.8	0	2.008	2.7525
2.8	0	2.0075	2.752
2.8	0	2.007	2.7535
2.8	0	2.009	2.7525
2.8	0	2.009	2.752
2.8	0	2.009	2.7505
2.8	0	2.008	2.7525
2.8	0	2.01	2.752
2.8	0	2.0085	2.7525
2.8	0	2.009	2.7525
2.8	0	2.008	2.753
2.8	0	2.0095	2.754
2.8	0	2.008	2.7525
2.8	0	2.008	2.751
2.8	0	2.01	2.7515
2.8	0	2.006	2.7525
2.8	0	2.008	2.755
2.8	0	2.0085	2.753
2.8	0	2.0095	2.7545
2.8	0	2.0105	2.7525
2.8	0	2.0105	2.755
2.8	0	2.0095	2.7525
2.8	0	2.0085	2.7535
2.8	0	2.009	2.7525
2.8	0	2.0095	2.7525
2.8	0.5	2.009	2.7545

2.8	0.5	2.0095	2.754
2.8	0.5	2.01	2.752
2.8	0.5	2.0075	2.7525
2.8	0.5	2.009	2.755
2.8	0.5	2.0075	2.754
2.8	0.5	2.0075	2.753
2.8	0.5	2.008	2.7545
2.8	0.5	2.0065	2.7515
2.8	0.5	2.007	2.754
2.8	0.5	2.009	2.754
2.8	0.5	2.009	2.7545
2.8	0.5	2.009	2.7555
2.8	0.5	2.0095	2.754
2.8	0.5	2.009	2.754
2.8	0.5	2.0065	2.7525
2.8	0.5	2.01	2.7535
2.8	0.5	2.0075	2.7545
2.8	0.5	2.009	2.7545
2.8	0.5	2.0075	2.7525
2.8	0.5	2.009	2.7555
2.8	0.5	2.006	2.754
2.8	0.5	2.0095	2.7535
2.8	0.5	2.0085	2.7525
2.8	0.5	2.008	2.7535
2.8	0.5	2.0055	2.7545
2.8	0.5	2.0095	2.7545
2.8	0.5	2.0085	2.7535
2.8	0.5	2.0095	2.753
2.8	0.5	2.008	2.754
2.8	0.5	2.0095	2.7545
2.8	0.5	2.009	2.754
2.8	0.5	2.0095	2.7545
2.8	0.5	2.0085	2.7535
2.8	0.5	2.008	2.752
2.8	0.5	2.007	2.7545
2.8	0.5	2.008	2.754
2.8	0.5	2.004	2.755
2.8	0.5	2.01	2.753
2.8	0.5	2.0095	2.753
2.8	0.5	2.0075	2.7535
2.8	0.5	2.0085	2.755

2.8	0.5	2.0095	2.7535
2.8	0.5	2.008	2.753
2.8	0.5	2.008	2.7535
2.8	0.5	2.007	2.7535
2.8	0.5	2.008	2.7535
2.8	0.5	2.0085	2.753
2.8	0.5	2.0105	2.7535
2.8	0.5	2.009	2.755
2.8	0.5	2.009	2.7545
2.8	0.5	2.0065	2.7525
2.8	0.5	2.005	2.752
2.8	0.5	2.0095	2.753
2.8	0.5	2.006	2.752
2.8	0.5	2.009	2.7535
2.8	0.5	2.0095	2.753
2.8	0.5	2.009	2.752
2.8	0.5	2.006	2.754
2.8	0.5	2.007	2.7535
2.8	0.5	2.007	2.7525
2.8	0.5	2.0095	2.752
2.8	0.5	2.0075	2.7525
2.8	0.5	2.0055	2.7545
2.8	0.5	2.008	2.754
2.8	0.5	2.007	2.7525
2.8	0.5	2.008	2.7535
2.8	0.5	2.0065	2.752
2.8	0.5	2.0065	2.753
2.8	0.5	2.008	2.754
2.8	0.5	2.007	2.7545
2.8	0.5	2.0055	2.7545
2.8	0.5	2.007	2.7525
2.8	0.5	2.0065	2.754
2.8	0.5	2.0055	2.7535
2.8	0.5	2.009	2.7525
2.8	0.5	2.008	2.7535
2.8	0.5	2.008	2.7535
2.8	0.5	2.0085	2.7545
2.8	0.5	2.0055	2.752
2.8	0.5	2.0075	2.7525
2.8	0.5	2.009	2.753
2.8	0.5	2.009	2.754

2.8	0.5	2.01	2.752
2.8	0.5	2.0075	2.754
2.8	0.5	2.0085	2.753
2.8	0.5	2.01	2.7535
2.8	0.5	2.0085	2.7545
2.8	0.5	2.0065	2.7535
2.8	0.5	2.008	2.7535
2.8	1	2.0075	2.7525
2.8	1	2.0095	2.7525
2.8	1	2.007	2.7545
2.8	1	2.007	2.7525
2.8	1	2.005	2.7535
2.8	1	2.0065	2.7515
2.8	1	2.008	2.7525
2.8	1	2.009	2.752
2.8	1	2.009	2.752
2.8	1	2.007	2.753
2.8	1	2.0065	2.753
2.8	1	2.006	2.753
2.8	1	2.0095	2.753
2.8	1	2.0075	2.753
2.8	1	2.006	2.7535
2.8	1	2.0095	2.7525
2.8	1	2.0075	2.755
2.8	1	2.0085	2.754
2.8	1	2.0075	2.751
2.8	1	2.008	2.7525
2.8	1	2.008	2.7525
2.8	1	2.01	2.754
2.8	1	2.009	2.753
2.8	1	2.005	2.7525
2.8	1	2.0085	2.7535
2.8	1	2.008	2.752
2.8	1	2.0075	2.7535
2.8	1	2.007	2.7525
2.8	1	2.0075	2.7545
2.8	1	2.009	2.754
2.8	1	2.0095	2.752
2.8	1	2.0105	2.754
2.8	1	2.0045	2.7535
2.8	1	2.008	2.753

2.8	1	2.0085	2.753
2.8	1	2.006	2.751
2.8	1	2.008	2.752
2.8	1	2.0095	2.754
2.8	1	2.0105	2.7545
2.8	1	2.0095	2.7545
2.8	1	2.005	2.7525
2.8	1	2.007	2.754
2.8	1	2.007	2.755
2.8	1	2.0085	2.753
2.8	1	2.0085	2.754
2.8	1	2.008	2.753
2.8	1	2.006	2.7525
2.8	1	2.009	2.7525
2.8	1	2.0065	2.753
2.8	1	2.008	2.755
2.8	1	2.0085	2.7545
2.8	1	2.0075	2.754
2.8	1	2.0085	2.754
2.8	1	2.0075	2.754
2.8	1	2.009	2.751
2.8	1	2.0065	2.7535
2.8	1	2.007	2.752
2.8	1	2.0105	2.753
2.8	1	2.0105	2.7525
2.8	1	2.0075	2.7535
2.8	1	2.0085	2.7535
2.8	1	2.0095	2.7535
2.8	1	2.007	2.753
2.8	1	2.0095	2.7525
2.8	1	2.0055	2.7515
2.8	1	2.0095	2.7525
2.8	1	2.007	2.7525
2.8	1	2.01	2.754
2.8	1	2.008	2.7505
2.8	1	2.0075	2.7515
2.8	1	2.0085	2.754
2.8	1	2.0085	2.7525
2.8	1	2.0095	2.7535
2.8	1	2.0085	2.753
2.8	1	2.007	2.754

2.8	1	2.006	2.7535
2.8	1	2.008	2.7525
2.8	1	2.007	2.753
2.8	1	2.008	2.7525
2.8	1	2.007	2.7525
2.8	1	2.0035	2.753
2.8	1	2.007	2.754
2.8	1	2.007	2.7535
2.8	1	2.0095	2.754
2.8	1	2.007	2.754
2.8	1	2.0075	2.753
2.8	1	2.005	2.754
2.8	1	2.008	2.753
2.8	1	2.007	2.7535
2.8	1	2.0085	2.754
3	0	2.0085	2.753
3	0	2.01	2.752
3	0	2.0085	2.7535
3	0	2.007	2.754
3	0	2.0105	2.7535
3	0	2.0095	2.753
3	0	2.009	2.7545
3	0	2.009	2.7545
3	0	2.0075	2.754
3	0	2.0105	2.7545
3	0	2.0095	2.7525
3	0	2.007	2.753
3	0	2.0085	2.752
3	0	2.011	2.7545
3	0	2.009	2.7545
3	0	2.007	2.7525
3	0	2.008	2.753
3	0	2.0085	2.754
3	0	2.008	2.754
3	0	2.009	2.752
3	0	2.0085	2.754
3	0	2.008	2.7525
3	0	2.0085	2.751
3	0	2.0075	2.7545
3	0	2.008	2.7525
3	0	2.0065	2.7545

3	0	2.0095	2.7545
3	0	2.01	2.7525
3	0	2.008	2.7535
3	0	2.008	2.7525
3	0	2.0085	2.753
3	0	2.008	2.7545
3	0	2.009	2.7525
3	0	2.0085	2.7535
3	0	2.0085	2.7545
3	0	2.0085	2.753
3	0	2.009	2.7535
3	0	2.0075	2.7525
3	0	2.009	2.7525
3	0	2.0105	2.754
3	0	2.0085	2.754
3	0	2.0055	2.754
3	0	2.009	2.7535
3	0	2.0075	2.752
3	0	2.0075	2.7535
3	0	2.0085	2.7545
3	0	2.01	2.7535
3	0	2.01	2.7545
3	0	2.01	2.753
3	0	2.0095	2.7535
3	0.5	2.0075	2.753
3	0.5	2.0055	2.752
3	0.5	2.0105	2.7525
3	0.5	2.007	2.754
3	0.5	2.0085	2.753
3	0.5	2.0105	2.752
3	0.5	2.0075	2.7525
3	0.5	2.007	2.7535
3	0.5	2.0095	2.7535
3	0.5	2.009	2.7535
3	0.5	2.0055	2.7525
3	0.5	2.01	2.7535
3	0.5	2.0105	2.7535
3	0.5	2.011	2.7525
3	0.5	2.0095	2.7525
3	0.5	2.0065	2.753
3	0.5	2.0085	2.7525

3	0.5	2.009	2.7535
3	0.5	2.008	2.7535
3	0.5	2.006	2.7535
3	0.5	2.0065	2.754
3	0.5	2.0085	2.7535
3	0.5	2.0065	2.7525
3	0.5	2.0085	2.754
3	0.5	2.007	2.754
3	0.5	2.0085	2.7535
3	0.5	2.005	2.7525
3	0.5	2.0085	2.7535
3	0.5	2.01	2.7535
3	0.5	2.008	2.7535
3	0.5	2.0075	2.7535
3	0.5	2.0075	2.754
3	0.5	2.0075	2.752
3	0.5	2.006	2.75
3	0.5	2.0085	2.7535
3	0.5	2.009	2.752
3	0.5	2.0075	2.7525
3	0.5	2.0105	2.753
3	0.5	2.009	2.7535
3	0.5	2.0075	2.753
3	0.5	2.0085	2.755
3	0.5	2.009	2.7525
3	0.5	2.0065	2.7515
3	0.5	2.009	2.751
3	0.5	2.0075	2.7515
3	0.5	2.0085	2.7535
3	0.5	2.0085	2.7535
3	0.5	2.008	2.7545
3	0.5	2.009	2.7535
3	0.5	2.0085	2.7525
3	0.5	2.007	2.7535
3	0.5	2.009	2.7525
3	0.5	2.009	2.753
3	0.5	2.0075	2.753
3	0.5	2.0095	2.7535
3	0.5	2.0085	2.7525
3	0.5	2.0055	2.751
3	0.5	2.0085	2.7545

3	0.5	2.0095	2.7535
3	0.5	2.0075	2.753
3	0.5	2.0055	2.7515
3	0.5	2.009	2.755
3	0.5	2.007	2.7535
3	0.5	2.007	2.7515
3	0.5	2.006	2.7545
3	0.5	2.008	2.755
3	0.5	2.0065	2.753
3	0.5	2.008	2.7535
3	0.5	2.009	2.7535
3	0.5	2.009	2.7535
3	0.5	2.009	2.7535
3	0.5	2.006	2.7535
3	0.5	2.008	2.752
3	0.5	2.0095	2.752
3	0.5	2.007	2.753
3	0.5	2.009	2.7515
3	0.5	2.009	2.753
3	0.5	2.0085	2.7545
3	0.5	2.008	2.7525
3	0.5	2.008	2.753
3	1	2.009	2.7525
3	1	2.009	2.751
3	1	2.0075	2.7535
3	1	2.008	2.7505
3	1	2.0095	2.7525
3	1	2.0095	2.754
3	1	2.0095	2.7535
3	1	2.0075	2.7525
3	1	2.009	2.754
3	1	2.0095	2.755
3	1	2.009	2.7535
3	1	2.009	2.753
3	1	2.01	2.752
3	1	2.007	2.7525
3	1	2.008	2.7525
3	1	2.0095	2.7525
3	1	2.009	2.754
3	1	2.0075	2.754
3	1	2.01	2.753

3	1	2.0085	2.7525
3	1	2.009	2.7545
3	1	2.007	2.7545
3	1	2.009	2.7525
3	1	2.009	2.7545
3	1	2.0095	2.7535
3	1	2.0065	2.753
3	1	2.009	2.7545
3	1	2.0075	2.7525
3	1	2.008	2.7545
3	1	2.0075	2.7525
3	1	2.007	2.7525
3	1	2.009	2.7535
3	1	2.01	2.752
3	1	2.007	2.7525
3	1	2.0095	2.7525
3	1	2.008	2.7535
3	1	2.01	2.755
3	1	2.01	2.754
3	1	2.0085	2.7525
3	1	2.009	2.7545
3	1	2.007	2.7525
3	1	2.01	2.754
3	1	2.009	2.752
3	1	2.0085	2.755
3	1	2.0075	2.7545
3	1	2.01	2.7545
3	1	2.008	2.7525
3	1	2.0085	2.7545
3	1	2.01	2.754
3	1	2.011	2.753
3	1	2.0085	2.753
3	1	2.0095	2.753
3	1	2.0085	2.7525
3	1	2.005	2.753
3	1	2.009	2.754
3	1	2.0085	2.751
3	1	2.007	2.7525
3	1	2.0095	2.753
3	1	2.009	2.7545
3	1	2.0075	2.7535

3	1	2.0085	2.7535
3	1	2.0075	2.754
3	1	2.0095	2.7525
3	1	2.008	2.7545
3	1	2.0065	2.753
3	1	2.0095	2.754
3	1	2.0075	2.752
3	1	2.01	2.7545
3	1	2.008	2.753
3	1	2.008	2.753
3	1	2.008	2.7545
3	1	2.0065	2.752
3	1	2.008	2.754
3	1	2.009	2.7525
3	1	2.0085	2.753
3	1	2.0085	2.7525
3	1	2.0095	2.753
3	1	2.0075	2.753
3	1	2.009	2.7525
3	1	2.0075	2.7535
3	1	2.008	2.7525
3	1	2.008	2.7525
3	1	2.0065	2.7535
3	1	2.008	2.752
3	1	2.009	2.754
3	1	2.008	2.7535
3	1	2.0085	2.751
3	1	2.0055	2.7535
3	1	2.009	2.7525

APPENDIX D.

.223 REMINGTON RANGE VELOCITY AND PRECISION DATA

Summary:

The following is the .223 Remington muzzle velocity and precision data measurements acquired during private range testing outside of Rolla, MO. The highlighted values in the table represent outlier values that were removed prior to normalizing the data.

Flash Hole Diameter (mm)	Offset Deviation (mm)	Offset Location	Velocity (fps)	Max Spread (CTC) (inches)	MOA (in)	Average to Center (in)	MOA (in)
1.4	0	Center	2760	1.828	1.746	0.503	0.481
1.4	0	Center	2640	1.828	1.746	0.503	0.481
1.4	0	Center	2666	1.828	1.746	0.503	0.481
1.4	0	Center	2594	1.828	1.746	0.503	0.481
1.4	0	Center	2599	1.828	1.746	0.503	0.481
1.4	0	Center	2650	1.828	1.746	0.503	0.481
1.4	0	Center	2594	1.828	1.746	0.503	0.481
1.4	0	Center	2656	1.828	1.746	0.503	0.481
1.4	0	Center	2640	1.828	1.746	0.503	0.481
1.4	0	Center	2650	1.828	1.746	0.503	0.481
1.4	0.5	Up	2677	2.006	1.916	0.679	0.649
1.4	0.5	Up	2604	2.006	1.916	0.679	0.649
1.4	0.5	Up	2619	2.006	1.916	0.679	0.649
1.4	0.5	Up	2640	2.006	1.916	0.679	0.649
1.4	0.5	Up	2645	2.006	1.916	0.679	0.649
1.4	0.5	Up	2614	2.006	1.916	0.679	0.649
1.4	0.5	Up	2624	2.006	1.916	0.679	0.649
1.4	0.5	Up	2614	2.006	1.916	0.679	0.649
1.4	0.5	Up	2619	2.006	1.916	0.679	0.649
1.4	0.5	Up	2564	2.006	1.916	0.679	0.649
1.4	0.5	Side	2588	1.568	1.498	0.65	0.621
1.4	0.5	Side	2624	1.568	1.498	0.65	0.621
1.4	0.5	Side	2629	1.568	1.498	0.65	0.621
1.4	0.5	Side	2614	1.568	1.498	0.65	0.621
1.4	0.5	Side	2624	1.568	1.498	0.65	0.621
1.4	0.5	Side	2624	1.568	1.498	0.65	0.621
1.4	0.5	Side	2604	1.568	1.498	0.65	0.621
1.4	0.5	Side	2629	1.568	1.498	0.65	0.621
1.4	0.5	Side	2635	1.568	1.498	0.65	0.621
1.4	0.5	Side	2635	1.568	1.498	0.65	0.621
1.4	0.5	Down	2682	2.104	2.01	0.649	0.619
1.4	0.5	Down	2721	2.104	2.01	0.649	0.619
1.4	0.5	Down	2672	2.104	2.01	0.649	0.619
1.4	0.5	Down	2666	2.104	2.01	0.649	0.619
1.4	0.5	Down	2699	2.104	2.01	0.649	0.619
1.4	0.5	Down	2682	2.104	2.01	0.649	0.619
1.4	0.5	Down	2704	2.104	2.01	0.649	0.619
1.4	0.5	Down	2710	2.104	2.01	0.649	0.619

1.4	0.5	Down	2682	2.104	2.01	0.649	0.619
1.4	0.5	Down	2704	2.104	2.01	0.649	0.619
1.4	1	Up	2614	3.353	3.203	0.989	0.944
1.4	1	Up	2624	3.353	3.203	0.989	0.944
1.4	1	Up	2599	3.353	3.203	0.989	0.944
1.4	1	Up	2614	3.353	3.203	0.989	0.944
1.4	1	Up	2624	3.353	3.203	0.989	0.944
1.4	1	Up	2754	3.353	3.203	0.989	0.944
1.4	1	Up	2635	3.353	3.203	0.989	0.944
1.4	1	Up	2661	3.353	3.203	0.989	0.944
1.4	1	Up	2645	3.353	3.203	0.989	0.944
1.4	1	Up	2661	3.353	3.203	0.989	0.944
1.4	1	Side	2640	1.562	1.492	0.633	0.604
1.4	1	Side	2666	1.562	1.492	0.633	0.604
1.4	1	Side	2599	1.562	1.492	0.633	0.604
1.4	1	Side	2645	1.562	1.492	0.633	0.604
1.4	1	Side	2749	1.562	1.492	0.633	0.604
1.4	1	Side	2704	1.562	1.492	0.633	0.604
1.4	1	Side	2688	1.562	1.492	0.633	0.604
1.4	1	Side	2666	1.562	1.492	0.633	0.604
1.4	1	Side	2682	1.562	1.492	0.633	0.604
1.4	1	Side	2645	1.562	1.492	0.633	0.604
1.4	1	Down	2677	2.143	2.047	0.697	0.666
1.4	1	Down	2842	2.143	2.047	0.697	0.666
1.4	1	Down	2710	2.143	2.047	0.697	0.666
1.4	1	Down	2688	2.143	2.047	0.697	0.666
1.4	1	Down	2682	2.143	2.047	0.697	0.666
1.4	1	Down	2721	2.143	2.047	0.697	0.666
1.4	1	Down	2721	2.143	2.047	0.697	0.666
1.4	1	Down	2693	2.143	2.047	0.697	0.666
1.4	1	Down	2682	2.143	2.047	0.697	0.666
1.4	1	Down	2682	2.143	2.047	0.697	0.666
2	0	Center	2666	2.081	1.988	0.609	0.582
2	0	Center	2656	2.081	1.988	0.609	0.582
2	0	Center	2635	2.081	1.988	0.609	0.582
2	0	Center	2677	2.081	1.988	0.609	0.582
2	0	Center	2699	2.081	1.988	0.609	0.582
2	0	Center	2726	2.081	1.988	0.609	0.582
2	0	Center	2650	2.081	1.988	0.609	0.582
2	0	Center	2930	2.081	1.988	0.609	0.582
2	0	Center	2688	2.081	1.988	0.609	0.582

2	0	Center	2677	2.081	1.988	0.609	0.582
2	0.5	Up	2661	2.255	2.153	0.752	0.718
2	0.5	Up	2661	2.255	2.153	0.752	0.718
2	0.5	Up	2656	2.255	2.153	0.752	0.718
2	0.5	Up	2732	2.255	2.153	0.752	0.718
2	0.5	Up	2645	2.255	2.153	0.752	0.718
2	0.5	Up	2672	2.255	2.153	0.752	0.718
2	0.5	Up	2693	2.255	2.153	0.752	0.718
2	0.5	Up	2672	2.255	2.153	0.752	0.718
2	0.5	Up	2726	2.255	2.153	0.752	0.718
2	0.5	Up	2704	2.255	2.153	0.752	0.718
2	0.5	Side	2688	1.584	1.512	0.585	0.559
2	0.5	Side	2693	1.584	1.512	0.585	0.559
2	0.5	Side	2661	1.584	1.512	0.585	0.559
2	0.5	Side	2737	1.584	1.512	0.585	0.559
2	0.5	Side	2677	1.584	1.512	0.585	0.559
2	0.5	Side	2677	1.584	1.512	0.585	0.559
2	0.5	Side	2682	1.584	1.512	0.585	0.559
2	0.5	Side	2693	1.584	1.512	0.585	0.559
2	0.5	Side	2721	1.584	1.512	0.585	0.559
2	0.5	Side	2710	1.584	1.512	0.585	0.559
2	0.5	Down	2726	3.015	2.88	0.857	0.819
2	0.5	Down	2818	3.015	2.88	0.857	0.819
2	0.5	Down	2688	3.015	2.88	0.857	0.819
2	0.5	Down	2650	3.015	2.88	0.857	0.819
2	0.5	Down	2710	3.015	2.88	0.857	0.819
2	0.5	Down	2726	3.015	2.88	0.857	0.819
2	0.5	Down	2710	3.015	2.88	0.857	0.819
2	0.5	Down	2715	3.015	2.88	0.857	0.819
2	0.5	Down	2704	3.015	2.88	0.857	0.819
2	0.5	Down	2699	3.015	2.88	0.857	0.819
2	1	Up	2635	1.209	1.154	0.367	0.351
2	1	Up	2824	1.209	1.154	0.367	0.351
2	1	Up	2650	1.209	1.154	0.367	0.351
2	1	Up	2710	1.209	1.154	0.367	0.351
2	1	Up	2604	1.209	1.154	0.367	0.351
2	1	Up	2672	1.209	1.154	0.367	0.351
2	1	Up	2661	1.209	1.154	0.367	0.351
2	1	Up	2693	1.209	1.154	0.367	0.351
2	1	Up	2704	1.209	1.154	0.367	0.351
2	1	Up	2693	1.209	1.154	0.367	0.351

2	1	Side	2693	1.952	1.864	0.663	0.633
2	1	Side	2693	1.952	1.864	0.663	0.633
2	1	Side	2688	1.952	1.864	0.663	0.633
2	1	Side	2732	1.952	1.864	0.663	0.633
2	1	Side	2672	1.952	1.864	0.663	0.633
2	1	Side	2682	1.952	1.864	0.663	0.633
2	1	Side	2754	1.952	1.864	0.663	0.633
2	1	Side	2715	1.952	1.864	0.663	0.633
2	1	Side	2699	1.952	1.864	0.663	0.633
2	1	Side	2726	1.952	1.864	0.663	0.633
2	1	Down	2704	1.817	1.735	0.705	0.674
2	1	Down	2732	1.817	1.735	0.705	0.674
2	1	Down	2766	1.817	1.735	0.705	0.674
2	1	Down	2749	1.817	1.735	0.705	0.674
2	1	Down	2726	1.817	1.735	0.705	0.674
2	1	Down	2721	1.817	1.735	0.705	0.674
2	1	Down	2737	1.817	1.735	0.705	0.674
2	1	Down	2710	1.817	1.735	0.705	0.674
2	1	Down	2789	1.817	1.735	0.705	0.674
2	1	Down	2766	1.817	1.735	0.705	0.674
2.4	0	Center	2650	2.041	1.949	0.618	0.591
2.4	0	Center	2650	2.041	1.949	0.618	0.591
2.4	0	Center	2604	2.041	1.949	0.618	0.591
2.4	0	Center	2640	2.041	1.949	0.618	0.591
2.4	0	Center	2574	2.041	1.949	0.618	0.591
2.4	0	Center	2604	2.041	1.949	0.618	0.591
2.4	0	Center	2583	2.041	1.949	0.618	0.591
2.4	0	Center	2574	2.041	1.949	0.618	0.591
2.4	0	Center	2635	2.041	1.949	0.618	0.591
2.4	0	Center	2599	2.041	1.949	0.618	0.591
2.4	0.5	Up	2604	1.214	1.16	0.435	0.416
2.4	0.5	Up	2672	1.214	1.16	0.435	0.416
2.4	0.5	Up	2661	1.214	1.16	0.435	0.416
2.4	0.5	Up	2710	1.214	1.16	0.435	0.416
2.4	0.5	Up	2726	1.214	1.16	0.435	0.416
2.4	0.5	Up	2672	1.214	1.16	0.435	0.416
2.4	0.5	Up	2619	1.214	1.16	0.435	0.416
2.4	0.5	Up	2688	1.214	1.16	0.435	0.416
2.4	0.5	Up	2715	1.214	1.16	0.435	0.416
2.4	0.5	Up	2640	1.214	1.16	0.435	0.416
2.4	0.5	Side	2666	1.358	1.297	0.438	0.418

2.4	0.5	Side	2656	1.358	1.297	0.438	0.418
2.4	0.5	Side	2721	1.358	1.297	0.438	0.418
2.4	0.5	Side	2743	1.358	1.297	0.438	0.418
2.4	0.5	Side	2699	1.358	1.297	0.438	0.418
2.4	0.5	Side	2688	1.358	1.297	0.438	0.418
2.4	0.5	Side	2721	1.358	1.297	0.438	0.418
2.4	0.5	Side	2956	1.358	1.297	0.438	0.418
2.4	0.5	Side	2693	1.358	1.297	0.438	0.418
2.4	0.5	Side	2682	1.358	1.297	0.438	0.418
2.4	0.5	Down	2682	2.38	2.273	0.83	0.793
2.4	0.5	Down	2624	2.38	2.273	0.83	0.793
2.4	0.5	Down	2624	2.38	2.273	0.83	0.793
2.4	0.5	Down	2656	2.38	2.273	0.83	0.793
2.4	0.5	Down	2656	2.38	2.273	0.83	0.793
2.4	0.5	Down	2710	2.38	2.273	0.83	0.793
2.4	0.5	Down	2656	2.38	2.273	0.83	0.793
2.4	0.5	Down	2629	2.38	2.273	0.83	0.793
2.4	0.5	Down	2588	2.38	2.273	0.83	0.793
2.4	0.5	Down	2726	2.38	2.273	0.83	0.793
2.8	0	Center	2661	1.594	1.523	0.53	0.506
2.8	0	Center	2614	1.594	1.523	0.53	0.506
2.8	0	Center	2640	1.594	1.523	0.53	0.506
2.8	0	Center	2898	1.594	1.523	0.53	0.506
2.8	0	Center	2614	1.594	1.523	0.53	0.506
2.8	0	Center	2554	1.594	1.523	0.53	0.506
2.8	0	Center	2534	1.594	1.523	0.53	0.506
2.8	0	Center	2715	1.594	1.523	0.53	0.506
2.8	0	Center	2996	1.594	1.523	0.53	0.506
2.8	0	Center	2569	1.594	1.523	0.53	0.506
2.8	0.5	Up	2704	2.294	2.191	0.56	0.534
2.8	0.5	Up	2721	2.294	2.191	0.56	0.534
2.8	0.5	Up	2672	2.294	2.191	0.56	0.534
2.8	0.5	Up	2564	2.294	2.191	0.56	0.534
2.8	0.5	Up	2672	2.294	2.191	0.56	0.534
2.8	0.5	Up	2688	2.294	2.191	0.56	0.534
2.8	0.5	Up	2677	2.294	2.191	0.56	0.534
2.8	0.5	Up	2726	2.294	2.191	0.56	0.534
2.8	0.5	Up	2754	2.294	2.191	0.56	0.534
2.8	0.5	Up	2677	2.294	2.191	0.56	0.534
2.8	0.5	Side	2699	1.562	1.492	0.564	0.539
2.8	0.5	Side	2650	1.562	1.492	0.564	0.539

2.8	0.5	Side	2726	1.562	1.492	0.564	0.539
2.8	0.5	Side	2737	1.562	1.492	0.564	0.539
2.8	0.5	Side	2682	1.562	1.492	0.564	0.539
2.8	0.5	Side	2624	1.562	1.492	0.564	0.539
2.8	0.5	Side	2645	1.562	1.492	0.564	0.539
2.8	0.5	Side	2710	1.562	1.492	0.564	0.539
2.8	0.5	Side	2672	1.562	1.492	0.564	0.539
2.8	0.5	Side	2699	1.562	1.492	0.564	0.539
2.8	0.5	Down	2737	2.55	2.436	0.701	0.67
2.8	0.5	Down	2721	2.55	2.436	0.701	0.67
2.8	0.5	Down	2715	2.55	2.436	0.701	0.67
2.8	0.5	Down	2732	2.55	2.436	0.701	0.67
2.8	0.5	Down	2715	2.55	2.436	0.701	0.67
2.8	0.5	Down	2688	2.55	2.436	0.701	0.67
2.8	0.5	Down	2677	2.55	2.436	0.701	0.67
2.8	0.5	Down	2640	2.55	2.436	0.701	0.67
2.8	0.5	Down	2682	2.55	2.436	0.701	0.67
2.8	0.5	Down	2766	2.55	2.436	0.701	0.67
3	0	Center	2969	1.58	1.509	0.509	0.486
3	0	Center	2842	1.58	1.509	0.509	0.486
3	0	Center	2574	1.58	1.509	0.509	0.486
3	0	Center	2539	1.58	1.509	0.509	0.486
3	0	Center	2619	1.58	1.509	0.509	0.486
3	0	Center	2672	1.58	1.509	0.509	0.486
3	0	Center	2583	1.58	1.509	0.509	0.486
3	0	Center	2656	1.58	1.509	0.509	0.486
3	0	Center	2645	1.58	1.509	0.509	0.486
3	0	Center	2578	1.58	1.509	0.509	0.486
3	0.5	Up	2949	2.377	2.271	0.552	0.528
3	0.5	Up	2666	2.377	2.271	0.552	0.528
3	0.5	Up	2726	2.377	2.271	0.552	0.528
3	0.5	Up	2704	2.377	2.271	0.552	0.528
3	0.5	Up	2726	2.377	2.271	0.552	0.528
3	0.5	Up	2732	2.377	2.271	0.552	0.528
3	0.5	Up	2710	2.377	2.271	0.552	0.528
3	0.5	Up	2715	2.377	2.271	0.552	0.528
3	0.5	Up	2749	2.377	2.271	0.552	0.528
3	0.5	Up	2693	2.377	2.271	0.552	0.528
3	0.5	Side	2754	1.278	1.221	0.499	0.476
3	0.5	Side	2760	1.278	1.221	0.499	0.476
3	0.5	Side	2760	1.278	1.221	0.499	0.476

3	0.5	Side	2749	1.278	1.221	0.499	0.476
3	0.5	Side	2699	1.278	1.221	0.499	0.476
3	0.5	Side	2996	1.278	1.221	0.499	0.476
3	0.5	Side	2754	1.278	1.221	0.499	0.476
3	0.5	Side	2749	1.278	1.221	0.499	0.476
3	0.5	Side	2715	1.278	1.221	0.499	0.476
3	0.5	Side	2732	1.278	1.221	0.499	0.476
3	0.5	Down	2743	1.362	1.301	0.516	0.493
3	0.5	Down	2666	1.362	1.301	0.516	0.493
3	0.5	Down	2710	1.362	1.301	0.516	0.493
3	0.5	Down	2715	1.362	1.301	0.516	0.493
3	0.5	Down	2721	1.362	1.301	0.516	0.493
3	0.5	Down	2672	1.362	1.301	0.516	0.493
3	0.5	Down	2721	1.362	1.301	0.516	0.493
3	0.5	Down	2721	1.362	1.301	0.516	0.493
3	0.5	Down	2688	1.362	1.301	0.516	0.493
3	0.5	Down	2699	1.362	1.301	0.516	0.493

APPENDIX E.

.308 WINCHESTER RANGE VELOCITY AND PRECISION DATA

Summary:

The following is the .308 Winchester muzzle velocity and precision data measurements acquired during private range testing outside of Rolla, MO. The highlighted values in the table represent outlier values that were removed prior to normalizing the data.

Flash Hole Diameter (mm)	Offset Deviation (mm)	Offset Location	Velocity (fps)	Max Spread (CTC) (inches)	MOA (in)	Average to Center (in)	MOA (in)
1.4	0	Center	2693	3.732	3.565	0.984	0.94
1.4	0	Center	2693	3.732	3.565	0.984	0.94
1.4	0	Center	2677	3.732	3.565	0.984	0.94
1.4	0	Center	2666	3.732	3.565	0.984	0.94
1.4	0	Center	2666	3.732	3.565	0.984	0.94
1.4	0	Center	2656	3.732	3.565	0.984	0.94
1.4	0	Center	2635	3.732	3.565	0.984	0.94
1.4	0	Center	2650	3.732	3.565	0.984	0.94
1.4	0	Center	2666	3.732	3.565	0.984	0.94
1.4	0	Center	2704	3.732	3.565	0.984	0.94
1.4	0.5	Up	2661	3.483	3.326	1.048	1.001
1.4	0.5	Up	2677	3.483	3.326	1.048	1.001
1.4	0.5	Up	2677	3.483	3.326	1.048	1.001
1.4	0.5	Up	2672	3.483	3.326	1.048	1.001
1.4	0.5	Up	2677	3.483	3.326	1.048	1.001
1.4	0.5	Up	2672	3.483	3.326	1.048	1.001
1.4	0.5	Up	2677	3.483	3.326	1.048	1.001
1.4	0.5	Up	2677	3.483	3.326	1.048	1.001
1.4	0.5	Side	2688	1.955	1.867	0.62	0.592
1.4	0.5	Side	2704	1.955	1.867	0.62	0.592
1.4	0.5	Side	2726	1.955	1.867	0.62	0.592
1.4	0.5	Down	2650	3.514	3.356	0.975	0.932
1.4	0.5	Down	2515	3.514	3.356	0.975	0.932
1.4	0.5	Down	2635	3.514	3.356	0.975	0.932
1.4	0.5	Down	2656	3.514	3.356	0.975	0.932
1.4	0.5	Down	2650	3.514	3.356	0.975	0.932
1.4	0.5	Down	2525	3.514	3.356	0.975	0.932
1.4	0.5	Down	2672	3.514	3.356	0.975	0.932
1.4	0.5	Down	2677	3.514	3.356	0.975	0.932
1.4	0.5	Down	2624	3.514	3.356	0.975	0.932
1.4	0.5	Down	2743	3.514	3.356	0.975	0.932
1.4	1	Up	2614	2.34	2.235	0.869	0.83
1.4	1	Up	2599	2.34	2.235	0.869	0.83
1.4	1	Up	2619	2.34	2.235	0.869	0.83
1.4	1	Up	2624	2.34	2.235	0.869	0.83
1.4	1	Up	2743	2.34	2.235	0.869	0.83
1.4	1	Up	2743	2.34	2.235	0.869	0.83
1.4	1	Up	2666	2.34	2.235	0.869	0.83

1.4	1	Up	2629	2.34	2.235	0.869	0.83
1.4	1	Up	2588	2.34	2.235	0.869	0.83
1.4	1	Up	2544	2.34	2.235	0.869	0.83
1.4	1	Side	2604	2.666	2.546	0.777	0.742
1.4	1	Side	2710	2.666	2.546	0.777	0.742
1.4	1	Side	2754	2.666	2.546	0.777	0.742
1.4	1	Side	2704	2.666	2.546	0.777	0.742
1.4	1	Side	2715	2.666	2.546	0.777	0.742
1.4	1	Side	2732	2.666	2.546	0.777	0.742
1.4	1	Side	2737	2.666	2.546	0.777	0.742
1.4	1	Side	2760	2.666	2.546	0.777	0.742
1.4	1	Side	2743	2.666	2.546	0.777	0.742
1.4	1	Side	2749	2.666	2.546	0.777	0.742
1.4	1	Down	2677	2.441	2.331	0.825	0.788
1.4	1	Down	2559	2.441	2.331	0.825	0.788
1.4	1	Down	2520	2.441	2.331	0.825	0.788
1.4	1	Down	2619	2.441	2.331	0.825	0.788
1.4	1	Down	2766	2.441	2.331	0.825	0.788
1.4	1	Down	2693	2.441	2.331	0.825	0.788
1.4	1	Down	2732	2.441	2.331	0.825	0.788
1.4	1	Down	2564	2.441	2.331	0.825	0.788
1.4	1	Down	2892	2.441	2.331	0.825	0.788
1.4	1	Down	2923	2.441	2.331	0.825	0.788
2	0	Center	2710	3.017	2.882	0.88	0.84
2	0	Center	2710	3.017	2.882	0.88	0.84
2	0	Center	2710	3.017	2.882	0.88	0.84
2	0	Center	2721	3.017	2.882	0.88	0.84
2	0	Center	2721	3.017	2.882	0.88	0.84
2	0	Center	2699	3.017	2.882	0.88	0.84
2	0	Center	2710	3.017	2.882	0.88	0.84
2	0	Center	2693	3.017	2.882	0.88	0.84
2	0	Center	2726	3.017	2.882	0.88	0.84
2	0	Center	2726	3.017	2.882	0.88	0.84
2	0.5	Up	2672	3.122	2.982	1.024	0.978
2	0.5	Up	2682	3.122	2.982	1.024	0.978
2	0.5	Up	2688	3.122	2.982	1.024	0.978
2	0.5	Up	2710	3.122	2.982	1.024	0.978
2	0.5	Up	2682	3.122	2.982	1.024	0.978
2	0.5	Up	2677	3.122	2.982	1.024	0.978
2	0.5	Up	2688	3.122	2.982	1.024	0.978
2	0.5	Up	2645	3.122	2.982	1.024	0.978

2	0.5	Up	2699	3.122	2.982	1.024	0.978
2	0.5	Up	2672	3.122	2.982	1.024	0.978
2	0.5	Side	2688	3.148	3.006	0.953	0.911
2	0.5	Side	2682	3.148	3.006	0.953	0.911
2	0.5	Side	2666	3.148	3.006	0.953	0.911
2	0.5	Side	2688	3.148	3.006	0.953	0.911
2	0.5	Side	2672	3.148	3.006	0.953	0.911
2	0.5	Side	2693	3.148	3.006	0.953	0.911
2	0.5	Side	2693	3.148	3.006	0.953	0.911
2	0.5	Side	2672	3.148	3.006	0.953	0.911
2	0.5	Side	2704	3.148	3.006	0.953	0.911
2	0.5	Side	2682	3.148	3.006	0.953	0.911
2	0.5	Down	2682	4.12	3.935	1.117	1.067
2	0.5	Down	2715	4.12	3.935	1.117	1.067
2	0.5	Down	2715	4.12	3.935	1.117	1.067
2	0.5	Down	2699	4.12	3.935	1.117	1.067
2	0.5	Down	2737	4.12	3.935	1.117	1.067
2	0.5	Down	2732	4.12	3.935	1.117	1.067
2	0.5	Down	2710	4.12	3.935	1.117	1.067
2	0.5	Down	2688	4.12	3.935	1.117	1.067
2	0.5	Down	2721	4.12	3.935	1.117	1.067
2	0.5	Down	2682	4.12	3.935	1.117	1.067
2	1	Up	2661	3.422	3.269	1.196	1.142
2	1	Up	2661	3.422	3.269	1.196	1.142
2	1	Up	2682	3.422	3.269	1.196	1.142
2	1	Up	2666	3.422	3.269	1.196	1.142
2	1	Up	2645	3.422	3.269	1.196	1.142
2	1	Up	2688	3.422	3.269	1.196	1.142
2	1	Up	2656	3.422	3.269	1.196	1.142
2	1	Up	2666	3.422	3.269	1.196	1.142
2	1	Up	2656	3.422	3.269	1.196	1.142
2	1	Up	2704	3.422	3.269	1.196	1.142
2	1	Side	2682	2.674	2.554	0.703	0.671
2	1	Side	2688	2.674	2.554	0.703	0.671
2	1	Side	2693	2.674	2.554	0.703	0.671
2	1	Side	2661	2.674	2.554	0.703	0.671
2	1	Side	2650	2.674	2.554	0.703	0.671
2	1	Side	2666	2.674	2.554	0.703	0.671
2	1	Side	2650	2.674	2.554	0.703	0.671
2	1	Side	2656	2.674	2.554	0.703	0.671
2	1	Side	2693	2.674	2.554	0.703	0.671

2	1	Side	2677	2.674	2.554	0.703	0.671
2	1	Down	2693	4.046	3.864	1.089	1.04
2	1	Down	2640	4.046	3.864	1.089	1.04
2	1	Down	2721	4.046	3.864	1.089	1.04
2	1	Down	2688	4.046	3.864	1.089	1.04
2	1	Down	2677	4.046	3.864	1.089	1.04
2	1	Down	2640	4.046	3.864	1.089	1.04
2	1	Down	2650	4.046	3.864	1.089	1.04
2	1	Down	2693	4.046	3.864	1.089	1.04
2	1	Down	2656	4.046	3.864	1.089	1.04
2	1	Down	2699	4.046	3.864	1.089	1.04
2.4	0	Center	2688	2.729	2.606	0.984	0.94
2.4	0	Center	2688	2.729	2.606	0.984	0.94
2.4	0	Center	2661	2.729	2.606	0.984	0.94
2.4	0	Center	2656	2.729	2.606	0.984	0.94
2.4	0	Center	2640	2.729	2.606	0.984	0.94
2.4	0	Center	2682	2.729	2.606	0.984	0.94
2.4	0	Center	2594	2.729	2.606	0.984	0.94
2.4	0	Center	2677	2.729	2.606	0.984	0.94
2.4	0	Center	2650	2.729	2.606	0.984	0.94
2.4	0	Center	2682	2.729	2.606	0.984	0.94
2.4	0.5	Up	2624	3.238	3.092	0.901	0.86
2.4	0.5	Up	2629	3.238	3.092	0.901	0.86
2.4	0.5	Up	2661	3.238	3.092	0.901	0.86
2.4	0.5	Up	2688	3.238	3.092	0.901	0.86
2.4	0.5	Up	2688	3.238	3.092	0.901	0.86
2.4	0.5	Up	2682	3.238	3.092	0.901	0.86
2.4	0.5	Up	2650	3.238	3.092	0.901	0.86
2.4	0.5	Up	2699	3.238	3.092	0.901	0.86
2.4	0.5	Up	2677	3.238	3.092	0.901	0.86
2.4	0.5	Side	2656	2.632	2.514	0.939	0.897
2.4	0.5	Side	2635	2.632	2.514	0.939	0.897
2.4	0.5	Side	2629	2.632	2.514	0.939	0.897
2.4	0.5	Side	2629	2.632	2.514	0.939	0.897
2.4	0.5	Side	2677	2.632	2.514	0.939	0.897
2.4	0.5	Side	2645	2.632	2.514	0.939	0.897
2.4	0.5	Side	2645	2.632	2.514	0.939	0.897
2.4	0.5	Side	2672	2.632	2.514	0.939	0.897
2.4	0.5	Side	2693	2.632	2.514	0.939	0.897
2.4	0.5	Side	2666	2.632	2.514	0.939	0.897
2.4	0.5	Down	2650	2.421	2.313	0.821	0.785

2.4	0.5	Down	2583	2.421	2.313	0.821	0.785
2.4	0.5	Down	2661	2.421	2.313	0.821	0.785
2.4	0.5	Down	2682	2.421	2.313	0.821	0.785
2.4	0.5	Down	2688	2.421	2.313	0.821	0.785
2.4	0.5	Down	2645	2.421	2.313	0.821	0.785
2.4	0.5	Down	2661	2.421	2.313	0.821	0.785
2.4	0.5	Down	2666	2.421	2.313	0.821	0.785
2.4	0.5	Down	2677	2.421	2.313	0.821	0.785
2.4	0.5	Down	2661	2.421	2.313	0.821	0.785
2.4	1	Up	2619	2.579	2.463	0.921	0.879
2.4	1	Up	2614	2.579	2.463	0.921	0.879
2.4	1	Up	2661	2.579	2.463	0.921	0.879
2.4	1	Up	2640	2.579	2.463	0.921	0.879
2.4	1	Up	2614	2.579	2.463	0.921	0.879
2.4	1	Up	2650	2.579	2.463	0.921	0.879
2.4	1	Up	2661	2.579	2.463	0.921	0.879
2.4	1	Up	2629	2.579	2.463	0.921	0.879
2.4	1	Up	2629	2.579	2.463	0.921	0.879
2.4	1	Up	2693	2.579	2.463	0.921	0.879
2.4	1	Side	2650	2.98	2.847	0.902	0.861
2.4	1	Side	2640	2.98	2.847	0.902	0.861
2.4	1	Side	2624	2.98	2.847	0.902	0.861
2.4	1	Side	2640	2.98	2.847	0.902	0.861
2.4	1	Side	2666	2.98	2.847	0.902	0.861
2.4	1	Side	2710	2.98	2.847	0.902	0.861
2.4	1	Side	2693	2.98	2.847	0.902	0.861
2.4	1	Side	2661	2.98	2.847	0.902	0.861
2.4	1	Side	2710	2.98	2.847	0.902	0.861
2.4	1	Down	2624	2.814	2.688	0.74	0.707
2.4	1	Down	2599	2.814	2.688	0.74	0.707
2.4	1	Down	2650	2.814	2.688	0.74	0.707
2.4	1	Down	2583	2.814	2.688	0.74	0.707
2.4	1	Down	2666	2.814	2.688	0.74	0.707
2.4	1	Down	2677	2.814	2.688	0.74	0.707
2.4	1	Down	2661	2.814	2.688	0.74	0.707
2.4	1	Down	2677	2.814	2.688	0.74	0.707
2.4	1	Down	2688	2.814	2.688	0.74	0.707
2.4	1	Down	2693	2.814	2.688	0.74	0.707
2.8	0	Center	2710	2.946	2.814	1.073	1.025
2.8	0	Center	2710	2.946	2.814	1.073	1.025
2.8	0	Center	2699	2.946	2.814	1.073	1.025

2.8	0	Center	2672	2.946	2.814	1.073	1.025
2.8	0	Center	2726	2.946	2.814	1.073	1.025
2.8	0	Center	2732	2.946	2.814	1.073	1.025
2.8	0	Center	2704	2.946	2.814	1.073	1.025
2.8	0	Center	2743	2.946	2.814	1.073	1.025
2.8	0	Center	2710	2.946	2.814	1.073	1.025
2.8	0	Center	2699	2.946	2.814	1.073	1.025
2.8	0.5	Up	2682	2.013	1.922	0.718	0.685
2.8	0.5	Up	2656	2.013	1.922	0.718	0.685
2.8	0.5	Up	2635	2.013	1.922	0.718	0.685
2.8	0.5	Up	2629	2.013	1.922	0.718	0.685
2.8	0.5	Up	2661	2.013	1.922	0.718	0.685
2.8	0.5	Up	2609	2.013	1.922	0.718	0.685
2.8	0.5	Up	2656	2.013	1.922	0.718	0.685
2.8	0.5	Up	2672	2.013	1.922	0.718	0.685
2.8	0.5	Up	2677	2.013	1.922	0.718	0.685
2.8	0.5	Up	2677	2.013	1.922	0.718	0.685
2.8	0.5	Side	2640	2.588	2.472	0.864	0.825
2.8	0.5	Side	2656	2.588	2.472	0.864	0.825
2.8	0.5	Side	2614	2.588	2.472	0.864	0.825
2.8	0.5	Side	2599	2.588	2.472	0.864	0.825
2.8	0.5	Side	2635	2.588	2.472	0.864	0.825
2.8	0.5	Side	2640	2.588	2.472	0.864	0.825
2.8	0.5	Side	2629	2.588	2.472	0.864	0.825
2.8	0.5	Side	2635	2.588	2.472	0.864	0.825
2.8	0.5	Side	2635	2.588	2.472	0.864	0.825
2.8	0.5	Side	2599	2.588	2.472	0.864	0.825
2.8	0.5	Down	2588	3.343	3.193	1.027	0.981
2.8	0.5	Down	2604	3.343	3.193	1.027	0.981
2.8	0.5	Down	2588	3.343	3.193	1.027	0.981
2.8	0.5	Down	2661	3.343	3.193	1.027	0.981
2.8	0.5	Down	2635	3.343	3.193	1.027	0.981
2.8	0.5	Down	2619	3.343	3.193	1.027	0.981
2.8	0.5	Down	2645	3.343	3.193	1.027	0.981
2.8	0.5	Down	2640	3.343	3.193	1.027	0.981
2.8	0.5	Down	2661	3.343	3.193	1.027	0.981
2.8	0.5	Down	2619	3.343	3.193	1.027	0.981
2.8	1	Up	2650	2.733	2.61	0.843	0.805
2.8	1	Up	2624	2.733	2.61	0.843	0.805
2.8	1	Up	2645	2.733	2.61	0.843	0.805
2.8	1	Up	2640	2.733	2.61	0.843	0.805

2.8	1	Up	2619	2.733	2.61	0.843	0.805
2.8	1	Up	2650	2.733	2.61	0.843	0.805
2.8	1	Up	2650	2.733	2.61	0.843	0.805
2.8	1	Up	2640	2.733	2.61	0.843	0.805
2.8	1	Up	2629	2.733	2.61	0.843	0.805
2.8	1	Up	2656	2.733	2.61	0.843	0.805
2.8	1	Side	2624	2.145	2.049	0.766	0.732
2.8	1	Side	2640	2.145	2.049	0.766	0.732
2.8	1	Side	2640	2.145	2.049	0.766	0.732
2.8	1	Side	2624	2.145	2.049	0.766	0.732
2.8	1	Side	2661	2.145	2.049	0.766	0.732
2.8	1	Side	2672	2.145	2.049	0.766	0.732
2.8	1	Side	2677	2.145	2.049	0.766	0.732
2.8	1	Side	2677	2.145	2.049	0.766	0.732
2.8	1	Side	2650	2.145	2.049	0.766	0.732
2.8	1	Side	2677	2.145	2.049	0.766	0.732
2.8	1	Down	2614	3.253	3.107	1.05	1.003
2.8	1	Down	2656	3.253	3.107	1.05	1.003
2.8	1	Down	2645	3.253	3.107	1.05	1.003
2.8	1	Down	2666	3.253	3.107	1.05	1.003
2.8	1	Down	2699	3.253	3.107	1.05	1.003
2.8	1	Down	2661	3.253	3.107	1.05	1.003
2.8	1	Down	2650	3.253	3.107	1.05	1.003
2.8	1	Down	2693	3.253	3.107	1.05	1.003
2.8	1	Down	2693	3.253	3.107	1.05	1.003
2.8	1	Down	2656	3.253	3.107	1.05	1.003
3	0	Center	2661	2.577	2.461	0.892	0.852
3	0	Center	2699	2.577	2.461	0.892	0.852
3	0	Center	2693	2.577	2.461	0.892	0.852
3	0	Center	2688	2.577	2.461	0.892	0.852
3	0	Center	2699	2.577	2.461	0.892	0.852
3	0	Center	2704	2.577	2.461	0.892	0.852
3	0	Center	2710	2.577	2.461	0.892	0.852
3	0	Center	2721	2.577	2.461	0.892	0.852
3	0	Center	2704	2.577	2.461	0.892	0.852
3	0	Center	2661	2.577	2.461	0.892	0.852
3	0.5	Up	2693	2.45	2.34	0.709	0.677
3	0.5	Up	2666	2.45	2.34	0.709	0.677
3	0.5	Up	2677	2.45	2.34	0.709	0.677
3	0.5	Up	2645	2.45	2.34	0.709	0.677
3	0.5	Up	2656	2.45	2.34	0.709	0.677

3	0.5	Up	2635	2.45	2.34	0.709	0.677
3	0.5	Up	2682	2.45	2.34	0.709	0.677
3	0.5	Up	2624	2.45	2.34	0.709	0.677
3	0.5	Up	2677	2.45	2.34	0.709	0.677
3	0.5	Up	2656	2.45	2.34	0.709	0.677
3	0.5	Side	2619	2.059	1.966	0.744	0.744
3	0.5	Side	2629	2.059	1.966	0.744	0.744
3	0.5	Side	2645	2.059	1.966	0.744	0.744
3	0.5	Side	2650	2.059	1.966	0.744	0.744
3	0.5	Side	2650	2.059	1.966	0.744	0.744
3	0.5	Side	2661	2.059	1.966	0.744	0.744
3	0.5	Side	2635	2.059	1.966	0.744	0.744
3	0.5	Side	2624	2.059	1.966	0.744	0.744
3	0.5	Side	2650	2.059	1.966	0.744	0.744
3	0.5	Side	2635	2.059	1.966	0.744	0.744
3	0.5	Down	2677	3.803	3.632	0.966	0.923
3	0.5	Down	2656	3.803	3.632	0.966	0.923
3	0.5	Down	2661	3.803	3.632	0.966	0.923
3	0.5	Down	2672	3.803	3.632	0.966	0.923
3	0.5	Down	2682	3.803	3.632	0.966	0.923
3	0.5	Down	2743	3.803	3.632	0.966	0.923
3	0.5	Down	2688	3.803	3.632	0.966	0.923
3	0.5	Down	2672	3.803	3.632	0.966	0.923
3	0.5	Down	2677	3.803	3.632	0.966	0.923
3	0.5	Down	2645	3.803	3.632	0.966	0.923
3	1	Up	2656	2.203	2.104	0.714	0.682
3	1	Up	2635	2.203	2.104	0.714	0.682
3	1	Up	2650	2.203	2.104	0.714	0.682
3	1	Up	2635	2.203	2.104	0.714	0.682
3	1	Up	2614	2.203	2.104	0.714	0.682
3	1	Up	2574	2.203	2.104	0.714	0.682
3	1	Up	2599	2.203	2.104	0.714	0.682
3	1	Up	2619	2.203	2.104	0.714	0.682
3	1	Up	2594	2.203	2.104	0.714	0.682
3	1	Up	2624	2.203	2.104	0.714	0.682
3	1	Side	2635	2.903	2.773	0.769	0.734
3	1	Side	2619	2.903	2.773	0.769	0.734
3	1	Side	2645	2.903	2.773	0.769	0.734
3	1	Side	2624	2.903	2.773	0.769	0.734
3	1	Side	2661	2.903	2.773	0.769	0.734
3	1	Side	2656	2.903	2.773	0.769	0.734

3	1	Side	2656	2.903	2.773	0.769	0.734
3	1	Side	2672	2.903	2.773	0.769	0.734
3	1	Side	2682	2.903	2.773	0.769	0.734
3	1	Side	2699	2.903	2.773	0.769	0.734
3	1	Down	2599	2.301	2.197	0.743	0.71
3	1	Down	2661	2.301	2.197	0.743	0.71
3	1	Down	2666	2.301	2.197	0.743	0.71
3	1	Down	2656	2.301	2.197	0.743	0.71
3	1	Down	2672	2.301	2.197	0.743	0.71
3	1	Down	2693	2.301	2.197	0.743	0.71
3	1	Down	2672	2.301	2.197	0.743	0.71
3	1	Down	2677	2.301	2.197	0.743	0.71
3	1	Down	2661	2.301	2.197	0.743	0.71
3	1	Down	2721	2.301	2.197	0.743	0.71

APPENDIX F.

.223 REMINGTON TARGETS

Summary:

The following images are scans of the 26 targets papers from the range precision testing of the .223 Remington caliber bullets. Testing took place at a private range outside of Rolla, MO. Each target is labelled with a date and the flash hole description related to the ammunition used on that target.

APPENDIX G.

.308 WINCHESTER TARGETS

Summary:

The following images are scans of the 35 targets papers from the range precision testing of the .308 Winchester caliber bullets. Testing took place at a private range outside of Rolla, MO. Each target is labelled with a date and the flash hole description related to the ammunition used on that target.

APPENDIX H.

.223 REMINGTON FIOCCHI VELOCITY AND PRESSURE DATA

Summary:

The following is the compilation of the .223 Remington muzzle velocity and chamber pressure measurements taken at Fiocchi of America (Ozark, MO). The highlighted values depict calculated outliers that were removed before normalizing the data.

Flash Hole Diameter (mm)	Offset Deviation (mm)	Offset Location	Pressure (psi)	Velocity (fps)
1.4	0	Center	36248	2961.5
1.4	0	Center	33800	2880.8
1.4	0	Center	35628	2949
1.4	0	Center	36985	2983
1.4	0	Center	34478	2917.6
1.4	0	Center	35481	2945.3
1.4	0	Center	33623	2906.7
1.4	0	Center	33417	2893.2
1.4	0	Center	32916	2890.8
1.4	0	Center	34626	2930.8
1.4	0.5	Up	35304	2961.1
1.4	0.5	Up	35569	2946.1
1.4	0.5	Up	34272	2920.4
1.4	0.5	Up	32916	2896.7
1.4	0.5	Up	35068	2941.8
1.4	0.5	Up	32444	2885
1.4	0.5	Up	36778	2974
1.4	0.5	Up	36542	2974.2
1.4	0.5	Up	33594	2913
1.4	0.5	Up	35186	2937.1
1.4	0.5	Side	34478	2935.8
1.4	0.5	Side	36218	2965.8
1.4	0.5	Side	33859	2919.5
1.4	0.5	Side	34036	2921.7
1.4	0.5	Side	32532	2881.4
1.4	0.5	Side	35422	2955.9
1.4	0.5	Side	35864	2962.7
1.4	0.5	Side	36955	2977.3
1.4	0.5	Side	37663	3004.6
1.4	0.5	Side	33358	2902.3
1.4	0.5	Down	36896	2987.3
1.4	0.5	Down	35275	2953.8
1.4	0.5	Down	33240	2898.7
1.4	0.5	Down	35451	2947.6
1.4	0.5	Down	35098	2949.7
1.4	0.5	Down	37309	2989
1.4	0.5	Down	36159	2962.4
1.4	0.5	Down	35392	2953
1.4	0.5	Down	36690	2983.1

1.4	0.5	Down	35216	2942.3
1.4	1	Up	33358	2919
1.4	1	Up	35628	2960.2
1.4	1	Up	34125	2919.9
1.4	1	Up	33122	2907.6
1.4	1	Up	35687	2966.3
1.4	1	Up	35068	2949.8
1.4	1	Up	34862	2952.1
1.4	1	Up	34419	2933.3
1.4	1	Up	35216	2951.5
1.4	1	Up	35304	2952.7
1.4	1	Side	35628	2958.9
1.4	1	Side	33859	2924.9
1.4	1	Side	33800	2920.4
1.4	1	Side	36307	2969.4
1.4	1	Side	38223	3003.6
1.4	1	Side	37456	2996.1
1.4	1	Side	33034	2905.7
1.4	1	Side	33830	2916.1
1.4	1	Side	35275	2938.7
1.4	1	Side	35157	2944.6
1.4	1	Down	34537	2944.1
1.4	1	Down	37162	2986.2
1.4	1	Down	35599	2954.3
1.4	1	Down	34980	2940.7
1.4	1	Down	34626	2937.1
1.4	1	Down	37987	2996
1.4	1	Down	35275	2948.8
1.4	1	Down	34036	2921.8
1.4	1	Down	34626	2942.3
1.4	1	Down	33623	2909.4
2	0	Center	34655	2928.9
2	0	Center	36896	2978.4
2	0	Center	35628	2951.4
2	0	Center	36071	2960
2	0	Center	36277	2962.8
2	0	Center	35216	2944.9
2	0	Center	34331	2929.9
2	0	Center	36365	2973.8
2	0	Center	36572	2971.3
2	0	Center	36365	2975.7

2	0.5	Up	37162	2997.3
2	0.5	Up	37132	3003.1
2	0.5	Up	36749	2996.9
2	0.5	Up	38665	3033
2	0.5	Up	36601	2999.6
2	0.5	Up	36808	2993.5
2	0.5	Up	36071	2980.7
2	0.5	Up	34095	2941.8
2	0.5	Up	35569	2965
2	0.5	Up	35776	2975.4
2	0.5	Side	36483	2992.9
2	0.5	Side	36218	2987.4
2	0.5	Side	34744	2946.6
2	0.5	Side	37191	2997.8
2	0.5	Side	35894	2960.7
2	0.5	Side	36307	2980
2	0.5	Side	34596	2936.9
2	0.5	Side	35039	2957.3
2	0.5	Side	36985	2998.4
2	0.5	Side	34449	2944.2
2	0.5	Down	36896	2993.3
2	0.5	Down	35275	2961.2
2	0.5	Down	38518	3022.6
2	0.5	Down	36985	2987.5
2	0.5	Down	36572	2982.9
2	0.5	Down	35894	2968.3
2	0.5	Down	36159	2965.9
2	0.5	Down	36307	2979
2	0.5	Down	37191	2991
2	0.5	Down	35746	2957
2	1	Up	36832	2995.5
2	1	Up	36979	2991
2	1	Up	35387	2953.5
2	1	Up	35210	2950.8
2	1	Up	33441	2912.9
2	1	Up	34591	2935.3
2	1	Up	35475	2964.1
2	1	Up	35328	2944
2	1	Up	35357	2953.5
2	1	Up	33382	2910.9
2	1	Side	33854	2919.2

2	1	Side	36183	2976.2
2	1	Side	32733	2886.9
2	1	Side	34561	2941
2	1	Side	34738	2944.1
2	1	Side	35829	2968
2	1	Side	33323	2912
2	1	Side	34326	2924.7
2	1	Side	35092	2947
2	1	Side	34827	2941.6
2	1	Down	36566	2991.3
2	1	Down	36036	2978.3
2	1	Down	36301	2971.8
2	1	Down	37303	2991.6
2	1	Down	36095	2971
2	1	Down	35623	2962.1
2	1	Down	36360	2977
2	1	Down	35652	2964.4
2	1	Down	35357	2954
2	1	Down	36153	2977.9
2.4	0	Center	35039	2936
2.4	0	Center	37456	3003.2
2.4	0	Center	39550	3050.3
2.4	0	Center	37545	2997.2
2.4	0	Center	36012	2966.8
2.4	0	Center	36513	2981.1
2.4	0	Center	35717	2959.4
2.4	0	Center	37338	2999.3
2.4	0	Center	36513	2983.5
2.4	0	Center	34685	2947.8
2.4	0.5	Up	35534	2969.1
2.4	0.5	Up	36950	2993.7
2.4	0.5	Up	36655	2985.4
2.4	0.5	Up	35800	2952.1
2.4	0.5	Up	35682	2965.1
2.4	0.5	Up	35800	2965.8
2.4	0.5	Up	34768	2933.5
2.4	0.5	Up	35829	2957.9
2.4	0.5	Up	36625	2980.8
2.4	0.5	Up	34797	2939.5
2.4	0.5	Side	36566	2976.8
2.4	0.5	Side	36507	2976.8

2.4	0.5	Side	36095	2970
2.4	0.5	Side	36655	2977.4
2.4	0.5	Side	34267	2925.7
2.4	0.5	Side	36419	2972.9
2.4	0.5	Side	33942	2916.7
2.4	0.5	Side	36773	2964
2.4	0.5	Side	35682	2959
2.4	0.5	Side	35564	2955.6
2.4	0.5	Down	36183	2966.7
2.4	0.5	Down	38011	3003.4
2.4	0.5	Down	35475	2957
2.4	0.5	Down	36950	2975.7
2.4	0.5	Down	37067	2979.7
2.4	0.5	Down	36596	2977
2.4	0.5	Down	35859	2969.6
2.4	0.5	Down	36743	2979.9
2.4	0.5	Down	36153	2967.3
2.4	0.5	Down	37687	2995.8
2.8	0	Center	34773	2941.5
2.8	0	Center	34302	2932.3
2.8	0	Center	36542	2970
2.8	0	Center	38665	3016.9
2.8	0	Center	35068	2948.3
2.8	0	Center	37044	2986.7
2.8	0	Center	36307	2962.9
2.8	0	Center	34655	2939.4
2.8	0	Center	34862	2937.6
2.8	0	Center	37604	2998.2
2.8	0.5	Up	37185	3002.2
2.8	0.5	Up	35770	2976.5
2.8	0.5	Up	36714	2987.9
2.8	0.5	Up	34473	2943.7
2.8	0.5	Up	37156	2993.2
2.8	0.5	Up	35652	2955.9
2.8	0.5	Up	34679	2946.2
2.8	0.5	Up	35829	2966.9
2.8	0.5	Up	37097	2993.7
2.8	0.5	Up	37421	2996.5
2.8	0.5	Side	36478	2975
2.8	0.5	Side	35239	2949
2.8	0.5	Side	34974	2947

2.8	0.5	Side	36183	2971.6
2.8	0.5	Side	34237	2936.3
2.8	0.5	Side	34797	2943
2.8	0.5	Side	36006	2970.7
2.8	0.5	Side	35181	2942.8
2.8	0.5	Side	34827	2950.9
2.8	0.5	Side	35063	2942.7
2.8	0.5	Down	37451	3000.6
2.8	0.5	Down	36183	2978.7
2.8	0.5	Down	36419	2985.1
2.8	0.5	Down	36773	2993.1
2.8	0.5	Down	35505	2954.2
2.8	0.5	Down	35652	2964.6
2.8	0.5	Down	37775	3005.5
2.8	0.5	Down	35328	2958.6
2.8	0.5	Down	35122	2953.6
2.8	0.5	Down	35269	2956.5
3	0	Center	35422	2952.4
3	0	Center	35098	2953.9
3	0	Center	36130	2968.6
3	0	Center	35776	2957.2
3	0	Center	37073	2996.5
3	0	Center	36955	2979.7
3	0	Center	36778	2988.9
3	0	Center	38253	3005.9
3	0	Center	34891	2944.1
3	0	Center	35540	2960.5
3	0.5	Up	37156	2992.9
3	0.5	Up	35977	2982
3	0.5	Up	34974	2960
3	0.5	Up	34915	2956.9
3	0.5	Up	38453	3022.1
3	0.5	Up	35475	2962.9
3	0.5	Up	35800	2964.3
3	0.5	Up	35829	2968.6
3	0.5	Up	35652	2972.6
3	0.5	Up	34090	2931
3	0.5	Side	35711	2965.8
3	0.5	Side	34561	2943.5
3	0.5	Side	36478	2987.3
3	0.5	Side	35298	2956.9

3	0.5	Side	36153	2980.2
3	0.5	Side	34355	2936.9
3	0.5	Side	35652	2968.8
3	0.5	Side	36095	2974.3
3	0.5	Side	34679	2943.5
3	0.5	Side	36419	2986.4
3	0.5	Down	36183	2977.9
3	0.5	Down	35918	2962.1
3	0.5	Down	35092	2953
3	0.5	Down	34915	2950.8
3	0.5	Down	36684	2983.5
3	0.5	Down	36478	2983.3
3	0.5	Down	36419	2985.6
3	0.5	Down	35151	2953.8
3	0.5	Down	37067	2984.8
3	0.5	Down	36979	2993.5

APPENDIX I.

.308 WINCHESTER FIOCCHI VELOCITY AND PRESSURE DATA

Summary:

The following is the compilation of the .308 Winchester muzzle velocity and chamber pressure measurements taken at Fiocchi of America (Ozark, MO). The highlighted values depict calculated outliers that were removed before normalizing the data.

Flash Hole Diameter (mm)	Offset Deviation (mm)	Offset Location	Pressure (psi)	Velocity (fps)
1.4	0	Center	50179	2805
1.4	0	Center	51379	2815.8
1.4	0	Center	51310	2812.9
1.4	0	Center	52441	2828
1.4	0	Center	51105	2814.6
1.4	0	Center	51173	2817.2
1.4	0	Center	48945	2784.4
1.4	0	Center	51276	2817.6
1.4	0	Center	50659	2809.9
1.4	0	Center	48431	2778
1.4	0	Center	51619	2821.8
1.4	0	Center	51584	2820.6
1.4	0	Center	50213	2804.8
1.4	0	Center	50625	2806.6
1.4	0	Center	51173	2811.9
1.4	0	Center	48019	2779.5
1.4	0	Center	52613	2834.9
1.4	0	Center	51619	2818.6
1.4	0	Center	50796	2811.7
1.4	0	Center	52202	2828.9
1.4	0.5	Up	52339	2826.6
1.4	0.5	Up	51619	2829.3
1.4	0.5	Up	51653	2822
1.4	0.5	Up	51242	2825.9
1.4	0.5	Up	52064	2827.7
1.4	0.5	Up	47951	2771.2
1.4	0.5	Up	51276	2818.7
1.4	0.5	Up	51756	2823.5
1.4	0.5	Up	51482	2826.6
1.4	0.5	Up	52099	2824.5
1.4	0.5	Up	50110	2806.2
1.4	0.5	Up	50453	2810.2
1.4	0.5	Up	47642	2769.6
1.4	0.5	Up	50625	2811.7
1.4	0.5	Up	49630	2791.5
1.4	0.5	Up	48739	2784.8
1.4	0.5	Up	51002	2814.8
1.4	0.5	Up	51482	2821.8
1.4	0.5	Up	49116	2789.6

1.4	0.5	Up	51859	2820.1
1.4	0.5	Side	50933	2812
1.4	0.5	Side	51276	2817.4
1.4	0.5	Side	51790	2824.3
1.4	0.5	Side	52270	2831.6
1.4	0.5	Side	50830	2814.6
1.4	0.5	Side	49528	2797.4
1.4	0.5	Side	49322	2795.8
1.4	0.5	Side	51824	2825.9
1.4	0.5	Side	49322	2789.1
1.4	0.5	Side	51722	2822.6
1.4	0.5	Side	51070	2813.3
1.4	0.5	Side	50385	2808.5
1.4	0.5	Side	51344	2818.1
1.4	0.5	Side	50008	2797.6
1.4	0.5	Side	53641	2845
1.4	0.5	Side	50967	2814.2
1.4	0.5	Side	49802	2791
1.4	0.5	Side	51516	2819.3
1.4	0.5	Side	50316	2804.1
1.4	0.5	Side	51790	2822.9
1.4	0.5	Down	50213	2808.6
1.4	0.5	Down	50145	2798.5
1.4	0.5	Down	52167	2829.5
1.4	0.5	Down	51550	2816.8
1.4	0.5	Down	51722	2821.8
1.4	0.5	Down	50453	2801.7
1.4	0.5	Down	50042	2799.7
1.4	0.5	Down	50865	2810
1.4	0.5	Down	51756	2824.7
1.4	0.5	Down	53161	2843.9
1.4	0.5	Down	53333	2844.1
1.4	0.5	Down	52167	2830.4
1.4	0.5	Down	51070	2812.4
1.4	0.5	Down	49013	2788.2
1.4	0.5	Down	48808	2786.1
1.4	0.5	Down	51550	2821.8
1.4	0.5	Down	48808	2791.6
1.4	0.5	Down	48533	2782.5
1.4	0.5	Down	53333	2844.9
1.4	0.5	Down	53093	2842.9

1.4	1	Up	52510	2832.1
1.4	1	Up	50008	2794.5
1.4	1	Up	47025	2747.3
1.4	1	Up	50933	2800.1
1.4	1	Up	51173	2801.5
1.4	1	Up	49390	2779.1
1.4	1	Up	48842	2773.8
1.4	1	Up	51036	2800.9
1.4	1	Up	50865	2802
1.4	1	Up	52064	2822
1.4	1	Up	52373	2819.6
1.4	1	Up	48293	2772.1
1.4	1	Up	52202	2821.6
1.4	1	Up	50042	2797.2
1.4	1	Up	49836	2798.2
1.4	1	Up	48636	2778.6
1.4	1	Up	49699	2786.1
1.4	1	Up	48431	2779.5
1.4	1	Up	49116	2786.6
1.4	1	Side	50522	2797.6
1.4	1	Side	51242	2813.5
1.4	1	Side	52373	2816.9
1.4	1	Side	48808	2778.6
1.4	1	Side	50282	2799
1.4	1	Side	49665	2782.9
1.4	1	Side	48602	2769.6
1.4	1	Side	46374	2746.1
1.4	1	Side	51344	2817.9
1.4	1	Side	49493	2781.7
1.4	1	Side	52339	2821.3
1.4	1	Side	50659	2801.8
1.4	1	Side	50453	2800.8
1.4	1	Side	51276	2810.2
1.4	1	Side	50796	2800.6
1.4	1	Side	53024	2832.7
1.4	1	Side	52956	2831.2
1.4	1	Side	51413	2814.7
1.4	1	Side	50522	2799.8
1.4	1	Side	48705	2778.3
1.4	1	Down	51619	2817.8
1.4	1	Down	48568	2781.1

1.4	1	Down	48465	2776
1.4	1	Down	49905	2798.5
1.4	1	Down	49528	2787.5
1.4	1	Down	53950	2873.6
1.4	1	Down	50865	2811.8
1.4	1	Down	46065	2745
1.4	1	Down	50967	2808.5
1.4	1	Down	52064	2822.7
1.4	1	Down	49082	2787.7
1.4	1	Down	49630	2792.5
1.4	1	Down	52099	2822.4
1.4	1	Down	50350	2802.5
1.4	1	Down	52476	2831.4
1.4	1	Down	51550	2812.6
1.4	1	Down	49836	2798
1.4	1	Down	49699	2796.9
1.4	1	Down	50247	2803.3
1.4	1	Down	49116	2784
2	0	Center	51790	2824.3
2	0	Center	53504	2841.6
2	0	Center	53367	2843
2	0	Center	53744	2846.3
2	0	Center	52030	2828.9
2	0	Center	52476	2825.8
2	0	Center	49802	2794.4
2	0	Center	52784	2837.7
2	0	Center	51893	2821.4
2	0	Center	53024	2831.3
2	0	Center	52441	2831.7
2	0	Center	52407	2830.8
2	0	Center	52956	2833.1
2	0	Center	50865	2809.6
2	0	Center	50419	2804.5
2	0	Center	54224	2852.1
2	0	Center	51756	2817.3
2	0	Center	53401	2832.8
2	0	Center	51790	2817.5
2	0.5	Up	51344	2810
2	0.5	Up	51584	2816.1
2	0.5	Up	51996	2819.8
2	0.5	Up	50693	2804.9

2	0.5	Up	52784	2829.3
2	0.5	Up	49116	2780.8
2	0.5	Up	51482	2809.7
2	0.5	Up	50556	2798.3
2	0.5	Up	49596	2791.2
2	0.5	Up	50693	2804.8
2	0.5	Up	51516	2812.4
2	0.5	Up	50693	2799.5
2	0.5	Up	48842	2779.7
2	0.5	Up	49905	2793.7
2	0.5	Up	52236	2823.2
2	0.5	Up	49939	2799.9
2	0.5	Up	50865	2797.7
2	0.5	Up	47299	2761.6
2	0.5	Up	51002	2804.1
2	0.5	Up	47505	2761.6
2	0.5	Side	51413	2812.7
2	0.5	Side	51687	2818.7
2	0.5	Side	51242	2808.5
2	0.5	Side	51996	2822.5
2	0.5	Side	51413	2814.5
2	0.5	Side	51482	2809.8
2	0.5	Side	52339	2825.5
2	0.5	Side	49596	2791.2
2	0.5	Side	49322	2785.8
2	0.5	Side	50590	2805
2	0.5	Side	50385	2800
2	0.5	Side	51002	2809.1
2	0.5	Side	52202	2820.7
2	0.5	Side	49939	2789.9
2	0.5	Side	52064	2820.4
2	0.5	Side	52270	2814.5
2	0.5	Side	52921	2831.1
2	0.5	Side	53881	2839.7
2	0.5	Side	51824	2816.7
2	0.5	Side	49288	2784
2	0.5	Down	52441	2823.1
2	0.5	Down	50179	2791
2	0.5	Down	51516	2810.6
2	0.5	Down	52133	2819.1
2	0.5	Down	50008	2789.4

2	0.5	Down	50110	2790.9
2	0.5	Down	51824	2813.8
2	0.5	Down	51584	2813.6
2	0.5	Down	51413	2810.3
2	0.5	Down	49802	2790.5
2	0.5	Down	52613	2832.6
2	0.5	Down	50659	2802.5
2	0.5	Down	51790	2809.7
2	0.5	Down	53573	2836.8
2	0.5	Down	49596	2783
2	0.5	Down	52339	2820.7
2	0.5	Down	52887	2829
2	0.5	Down	49630	2793.3
2	0.5	Down	51036	2807.1
2	0.5	Down	50008	2793
2	1	Up	51927	2822.1
2	1	Up	47711	2763.7
2	1	Up	49493	2788.3
2	1	Up	52681	2824.9
2	1	Up	51207	2809.2
2	1	Up	51653	2821.7
2	1	Up	53538	2834.4
2	1	Up	51893	2818.1
2	1	Up	48431	2778.5
2	1	Up	52064	2819.9
2	1	Up	54807	2854.5
2	1	Up	50247	2799.1
2	1	Up	50042	2796.6
2	1	Up	52476	2833.9
2	1	Up	53127	2828
2	1	Up	51996	2814.7
2	1	Up	51550	2813.8
2	1	Up	50796	2804.5
2	1	Up	52716	2828.7
2	1	Up	51173	2809.9
2	1	Side	48636	2774.5
2	1	Side	50282	2799.3
2	1	Side	50008	2797.2
2	1	Side	51996	2819.8
2	1	Side	50213	2796.5
2	1	Side	50967	2803.7

2	1	Side	47574	2759
2	1	Side	51687	2817.1
2	1	Side	53024	2835.1
2	1	Side	51276	2808.8
2	1	Side	48910	2779.3
2	1	Side	49459	2787.3
2	1	Side	49288	2781.7
2	1	Side	49082	2777.2
2	1	Side	52167	2819.8
2	1	Side	52202	2816.2
2	1	Side	51687	2820.1
2	1	Side	52613	2825.9
2	1	Side	52476	2826.6
2	1	Side	52956	2832
2	1	Down	50727	2807.1
2	1	Down	52956	2829
2	1	Down	48842	2779.4
2	1	Down	53607	2835.1
2	1	Down	54704	2853.5
2	1	Down	53744	2838.4
2	1	Down	49219	2783.3
2	1	Down	49082	2786.2
2	1	Down	53367	2833.7
2	1	Down	50625	2801.8
2	1	Down	54601	2855.9
2	1	Down	50899	2808.2
2	1	Down	48842	2782.3
2	1	Down	50830	2808.3
2	1	Down	53676	2844.4
2	1	Down	52784	2827.3
2	1	Down	53744	2846.8
2	1	Down	50933	2810.8
2	1	Down	52647	2832.2
2	1	Down	49699	2794
2.4	0	Center	52718	2830.5
2.4	0	Center	51586	2811.9
2.4	0	Center	51003	2801.7
2.4	0	Center	53026	2826
2.4	0	Center	51209	2801
2.4	0	Center	53917	2841.1
2.4	0	Center	50763	2802.1

2.4	0	Center	52820	2826.3
2.4	0	Center	55049	2850.8
2.4	0	Center	52992	2827.3
2.4	0	Center	52306	2820.2
2.4	0	Center	52066	2811.2
2.4	0	Center	50832	2799.7
2.4	0	Center	52580	2827.3
2.4	0	Center	50044	2789.8
2.4	0	Center	54260	2843.8
2.4	0	Center	52306	2822
2.4	0	Center	52272	2824.9
2.4	0	Center	53712	2837.4
2.4	0	Center	50763	2800.8
2.4	0.5	Up	50489	2797.2
2.4	0.5	Up	51278	2806.5
2.4	0.5	Up	53129	2833.1
2.4	0.5	Up	52409	2821.6
2.4	0.5	Up	53129	2832.8
2.4	0.5	Up	52786	2821.9
2.4	0.5	Up	53300	2833.6
2.4	0.5	Up	52958	2830.4
2.4	0.5	Up	53300	2839.7
2.4	0.5	Up	54912	2850.2
2.4	0.5	Up	52100	2819.7
2.4	0.5	Up	53540	2838.8
2.4	0.5	Up	52649	2826.1
2.4	0.5	Up	49975	2798
2.4	0.5	Up	51689	2815.5
2.4	0.5	Up	51483	2812
2.4	0.5	Up	53815	2845.8
2.4	0.5	Up	54123	2844.2
2.4	0.5	Side	52443	2823.9
2.4	0.5	Side	53849	2835.4
2.4	0.5	Side	51586	2812.5
2.4	0.5	Side	48569	2774.8
2.4	0.5	Side	53677	2832.7
2.4	0.5	Side	49941	2790.5
2.4	0.5	Side	51552	2809.7
2.4	0.5	Side	53232	2829.3
2.4	0.5	Side	50386	2793.6
2.4	0.5	Side	53438	2832.4

2.4	0.5	Side	50386	2798.7
2.4	0.5	Side	52992	2824.6
2.4	0.5	Side	54740	2849.6
2.4	0.5	Side	47678	2762.8
2.4	0.5	Side	50181	2791.6
2.4	0.5	Side	53095	2831.8
2.4	0.5	Side	51998	2815.6
2.4	0.5	Side	51621	2811.5
2.4	0.5	Side	52580	2823.9
2.4	0.5	Side	54329	2840
2.4	0.5	Down	53060	2827.3
2.4	0.5	Down	46821	2743.7
2.4	0.5	Down	53883	2845.4
2.4	0.5	Down	53815	2840.3
2.4	0.5	Down	50763	2806.9
2.4	0.5	Down	50729	2803.2
2.4	0.5	Down	47061	2746.2
2.4	0.5	Down	49392	2783.9
2.4	0.5	Down	49495	2784.5
2.4	0.5	Down	51381	2812
2.4	0.5	Down	51792	2815.5
2.4	0.5	Down	48878	2777.8
2.4	0.5	Down	53060	2833.8
2.4	0.5	Down	51003	2805
2.4	0.5	Down	52718	2831.3
2.4	0.5	Down	51072	2810
2.4	0.5	Down	50935	2804
2.4	0.5	Down	51998	2817.2
2.4	0.5	Down	49358	2783
2.4	0.5	Down	51586	2817.6
2.4	1	Up	53643	2845.4
2.4	1	Up	51963	2813.8
2.4	1	Up	49941	2790.4
2.4	1	Up	52752	2828
2.4	1	Up	52238	2821.1
2.4	1	Up	53917	2846.8
2.4	1	Up	49769	2793.1
2.4	1	Up	50489	2797.6
2.4	1	Up	51963	2815.1
2.4	1	Up	49461	2785
2.4	1	Up	51003	2808.8

2.4	1	Up	53232	2835.2
2.4	1	Up	52512	2823.1
2.4	1	Up	53746	2842
2.4	1	Up	52923	2827.4
2.4	1	Up	53815	2836.4
2.4	1	Up	51655	2812.6
2.4	1	Up	51689	2815
2.4	1	Up	52272	2820.8
2.4	1	Up	50386	2794.3
2.4	1	Side	50901	2802.5
2.4	1	Side	55083	2852.6
2.4	1	Side	51415	2814.9
2.4	1	Side	54329	2845.4
2.4	1	Side	52409	2822.6
2.4	1	Side	52615	2826.1
2.4	1	Side	51826	2817.1
2.4	1	Side	52306	2825.1
2.4	1	Side	50181	2802.9
2.4	1	Side	53472	2835.1
2.4	1	Side	52306	2824
2.4	1	Side	50009	2797.6
2.4	1	Side	50523	2805.5
2.4	1	Side	53300	2834.7
2.4	1	Side	53403	2833.1
2.4	1	Side	51278	2815.5
2.4	1	Side	51621	2818.2
2.4	1	Side	54672	2852.6
2.4	1	Side	54672	2848.7
2.4	1	Side	51243	2812.4
2.4	1	Down	52786	2826.2
2.4	1	Down	52889	2829.2
2.4	1	Down	50558	2799.8
2.4	1	Down	52889	2830.6
2.4	1	Down	50044	2795.5
2.4	1	Down	53849	2837.4
2.4	1	Down	52443	2822.9
2.4	1	Down	50901	2805.2
2.4	1	Down	54192	2838.6
2.4	1	Down	52238	2821.6
2.4	1	Down	51552	2813
2.4	1	Down	51998	2819.9

2.4	1	Down	52272	2828.7
2.4	1	Down	51483	2820.1
2.4	1	Down	54912	2858.6
2.4	1	Down	51209	2805
2.4	1	Down	52478	2826.5
2.4	1	Down	50215	2801.6
2.4	1	Down	48089	2771.7
2.4	1	Down	51483	2819
2.8	0	Center	54980	2857.9
2.8	0	Center	53952	2852.1
2.8	0	Center	54672	2855
2.8	0	Center	54329	2850.1
2.8	0	Center	54432	2851.8
2.8	0	Center	53540	2841.3
2.8	0	Center	54123	2853.3
2.8	0	Center	51312	2815.9
2.8	0	Center	54157	2850.9
2.8	0	Center	49838	2795
2.8	0	Center	52992	2837.3
2.8	0	Center	54603	2850.3
2.8	0	Center	52066	2820.3
2.8	0	Center	54020	2849.8
2.8	0	Center	52889	2838.5
2.8	0	Center	51861	2820.6
2.8	0	Center	53472	2841.1
2.8	0	Center	55974	2871.2
2.8	0	Center	52855	2831.2
2.8	0	Center	54020	2845.2
2.8	0.5	Up	49632	2787.6
2.8	0.5	Up	50626	2800.7
2.8	0.5	Up	53712	2832.9
2.8	0.5	Up	52238	2819.1
2.8	0.5	Up	53266	2830.2
2.8	0.5	Up	50009	2792.5
2.8	0.5	Up	49598	2787.6
2.8	0.5	Up	54637	2847.4
2.8	0.5	Up	52066	2817.9
2.8	0.5	Up	49975	2792.5
2.8	0.5	Up	50763	2804.4
2.8	0.5	Up	52409	2821.8
2.8	0.5	Up	53780	2840.6

2.8	0.5	Up	53266	2837.6
2.8	0.5	Up	52992	2826.4
2.8	0.5	Up	53712	2840.1
2.8	0.5	Up	52238	2820
2.8	0.5	Up	50283	2793.8
2.8	0.5	Up	52032	2818.3
2.8	0.5	Up	52820	2828
2.8	0.5	Side	53264	2832.8
2.8	0.5	Side	49082	2783.5
2.8	0.5	Side	51242	2802.2
2.8	0.5	Side	50659	2794.2
2.8	0.5	Side	50008	2787
2.8	0.5	Side	50419	2788
2.8	0.5	Side	51379	2804.4
2.8	0.5	Side	49390	2779.2
2.8	0.5	Side	50282	2789.2
2.8	0.5	Side	52613	2816.5
2.8	0.5	Side	51344	2802.6
2.8	0.5	Side	51996	2812.9
2.8	0.5	Side	52579	2819.6
2.8	0.5	Side	49630	2781.1
2.8	0.5	Side	50556	2795.2
2.8	0.5	Side	50727	2791.8
2.8	0.5	Side	48362	2764.3
2.8	0.5	Side	50693	2797.1
2.8	0.5	Side	49802	2783.8
2.8	0.5	Side	49322	2781.4
2.8	0.5	Down	50762	2797.5
2.8	0.5	Down	50008	2789.3
2.8	0.5	Down	53196	2823.7
2.8	0.5	Down	53538	2829
2.8	0.5	Down	50350	2793
2.8	0.5	Down	49939	2785.2
2.8	0.5	Down	51379	2801
2.8	0.5	Down	50145	2787.7
2.8	0.5	Down	51207	2808.3
2.8	0.5	Down	51550	2803.9
2.8	0.5	Down	51893	2809.2
2.8	0.5	Down	50659	2796.9
2.8	0.5	Down	51173	2802.3
2.8	0.5	Down	51139	2802.5

2.8	0.5	Down	48019	2763.1
2.8	0.5	Down	51105	2806.8
2.8	0.5	Down	48945	2777.6
2.8	0.5	Down	50076	2792.7
2.8	0.5	Down	50179	2792.8
2.8	0.5	Down	52716	2823.7
2.8	1	Up	50213	2794.4
2.8	1	Up	50933	2798.6
2.8	1	Up	50076	2792.9
2.8	1	Up	49905	2785.7
2.8	1	Up	52750	2828.5
2.8	1	Up	51276	2804.9
2.8	1	Up	54190	2842
2.8	1	Up	53059	2827.8
2.8	1	Up	54738	2848.5
2.8	1	Up	54018	2839.8
2.8	1	Up	51996	2812.3
2.8	1	Up	50213	2788.7
2.8	1	Up	50350	2794.6
2.8	1	Up	51722	2811
2.8	1	Up	50453	2798.2
2.8	1	Up	47985	2763.7
2.8	1	Up	52099	2818.7
2.8	1	Up	50625	2799.4
2.8	1	Up	54156	2842.3
2.8	1	Up	51447	2809.1
2.8	1	Side	49528	2787.3
2.8	1	Side	50522	2797
2.8	1	Side	51413	2810.8
2.8	1	Side	52407	2814.7
2.8	1	Side	52579	2824.8
2.8	1	Side	50522	2798.9
2.8	1	Side	47539	2759.4
2.8	1	Side	51584	2807.5
2.8	1	Side	52064	2815.2
2.8	1	Side	51139	2805.2
2.8	1	Side	49973	2787.4
2.8	1	Side	51550	2808.8
2.8	1	Side	49905	2787.3
2.8	1	Side	53299	2833.1
2.8	1	Side	51893	2817.4

2.8	1	Side	49013	2775.6
2.8	1	Side	50659	2800.8
2.8	1	Side	53299	2829.1
2.8	1	Side	53230	2824.2
2.8	1	Side	50350	2797.3
2.8	1	Down	53916	2839.6
2.8	1	Down	51516	2809.7
2.8	1	Down	54670	2845.8
2.8	1	Down	50865	2804.3
2.8	1	Down	51173	2805.7
2.8	1	Down	51242	2802.7
2.8	1	Down	54773	2844.2
2.8	1	Down	50590	2798.3
2.8	1	Down	53401	2835
2.8	1	Down	48773	2773.8
2.8	1	Down	50385	2799.8
2.8	1	Down	53059	2830.6
2.8	1	Down	50110	2796.9
2.8	1	Down	47676	2757.7
2.8	1	Down	52716	2828
2.8	1	Down	52064	2819.2
2.8	1	Down	51070	2805.4
2.8	1	Down	52304	2814.3
2.8	1	Down	51619	2812.9
2.8	1	Down	48739	2781.9
3	0	Center	54704	2856.2
3	0	Center	53504	2845.8
3	0	Center	55767	2872.5
3	0	Center	52853	2836.2
3	0	Center	54773	2863.2
3	0	Center	51344	2818.1
3	0	Center	51002	2815
3	0	Center	52030	2830.4
3	0	Center	53984	2843.2
3	0	Center	53264	2834.7
3	0	Center	50487	2798.5
3	0	Center	53093	2833
3	0	Center	52750	2837.5
3	0	Center	53710	2842
3	0	Center	51790	2822.4
3	0	Center	50316	2807.1

3	0	Center	53196	2838.5
3	0	Center	52990	2833.3
3	0	Center	53161	2837.6
3	0	Center	53264	2832.1
3	0.5	Up	51139	2806.9
3	0.5	Up	51859	2811
3	0.5	Up	49528	2783.4
3	0.5	Up	51722	2821.9
3	0.5	Up	55390	2854.7
3	0.5	Up	53504	2832.7
3	0.5	Up	51962	2817.3
3	0.5	Up	53264	2827.2
3	0.5	Up	49596	2789.4
3	0.5	Up	52064	2819.5
3	0.5	Up	53744	2838.9
3	0.5	Up	48088	2762.9
3	0.5	Up	55767	2865.4
3	0.5	Up	51927	2812.4
3	0.5	Up	50247	2799.5
3	0.5	Up	50247	2801.9
3	0.5	Up	54156	2841.9
3	0.5	Up	49973	2793.3
3	0.5	Up	53950	2843.3
3	0.5	Up	53710	2839.9
3	0.5	Side	52202	2817.6
3	0.5	Side	51105	2805.2
3	0.5	Side	52784	2826.2
3	0.5	Side	50693	2802.1
3	0.5	Side	50213	2797.2
3	0.5	Side	48705	2781.8
3	0.5	Side	53710	2836.8
3	0.5	Side	47848	2769.4
3	0.5	Side	52202	2820.9
3	0.5	Side	51139	2804.2
3	0.5	Side	48259	2768.3
3	0.5	Side	50762	2807.8
3	0.5	Side	49082	2784.2
3	0.5	Side	50042	2798.3
3	0.5	Side	49665	2781.9
3	0.5	Side	53881	2837.6
3	0.5	Side	51173	2808.1

3	0.5	Side	52167	2823.8
3	0.5	Side	48225	2772.9
3	0.5	Side	53367	2837.3
3	0.5	Down	51070	2805.5
3	0.5	Down	53641	2837.4
3	0.5	Down	53367	2839
3	0.5	Down	52681	2825.1
3	0.5	Down	49665	2788.9
3	0.5	Down	50590	2801.1
3	0.5	Down	53950	2837.7
3	0.5	Down	56521	2869.8
3	0.5	Down	54978	2851.3
3	0.5	Down	54875	2848.2
3	0.5	Down	54567	2846.4
3	0.5	Down	53436	2836.3
3	0.5	Down	52476	2822.2
3	0.5	Down	51207	2803.8
3	0.5	Down	52956	2829.4
3	0.5	Down	54601	2853.1
3	0.5	Down	49356	2786.7
3	0.5	Down	53436	2837.1
3	0.5	Down	53641	2837.7
3	0.5	Down	53161	2836.7
3	1	Up	52441	2817.6
3	1	Up	52544	2818.8
3	1	Up	53881	2836.9
3	1	Up	51105	2810.9
3	1	Up	55561	2850.5
3	1	Up	53504	2831.1
3	1	Up	50590	2804.2
3	1	Up	52339	2812.9
3	1	Up	50385	2798.9
3	1	Up	49802	2792.1
3	1	Up	49356	2791.1
3	1	Up	53333	2832.6
3	1	Up	51584	2817.8
3	1	Up	52956	2824.4
3	1	Up	50830	2803.1
3	1	Up	50213	2803.7
3	1	Up	52064	2818.8
3	1	Up	51105	2811.6

3	1	Up	53024	2834.5
3	1	Up	50727	2801.9
3	1	Side	50008	2797.6
3	1	Side	51722	2812.5
3	1	Side	51242	2811.4
3	1	Side	48842	2782.1
3	1	Side	52304	2819.7
3	1	Side	50590	2801.5
3	1	Side	52750	2824.9
3	1	Side	54018	2843.2
3	1	Side	51139	2805.5
3	1	Side	52647	2825.4
3	1	Side	53196	2831.6
3	1	Side	54258	2838
3	1	Side	50213	2799.2
3	1	Side	49459	2786
3	1	Side	48396	2769.4
3	1	Side	52510	2827.8
3	1	Side	50899	2807.3
3	1	Side	50865	2801.1
3	1	Side	51927	2810.4
3	1	Side	49768	2789.5
3	1	Down	49905	2793.4
3	1	Down	52304	2824
3	1	Down	51893	2816.3
3	1	Down	50522	2796.7
3	1	Down	52579	2825.3
3	1	Down	49973	2798.8
3	1	Down	51482	2815.7
3	1	Down	53916	2836
3	1	Down	52819	2828.9
3	1	Down	47985	2768.8
3	1	Down	55218	2851.4
3	1	Down	48808	2774.1
3	1	Down	49253	2786.9
3	1	Down	53778	2838.6
3	1	Down	50453	2800.5
3	1	Down	50865	2802.8
3	1	Down	52373	2819.5
3	1	Down	52270	2811.4
3	1	Down	52681	2827

3	1	Down	57584	2882.8

APPENDIX J.

EQUIPMENT

Summary:

The following is a list of descriptions of the various pieces of equipment used to conduct this research.

RCBS Rock Chucker Supreme Master Single Stage Press Kit (18)

Kit Includes:

- Rock Chucker Supreme Single

Stage press

- 505 scale
- Uniflow Powder Measure
- Speer Reloading Manual
- Hand priming tool with small and large primer plugs
- Folding Hex Key Set with 0.050", 1/16", 5/64", 3/32", 7/64", 1/8", 9/64" and 5/32"

keys

- Universal Case Loading Block, which holds 40 cases in most rifle and pistol calibers
- Case Lube Kit, which includes a 2 oz bottle of Case Lube-2, a case lube pad, 2 case

neck brushes for .22 through .30 calibers and an accessory handle

- Powder Funnel for .22 to .45 caliber, including the Winchester Short Magnum calibers
- Chamfer and deburring tool for .17 through .60 caliber

Lee Deluxe 3-Die Set 223 Remington (18)

Dies Included:

Full Length Sizing Die

Collet Neck Sizing Die

Bullet Seating Die

Die Size: Standard 7/8"-14 threads

Lee Pacesetter 3-Die Set 308 Winchester (18)

Dies Included:

Full Length Sizing Die

Bullet Seating Die

Factory Crimp Die

Die Size: 7/8"-14 threads

Lyman Electronic Caliper 6" Stainless Steel (18)

Type: 6" Electronic Caliper

Material: Stainless Steel

Function: Measures length

Accuracy: .001"/.1mm

Range: 0-6"

Hornady M-2 Case Tumbler 110 Volt (18)

Voltage:110 Volt

Bowl Capacity: Up to 500-38 Special Cases

Media Included: No

Material: Bowl is plastic

RCBS Formula 1 Brass Cleaning Media Walnut Hull 5 lb (18)

Material: Walnut Shell

Sieve Size: 12/12

Treated: Yes

Packaging: Plastic bag in a cardboard box

Weight: Approximately 5 lbs

Hyskore® DLX Precision Rifle Rest (19)

- Tames recoil without weights

- Welded-steel frame

- Remote trigger release included

Competition Electronics ProChrono Digital Chronograph (18)

Accuracy: +/-1% of measured velocity or better

Dimentions: 16" x 4" x 3-¼"

Measurement Units: Feet per Second or Meters Per Second

Operating Temperature Range: 32°F to 100°F

Tripod Mount: ¼ x 20 threaded hole

Velocity Range: 21-7000 fps

Bill Wiseman and Co. Pressure and Velocity Barrels (20)

Length: 24”

Material: Butto treated 416 Stainless Steel

Bill Wiseman and Co. Universal Receiver (20)

Bill Wiseman and Co. Pneumatic Firing Mechanism (20)

Eliminates 99.9% of misfires.

BIBLIOGRAPHY

1. Speer Bullets. Modern Cartridges & Their Components. *Speer Reloading Manual #14.* Lewiston : ATK/Speer, 2007, pp. 27, 41, 46-48.

2. George C. Nonte, Jr. *Firearms Encyclopedia.* New York : Outdoor Life, 1973. pp. 8, 16, 57, 58.

3. Parts of a Cartridge. *International Hunter Education Association.* [Online] 2002.

4. Maj. George C. Nonte, Jr. *Modern Handloading.* New York : Winchester Press, 1972. pp. 42, 102, 103, 276, 382.

5. Halstead, Mark. *December 2013 Meeting.* Ozark, December 2013.

6. Lake, E.R. *Percussion Primer, Designe Requirements.* St. Louis : McDonnel Aircraft Company, 1970.

7. Salazar, German A. Primers: Large vs. Small Flash Hole Test. *The Rifleman's Journal.* [Online] March 2011. http://riflemansjournal.blogspot.com/2011/03/primers-large-vs-small-flash-hole-test.html.

8. Dr. Martin MacCarthy, Martin O'Neill, Helen Cripps. *An Investigation into the use of sound moderators on firearms for game and feral management in New South Wales.* s.l. : Edith Cowan University, 2011.

9. Speer Bullets. Glossary. [book auth.] Speer Bullets. *Speer Reloading Manual #14.* Lewiston : ATK/Speer, 2007, p. 1133.

10. Nosler Inc. FAQ. *Nosler.* [Online] October 2013. http://faq.nosler.com/index.php?action=artikel&cat=21&id=28&artlang=en.

11. Krier, Herman. *Interior Ballistics of Guns.* New York : American Institute of Aeronautics and Astronautics, 1979. pp. 3, 4.

12. U.S. Army Material Command. *Interior Ballistics of Guns.* Washingto D.C. : United States Army Material Command, 1965.

13. Bill Pullum, Frank T. Hanenkrat. *Position Rifle Shooting: A How-To Text for Shooters and Coaches.* New York : Winchester Press, 1973. p. 165.

14. Halstead, Mark. *223 and 308 Quality Control.* October 2014.

15. —. *Previous Fiocchi Research.* November 2014.

16. R.L. Wagner, E.L. Miller. *Influence of Flash Hole Diameter on Percussion Primer Functioning Characteristics.* s.l. : Feltman Research and Engineering Laboratories, Picatinny Arsenal, 1959. Resticted to Public Viewing.

17. Young, Hugh D. and Freedman, Roger A. *University Physics.* San Francisco : Pearson Addison Wesley, 2003. p. 532. Vol. 1.

18. *Midway USA.* [Online] 2014. http://www.midwayusa.com.

19. *Cabela's.* [Online] 2014. http://www.cabelas.com.

20. Products. *Bill Wiseman & Co., Inc.* [Online] 2014. http://www.wisemanballistics.com.

VITA

Nicolaas Martin Schrier was born in Brampton, Ontario, Canada on September 19, 1988. He began his university career at the University of Guelph (Guelph, Ontario, Canada) in 2006. He received a Bachelor of Science Degree in Physics in June 2010 from the University of Guelph. Martin continued his academic career in 2013, pursuing a Master of Science in Explosives Engineering from the Missouri University of Science and Technology, graduating in May 2015.

Martin has been a member of the International Society of Explosives Engineers (ISEE) since 2013.

This is the first paper Nicolaas Martin Schrier has written to date.