The Accuracy Of Black Powder Muskets

By
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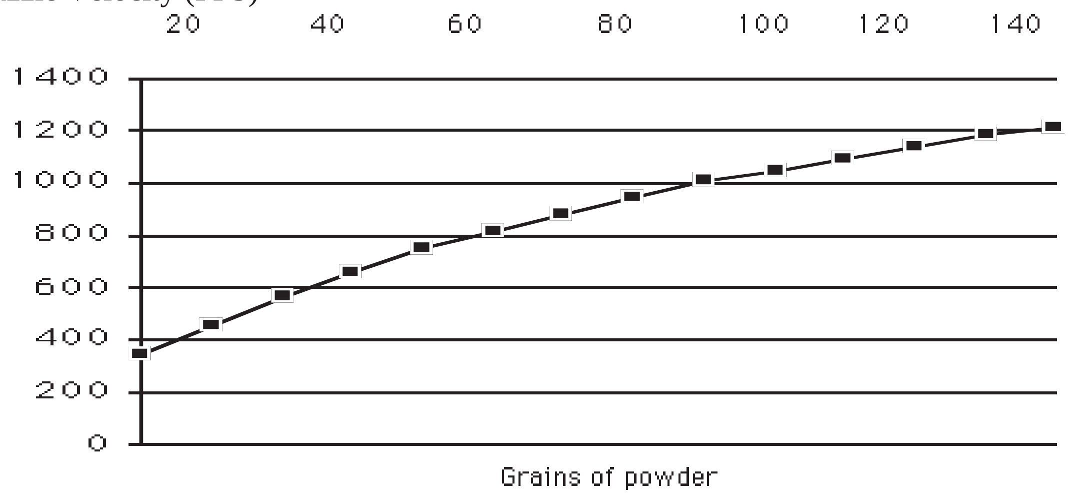
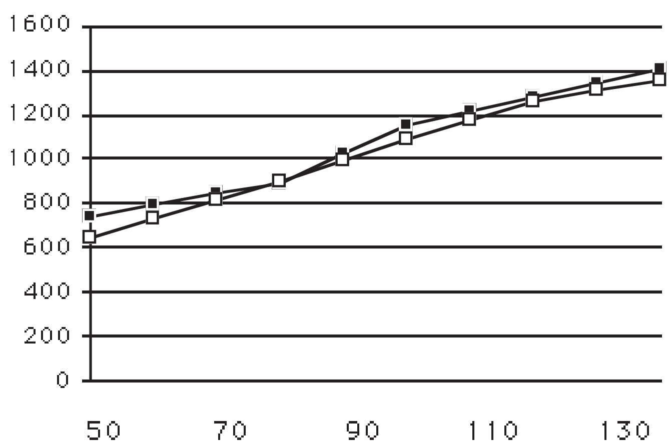
Introduction
This article covers an attempt of mine to analyze some data I have come across regarding the Brown Bess Musket.

Muzzle Velocity
How the amount of powder loaded into the weapon affects the muzzle velocity is shown by the following chart. This test was conducted using a greased and patched .715" ball weighing 545 grs. using modern FFg power[1]. I would think that in battle, a hastily loaded weapon would not perform as well and certainly not as consistently. The actual standard load of a Brown Bess cartridge was 6 to 8 drams[2]. A dram equals about 27.5 grains, so the actual load for the period would be 165 to 220 grains minus the amount used to prime the pan. However modern black powders have much better quality as far as consistency and power[3].

Muzzle Velocity (FPS)



Quality of Powder
Some other tests were conducted with a standard Civil War Minnie ball using two different grades of modern commercially available black power[4]. The interesting thing is the change in muzzle velocity based upon the power used. That this could have a some effect on accuracy at longer ranges as will be seen in the next section. If modern powders could be this different, it hard to imagine what things were like during the Napoleonic wars, especially on an extended campaign[5].

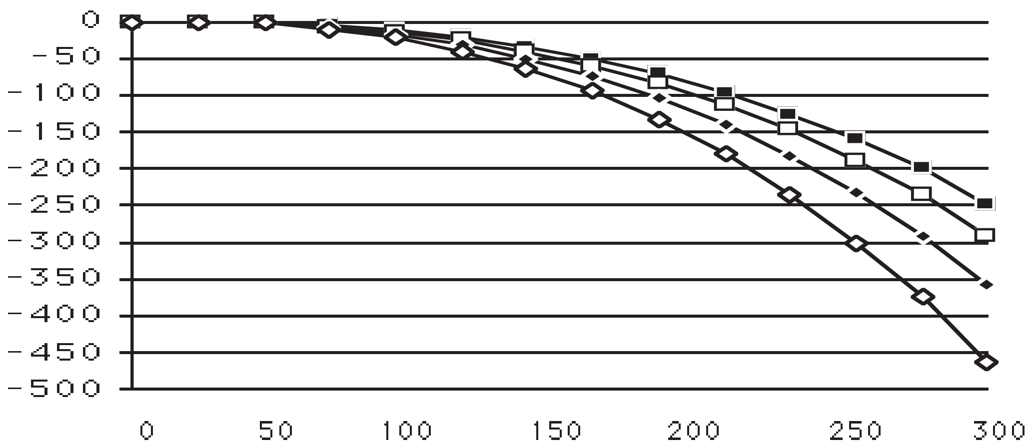


Resulting Drop

The following chart shows the expected drop from a brown bess musket at various ranges and muzzle velocities[6]. Remember that this is theoretical data, not what one would see on every shot. Imperfections of many sorts would make it difficult to have repeatable results at longer ranges, but for that sake of this discussion, lets go with the only data available.

Graphs for muzzle velocity of 1000 fps, 900 fps, 800 fps and 700 fps.

inches of drop



The drop of a ball fired from a brown bess is considerable, from 250 to 450 inches at 300 yards, depending upon muzzle velocity. Note that a 5ÿ8" high man is only 68" high. At 300 yards a ball fired at 1000 fps will drop a total of more than 20 feet. In other words to hit a target at 300 yards the musket barrel must be pointed directly at a spot 20 feet 7.2 inches above the target!! However at 75 yards the worst case drop is only 22 inches, less than two feet!

Notice that the difference between the drop of a high velocity 1000fps and low velocity ball 700fps is almost as much as the total drop of the high velocity ball. Drop is important because it affects how much you must raise the front of the barrel to be able to hit a target at longer ranges. It will also affect the difference between the minimum and maximum elevations at which a brown bess must be aimed to hit a target at a given range. A ball that is fired out to a range that has a lot of drop has a smaller chance to hit a target. If the target is closer than expected the ball may fly over it. If the target is farther than expected the ball will land short. However at close range the chances are the ball will strike close to the target, because the musket is aimed fairly close to level. A ball fired at higher velocity will cover more area between the time it reaches a height say 5ÿ8" that could hit a man and before it hits the ground.

Sighting and the "Danger Zone"

Sights on the brown bess consisted of a piece of metal mounted at the front of barrel. Some say that the sight was really just a mounting point for the bayonet.

The danger zone is a term I have borrowed from naval warfare. When firing a weapon at a distance the ball will have a chance of hitting a target at a longer range than expected. That is the target is not a point, but a certain height. When the target is further than expected, the ball may still hit if it does not strike the ground before it reaches the target. Conversely, if the target is closer than expected, the target may still be hit, if the ball falls to the maximum height of the target before it passes beyond the target.

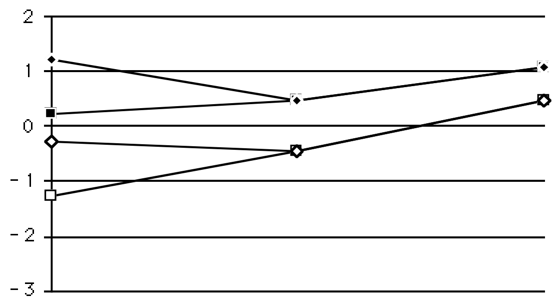
Since I do not know at what ranges the various weapons tended to be sighted in for (I am using this term loosely, given the primitive sights of weapons involved). I have run some calculations on what the danger zone would be if the weapons were sighted in at 75, 150 and 250 yards. This should give you some idea of how much error would be allowed before a miss occurred.

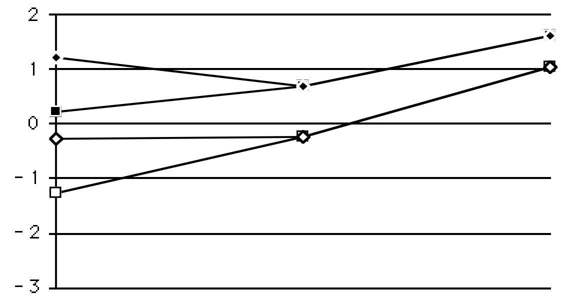
There are several assumptions taking place here.
— The musket is fired from a height of 60 inches
— The target is 68 inches high.
— The ball has a muzzle velocity of 900 fps and another batch of data was calculated with a muzzle velocity of 700 fps. A ball with a slower muzzle velocity would have a smaller danger zone and a ball with a faster muzzle velocity would have a larger danger zone.

The danger zone is expressed in terms of the amount of deviation in degrees that the musket barrel might take from true (aimed 8 inches below the top of the target) and still allow the ball to hit the target without flying over or hitting the ground first. High is the amount of degrees higher than the target that the weapon can be aimed and still achieve a hit. Low is the amount of degrees lower than the target that the weapon can be aimed and still achieve a hit. The best results will normally be achieved when the high and low angles are centered on the target. That way a slight deviation in either direction will still achieve a hit. Note that the total ”degrees of freedom‘ does not change with the sighting range only where the shot will be centered.

Several things affect accuracy as the range is increased.

1) There is less degrees of freedom because the target occupies a smaller angle in the field of view.
2) The danger zone is smaller making the degrees of freedom smaller.
3) Unless the weapon is sighted in at a longer range or is pointed high, the balls will tend to fall short.



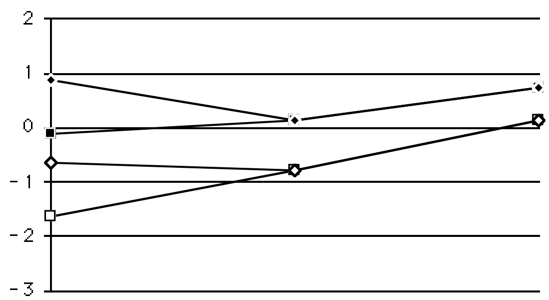


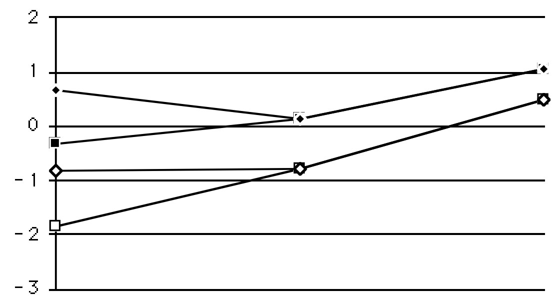
Danger zone if sighted in at 75 (900 fps)

range	elev.	high	low	ave	total
75	0.28	0.22	-1.28	-0.53	1.5
75(low)	0.28	1.22	-0.28	0.47	1.5
150	0.28	0.47	-0.45	0.01	0.92
250	0.28	1.08	0.47	0.78	0.61

Danger zone if sighted in at 75 (700 fps)

range	elev.	high	low	ave	total
75	0.45	0.22	-1.28	-0.53	1.5
75(low)	0.45	1.22	-0.28	0.47	1.5
150	0.45	0.68	-0.24	0.22	0.92
250	0.45	1.62	1.04	1.33	0.58



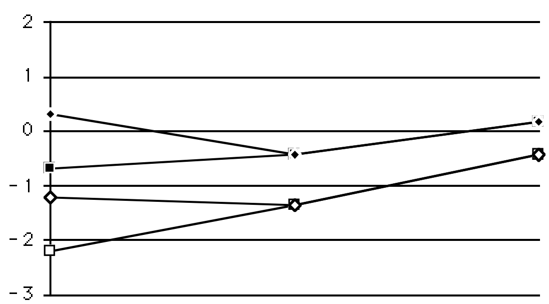


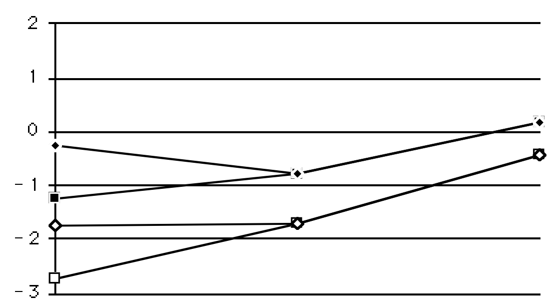
Danger zone if sighted in at 150 (900fps)

range	elev.	high	low	ave	total
75	0.62	-0.12	-1.62	-0.87	1.5
75 (low)	0.62	0.88	-0.62	0.13	1.5
150	0.62	0.13	-0.79	-0.33	0.92
250	0.62	0.74	0.13	0.44	0.61

Danger zone if sighted in at 150 (700fps)

range	elev.	high	low	ave	total
75	1.0	-0.33	-1.83	1.08	1.5
75 (low)	1.0	0.67	-0.83	0.08	1.5
150	1.0	0.13	-0.79	-0.33	0.92
250	1.0	1.07	0.49	0.78	0.58





Danger zone if sighted in at 250 (900 fps)

range	**elev.**	**high**	**low**	**ave**	**total**
75	1.19	-0.69	-2.19	-1.44	1.5
75(low)	1.19	0.31	-1.19	-0.44	1.5
150	1.19	-0.44	-1.36	-0.9	.92
250	1.19	0.17	-0.44	-0.135	.61

Danger zone if sighted in at 250 (700fps)

range	**elev.**	**high**	**low**	**ave**	**total**
75	1.91	-1.24	-2.74	-1.98	1.5
75 (low)	1.91	-0.24	-1.74	-0.98	1.5
150	1.91	-0.78	-1.70	-1.24	0.92
250	1.91	0.16	-0.42	-0.13	0.58

The closer to zero the average is, the greater the effect a given volley will have. This is because shots will be centered around this point. If the point is not centered on the target the shots will be more likely to miss. Given all these assumptions, a Brown Bess fired at 900 fps and sighted in at 150 yards, and aimed low at 75 yards will be the best performer with a total average of .90. The second best is the same setup only at 700 fps with a total of 1.19. The worst total is 3.35 sighted in at 250 yards. This tends to show that aim point is more significant than muzzle velocity in accuracy, which would seem to make sense. Remember that this is only a small sample of an infinite number of combinations.

Effect of muzzle velocity

The difference between 700 and 900 fps is very small at 75 yards and increases slightly at 150 yards. Only at 250 yards does it become really significant. The muzzle velocities listed here are lower than those reported for black powder era flintlock muskets. This should not greatly affect our presumptions, because muzzle velocity is shown to be a small factor in accuracy.

REPORTED HISTORIC MUZZLE VELOCITIES

U.S. .69 Cal. flintlock musket	110 grains powder	412 gr ball	1500 fps[7]
U.S. .69 Cal. musket	120 grains powder		1426 fps[8]

Adjustment for close range firing at feet

The above tables list an alternate danger zone, labeled low. This the effect the firing at the targets feet at close range will have. This can be calculated to have an effect of slightly less than 1 degree at 75 yards range. It is assumed that firing at the targets feet did not occur at much greater ranges than this. In fact at 150 yards, firing at the feet of the target only affects the aim point by .5 degrees. It is easily discernible in the data presented here that firing at the target's feet has a positive effect on accuracy at close range no matter how the weapon is sighted. The effect of firing low (at the targets feet) at 75 yards has a very beneficial and natural effect of correcting a possible overshoot situation at close range and still allows for hitting a target at 150 yards without having the shot fall short.

Possible overshoot or undershoot

A musket ranged at 250 yards would have a tendency to overshoot a target at 75 yards unless the weapon was aimed at the ground in front of the target. A musket ranged at 75 or 150 yards will have a tendency to fall short at 250 yards unless the weapons is aimed above the target. A weapon sighted in at somewhere between 75 and 150 yards should perform well at any range under 150 yards, assuming it is fired low at the closer ranges.

A Reminder

You must remember that the weapons of the era did not have adjustable sights, but these charts show what could be possible with such sights and what adjustments must be made to hit a target at given range.

Hammer Drop, Flash and Delay

Several other factors affecting the ability to hit a target a given range. One of the most significant is the ignition system of a flint lock musket. Just the impact of the heavy hammer on the frizzen will shake the weapon, no matter how firmly the it is held[9]. Then the flash of powder going off in the pan will more likely than not cause the person firing the weapon to jump. Anyone who has slowly pressed the trigger of a weapon with a hair (or double set) trigger has probably experienced an involunary jump, when he or she expected the weapon to go off, but it didn't. I am quite sure the vast majority of soldiers of the time jumped when pulling the trigger. Finally, in a flint lock weapon, there is delay between the time when the trigger is pulled and when the ball leaves the barrel. During this time the hammer falls on the frizzen causing a spark which ignites the primer charge which ignites the main charge. Given all of this activity, it is unlikely the barrel is still pointing exactly where it was aimed when the person pulled the trigger.

However the actual recoil of the weapon does not adversely affect accuracy in any significant way[10].

Now consider that a weapon perfectly loaded and aimed at 75 yards can only deviate .75 degrees up or down to have any chance of hitting the target. Considering a brown bess to be a 59" long lever, that implies that the tip of the barrel may not move more than .77 inches up or down. At 250 yards the margin would be only around .3 degrees either way which translates to about .3 inches. That is assuming you could aim at some point exactly some distance above the target without a rear sight!

Now I suggest you get out your replica Brown Bess and see how easy it is to hold it that steady under ideal conditions. Now imagine how you would fare in the tussling, noise and confusion of a battle line after a 10 mile forced march, with nothing in your stomach.

Windage

A cross wind can have some effect on the accuracy of a weapon. However since the target was usually a long line of troops, unless one was aiming at near the end of that line, crosswinds would have little effect on the result. After all the worst case result listed here is a deflection of only about 12 feet[11].

MUZZLE VELOCITY	DISTANCE	WIND	DEFLECTION
700	100	10	7
700	100	20	14
700	200	10	30
700	200	20	59
700	300	10	71
700	300	20	142
900	100	10	6
900	100	20	12
900	200	10	25
900	200	20	51
900	300	10	59
900	300	20	118

A head wind or tail wind can also affect accuracy. A head wind will cause the bullet to go lower than normal, and a tail wind will cause the bullet to go high. The effect of a 20 mph head or tail wind is minimal causing a deviation of only a few inches[12], even at a couple hundred yards. Given that the normal drop of a brown bess at 200 yards is over 50 inches, we can not consider this effect significant to our discussion.

Spin on Ball and Bouncing Inside Barrel

It is a given that the barrels manufactured in the era were imperfect and could affect accuracy. Without testing vintage weapons, it is impossible the know what these effects were and how they varied from weapon to weapon. It can only be assumed that the ball leaving the barrel probably will not be in perfect condition and alignment with bore. Also the ball will bounce down the barrel taking on a spin from the last bounce before leaving the weapon[13]. This spin is not that of a rifled projectile, but that of a curving baseball. Since these things will adversely affect accuracy, it will be worse than theoretical, but how much worse no one can say, except that it will vary from shot to shot.

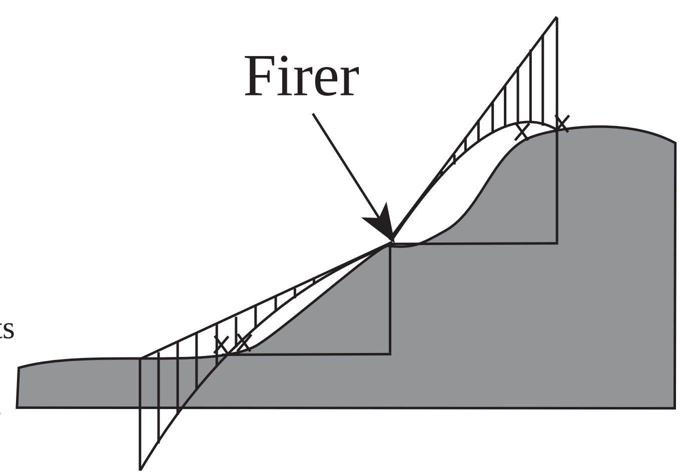
Relative Height

As is well known, firing up or down at a target will cause a slight overshoot when compared to firing on a level. This is a physical phenomenon related to how gravity will pull the ball straight down regardless of angle of fire. In other words, the expected drop at a given range is straight down, not relative to the line of fire. However this affect is not great and can be calculated[14]. For most military situations, this effect can be ignored. From these few examples listed, only at 200 yards and 30 degrees does this effect become significant. However at this range the drop is already over 50 inches, which would normally result in undershoot. Thus, this effect probably slightly helps accuracy at longer ranges and very high or low elevations since the musket of the period had fixed sights.

Overshoot at 900 fps	15 degrees	30 degrees	general formula
100 yards	0.852	3.349	drop-COS(angle*PI()/180)*drop
200 yards	3.85	15.14	

If this is really the case, why do we constantly read about troops on lower elevations suffering less than those on heights. Traditionally, the explanation has been that the height differences cause the troops on high ground to overshoot. If this is true, why don't troops on heights get the same advantage. I have never read of a case where troops on heights noted that the enemy was shooting high because of the relative height.

If you look closely at the provided figure. It shows an exaggerated, trajectory of a ball fired uphill and another with the same drop, downhill. You see that the trajectory of a shot fired uphill but too high will tend to fall close to the target. Firing uphill will shorten the effective range of a shot. The same shot fired too high at a downhill target., will go far over the target because firing downhill lengthens the range. Because overshoots are landing closer to target there is a greater chance of damage being done, when firing uphill. I am not sure that even I buy this argument, but there may be something to this.



Human

The final factor to adversely affect accuracy is the fact that soldiers of the era had little or no target practice. They were not expected to hit individual targets at long ranges, they were only expected to be able to load and discharge their weapons in accordance with a very precise set of procedures that would enable a group of men to maneuver and fire a volley in unison. They were not expected to judge ranges and adjust. In fact, even if they could judge the range, they had no way to adjust for it. They had to fire at a close range so that some balls would happen to hit the enemy. Firing a military musket during the late 18th and early 19th century was not a science and was it was not intended to be. The tactics of the time depended not upon accuracy, but effect of noise and volume of fire to weaken the enemy, before the bayonet would finish the work[15]. I guess you could compare musketry of that time, to the strategic bombing of the Second World War. You were not able to defeat a determined enemy with it, but you sure could hurt him if you threw enough metal his way.

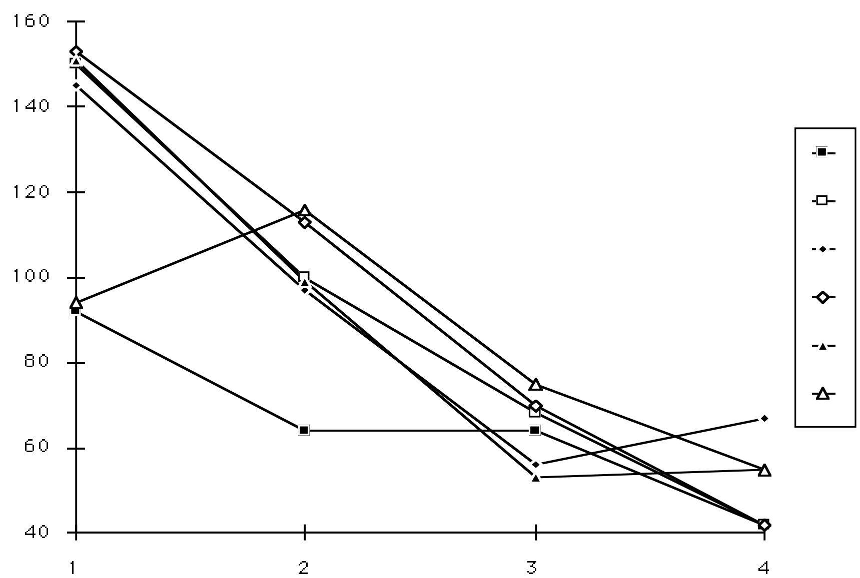
Conclusion

Gibbon in his "Artillerist's Manual" points out the variations from shot to shot may often exceed 36" to 54" in a musket at 200 yards[16]. He was describing a best case target practice type situation. He wrote his manual just before the American Civil War and was most likely referring to the US .69 caliber percussion smoothbore musket. Though not rifled, this weapon would perform far better than a flintlock musket such as a brown bess.

It is my conclusion that effective musket fire was not possible at ranges above 150 yards. This echoes the sentiment of some contemporary writers[17]. Furthermore given the poor field conditions and the little or no target practice that the conscripts had, really effective fire could probably not be delivered at ranges above 100 to 150 yards!!

Predicted Effect Versus Actual

After all of this discussion, we come to the crux of the matter.



This chart shows the relative power of 6 muskets tested by the Prussians at 4 different ranges[18]. We can apply some thought and the previous discussions to the problem of determining why there are several aberrations in this information

—Why the first musket seemed to perform normally at long range and poorly at the closer ranges of 80 and 160 yards.

—Why performance of 3 and 5 increase from 240 to 320 yards.

—Why the sixth musket performed dismally at the closest range, yet is the best musket at longer ranges.

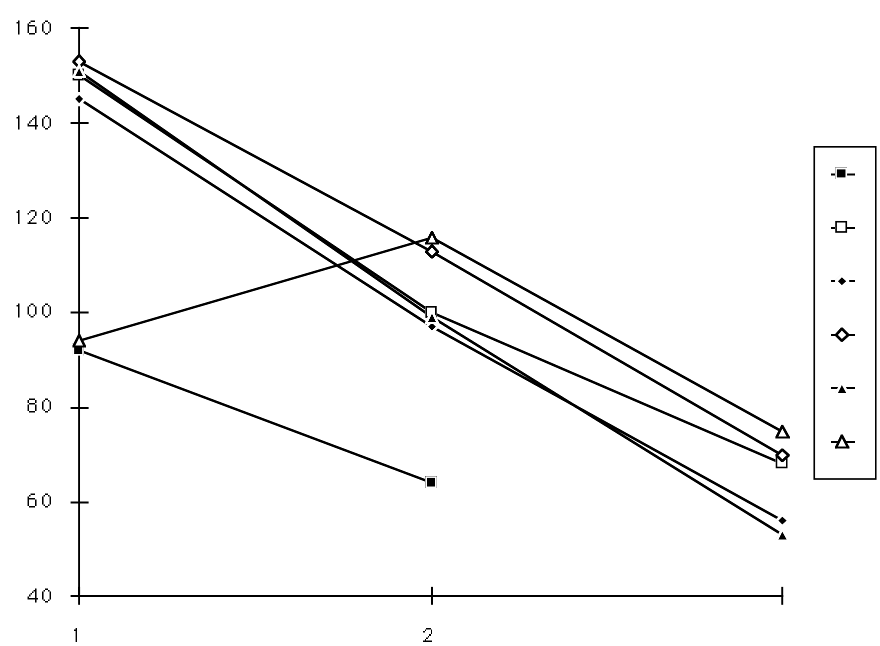
First of all lets discuss the results at 320 yards. Let's consider how difficult it must have been to hit a target in ideal conditions at 250 yards, since we have some hard data for that range. Assuming you have a musket loaded to fire a ball at 900 fps muzzle velocity and sighted in at 75 yards, you must sight the musket at an elevation of between .5 and 1 degree above the target. That is sighting the weapon at an elevation of over 6 feet above the target. Furthermore, if you accidentally loaded 80 grains of powder instead of 110 (or the powder was poorer quality than you were used to), the ball actually would leave the muzzle at 700 fps. You would then miss the target by being 6 feet low. Since in battle there are few such reference points convenient to the target even if you did know the exact elevation required, I would consider it random luck to score a hit even at 250 yards. However the prussions used a sheet of canvas to count hits. At that range I suspect that they were also counting the number of balls that bounced up and back through the sheet. Gibbon describes similar tests in his manual in which thin boards are used as a target. He specifically mentions that ricochets do not count[19]. It is hard to say how the ricochets are detected when a company fires in unison, which is what appears that the prussians have done. Muskets 3 and 5 actually improved in performance between 240 and 320 yards.   I suspect this is because some balls from those muskets actually went high at a range of 240, but that would not be likely at 320 yards. Most all of the balls fired at the longest ranges would hit the ground before hitting the target. A point that may be made to help support this point is the poor performance of weapons 3 and 5 at ranges 240 and closer. Since effectiveness drops off consistantly at these closer ranges, it is not likely that these weapons were sighted to shoot at 320 yards, since you would expect poor performance at closer ranges, as the balls would tend to go over the heads of those closer targets.

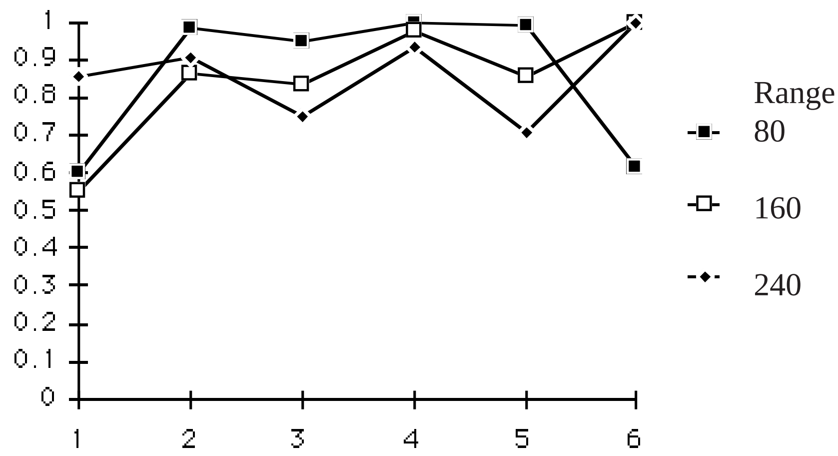
I would recommend we disregard any information from this longer range, as deflections may penetrate cloth, but would not have a great chance of seriously injuring a man. I personally know of one incident where a reproduction black powder era weapon was fired at target at point blank range and the ball bounced back and hit the person firing the weapon with no physical damage done (Don't try this yourself!!!).

Now lets consider the effectiveness of the first weapon, which starts out terribly, then catches up to the rest of the pack at 240 yards.   My feeling here is that this weapon is so bad the effect which occurs at 320 yards for weapons 3 and 5 occurs at 240 yards for this weapon. One of two things could be the root cause of this. First the velocity of balls fired from this weapons is so bad that the balls do not carry well at 240 yards, unless aimed ridiculously high. Second: the weapon is sighted in so low that most balls are deflecting off the ground even at close range. My gut feeling says the former is true. The effect of either is bad. So I believe we must disregard the 240 and 320 yard ranges of this weapon as ineffective.

Finally lets consider the sixth weapon which seems to perform admirably, except, strangely enough, at the closest range. My feeling is that this weapon is ranged to fire at 150 yards compared to weapons 2 and 4 which are ranged in at about 75 yards. It is firing high at the close range, then settling in and doing very well.

The result of these discussions is a new chart with no 320 yard range and no 240 yard range for weapon number 1. The results now seem to make a little more sense although I suspect weapons 2 and 3 may be benefiting from some of that bounce effect at 240 yards.





Finally by rating each musket at ranges of 80, 160 and 240 a picture of the theoretical effectiveness of each weapon becomes clear. This modified chart shows each weapons rating as compared to the best at that range. This rating is simply the percent of hits as compared to the best at that range.

1) A pretty marginal weapon, only 50 to 60 percent effective as the best weapon at under 160 yards. As noted before, worthless at longer ranges.

2) A decent weapon although dropping to 85 percent maximum effectiveness at only 160 yards. Seems to lack muzzle velocity, a suspected bounce effect may be occurring at 240 yards.

3) A decent weapon comparable to 2, but with better muzzle velocity. It drops to 75 percent maximum effectiveness at 240 yards.

4) An excellent weapon, seems to have no defects.

5) A decent weapon. It drops to 70 percent maximum effectiveness at 240 yards.

6) Would be a fine weapon, but has a serious overshoot problem at close range.

One other factor to consider here is that the differences between 2-5 at close range were minimal as we might expect from the ballistic data we have already considered. The only things that may seriously affect close range would be just a poorly designed or operated weapon, such as number 6 which could have been sighted in too high or number 1 which just seems poorly designed.

IDEAS FOR GAMERS

Since I am a wargamer, I will throw out some gaming type suggestions.
1) Fire should not be allowed at ranges above 150 yards.
2) A standard musket should have a fairly flat function of decreasing power out to 150 yards at which point it should be considered ineffective.
2) Deductions may be made for troops with type 1 muskets that are only 50 to 60 percent as effective as the standard.
3) Deductions may be made at close range only, for troops with type 6 muskets.
4) You may consider a deduction for firing at troops over 100 yards away and on a lower elevation.

1 BlackPowder Handbook, C. Kenneth Ramage, editor, 1975, Lyman Products for Shooters, Middlefield, Connecticut, page 142.
2 Red Coat and Brown Bess, Anthony D. Darling, 1971, Museum Restoration Service, Alexandria Bay, N.Y., page 11.
3 Black Powder Guide, Major George Nonte, 1969,Stoeger Publishing Company, South Hackensack, New Jersey, page 191.
4 [1] page 126
5 Artillerist's Manual, John Gibbon, 1860, D Van Nostrand, New York, page 224
6 [1] page 235
7 [3] page 191
8 [5] page 224
9 [1] page 44
10 [5] page 225
11 [1] page 235
12 [1] page 172
13 [5] page 236
14 [1] page 174
15 [2] page 11
16 [5] page 248
17 [2] page 11
18 The Power of Musketry in the Napoleonic Wars, G.F. Nafziger, Empires Eagles & Lions, #6.
19 [5] page 230