

Calculated Shotgun Pellet Penetration And Relevant Considerations

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The purpose of this paper is to provide accurate information on how velocity increases at the muzzle affects the down range performance of lead and steel shot. My information is as accurate as the tables and ballistic calculators I got it from, and that's the only definitive claim I can make about it. In this paper I provide the reader with the following...

Equations for:

- pellet penetration given an impact velocity
- the minimum impact velocity required for a desired amount of penetration
- calculating recoil energy based on shot velocity, gun weight, and load weight

Tables for:

- shotgun recoil for 6&7 pound guns with shot charges of 1oz-2.25oz, at muzzle velocities of 1000fps-1700fps
- chilled lead shot penetration in ballistics gel from the muzzle to 75 yards, for shot sizes #2-#7 ½, at muzzle velocities from 1000fps-1600fps, and 1100-1600fps for shot sizes #8 and #9
- steel shot penetration from the muzzle to 75 yards, for steel shot sizes BBB-#6, at muzzle velocities of 1300fps-1700fps
- buckshot penetration from the muzzle to 100 yards for sizes #4 buck-0000 buck, at muzzle velocities from 900fps-1400fps
- the minimum impact velocity for chilled lead shot (sizes #2-#9), and steel shot (sizes BBB-#6) penetrate 1.5", 1.75", and 2.25" into ballistics gel
- the penetration of a triple .600" ball load at 1100fps
- the penetration of .690", and .729" round ball shotgun loads
- the effect of increased muzzle velocities on target lead for steel shot (sizes BBB-#6), at 40 yards

Below each table the range which the pellets would penetrate 1.5", 1.75", and 2.25", (given the muzzle velocity for the pellets in that table) are listed.

I also explain how to use my equations.

To all of the Math and English teachers who put up with me over the years.

Recoil

Newton's third law states that for every force there is another force of equal magnitude, but opposite direction, simply put that's what recoil is.

While gun fit and recoil pads affect how the recoil feels, the force doesn't change, and since interpretations of felt recoil are as diverse and numerous as there are shooters, I'll leave that topic alone.

To calculate the actual recoil you need to know the weight of the gun, shot, powder, wad, the velocity of the shot, and gasses as they leave the barrel. There are some formulas that get close to the "exact" values, (SAMMI published a good one, I'll include the link at the bottom of the last page on recoil). I'm leaving powder out of my formula because different powders burn at different velocities and you may require more, or less of different types of powder to achieve identical velocities for the same weight of shot. For example, all other components being equal, you would not use the same charge of Longshot as you would Bluedot to get identical velocities. I left the wad weight out of it too, there are hundreds of types, each with their own weight, and the impact of the wad weight on recoil is fairly insignificant. The formula for recoil, not including the recoil produced by the gunpowder and wad, is as follows;

S_v = shot velocity in fps. G_w =Gun weight in grains. S_w =Shot weight in grains. R =recoil in foot pounds.

$$R = \frac{\left(\frac{\text{Shot Velocity}}{\left(\frac{\text{Gun weight}}{\text{Shot weight}} \right)} \right)^2 \times \text{Gun weight}}{450240}$$

$$R = \frac{\left(\frac{S_v}{\left(\frac{G_w}{S_w} \right)} \right)^2 \times G_w}{450240}$$

So applied to the 1200fps load and 1600fps load, assuming 1 1/8oz of shot in both cases, and a 7lb gun.

For the 1200fps load

$$\frac{\left(\frac{1200}{\left(\frac{49000}{492}\right)}\right)^2 \times 49000}{450240}$$

= 15.79ft-lbs of recoil

For the 1600fps load

$$\frac{\left(\frac{1600}{\left(\frac{49000}{492}\right)}\right)^2 \times 49000}{450240}$$

=28ft-lbs of recoil

Keep in mind my recoil formula only accounts for the gun weight, projectile velocity, and projectile mass. The actual recoil will be higher due to the volume and combustion speed of the powder used.

My point in this part is, if you have a 1 1/8oz load with a muzzle velocity of 1600fps, but the pellets will penetrate sufficiently at your maximum range if the muzzle velocity is 1200fps, there is no advantage to having a higher than necessary muzzle velocity. You could instead opt for a 1 1/2oz load of pellets at 1200fps for equivalent recoil to the 1600fps load, but a 33% increase in pellet count. Assuming the gun patterns it well, that means a potential 33% increase in lethal hit probability.

The following two charts were created with the recoil formula above.

All charge weights are listed as the decimal equivalents from 1 ounce to 2 1/4 ounces.

6lb Gun

Velocity/Charge Weight	1.00	1.125	1.250	1.375	1.50	1.625	1.75	1.875	2.00	2.125	2.25
1000	10.1	12.8*	15.7	19.1	22.7	26.7	30.9	35.5	40.4*	45.7	51.2
1100	12.2	15.4	19.0	23.1	27.5	32.3	37.5	43.0	48.9	55.3	62.0

1200	14.5	18.4	22.7	27.5	32.7	38.4	44.6	51.2	58.3	65.8	73.7
1300	17.1	21.6	26.6	32.3	38.4	45.1	52.3	60.1	68.4	77.2	86.5
1400	19.8	25.0	30.8	37.5	44.6	52.3	60.7	69.7	79.3	89.5	100.4
1500	22.7	28.8	35.4	43.0	51.2	60.1	69.7	80.6	91.0	102.8	115.2
1600	25.9	32.7	40.3	48.9	58.3	68.4	79.3	91.0	103.6	117.0	131.1
1700	29.25	36.9	45.5	55.3	65.8	77.2	89.5	102.8	117.0	132.0	148.0

7lb gun

Velocity/Charge Weight	1.00	1.125	1.25	1.375	1.50	1.625	1.75	1.875	2.00	2.125	2.25
1000	8.6	10.9	13.4	16.3	19.4	22.8	26.4	30.4	34.6	39.1	43.8
1100	10.4	13.2	16.2	19.8	23.5	27.6	32.1	36.8	41.9	47.4	53.1
1200	12.4	15.7	19.4	23.5	28.0	32.9	38.2	43.8	49.9	56.4	63.1
1300	14.6	18.5	22.8	27.6	32.9	38.6	44.8	51.5	58.6	66.1	74.1
1400	16.9	21.4	26.4	32.1	38.2	44.8	52.0	59.7	67.9	76.7	86.0
1500	19.4	24.6	30.3	36.8	43.8	51.5	59.7	69.0	78.0	88.1	98.7
1600	22.2	28.0	34.5	41.9	49.9	58.6	67.9	78.0	88.8	100.2	112.3
1700	25.2	31.6	39.0	47.4	56.4	66.1	76.71	88.1	100.2	113.1	126.8

The tables show that:

The recoil will change in direct proportion to the weight increase of the firearm. A 7 pound gun is 1/6th heavier (16.666%) than a 6 pound gun, and therefore the recoil (with identical loads) is 1/6th (16.666%) less. A 6 pound gun is 1/7th lighter than a 7 pound gun so recoil (with identical loads) will be 1/7th more.

The recoil will increase by the square of the ratio of the charge weight between two loads, multiplied by the recoil of the first load (given identical velocities)

$$(1.125oz \div 2oz)^2 \times 12.8ftlbs = 40.45ftlbs.*$$

The recoil will increase in direct proportion to the difference in the velocities of two loads, squared. For example, the recoil of a 1oz load at 1000 fps is 8.6 ft-lbs, and 10.4 ft-lbs at 1100 fps, assuming a 7lb gun. The difference in the velocities is 1.1, 1.1 squared is 1.21, 1.21 times 8.6 = 10.4.

I have found an equation that relates momentum to penetration. The equation is my own creation and it gives me a great deal of pride to be able to share it. While I'm sure others may have come up with something similar at some point, this work is my own. I believe it's completely original.

The key is a ratio, frontal pellet area over momentum in pounds. Essentially....

$$Penetration = \frac{\left(\frac{Impact\ Momentum}{\frac{1}{2} Pellet\ Surface\ Area} - 2.7 \right)}{1.1} \times .25$$

That's it. It's an explicit formula for pellet penetration given a velocity. The following page will better explain how it works, and how I created it.

Velocity will be measured in feet per second

Weight will be measured in grains

Momentum will be measured in pounds $\frac{Weight\ of\ pellet \times Velocity}{7000}$

1/2 pellet surface area is most easily calculated by multiplying the diameter of the pellet by π , then by the radius. $D\pi R$

If a graphing calculator is used and the momentum is broken up into $\frac{mv}{7000}$, and the velocity is left as a variable, and the numerical value for 1/2 the surface area is used, a line will be created. The X axis of this line will be the impact velocity, the corresponding Y values will be the penetration for that velocity. In the equation for the line (which is below) the V is the X variable, and the P is the Y variable.

$$P = \left(\frac{\left(\frac{\left(\frac{Mass \times V}{7000} \right)}{\frac{1}{2} pellet\ surface\ area} \right) - 2.7}{1.1} \right) \times .25$$

Shot Size/Diameter in Inches (Composition)	Shot Weight in Grains	Frontal Area (1/2 the Surface Area)	Momentum At Impact (For Penetration*)	Momentum/Area	Penetration in Inches
Steel BB, .18	6.1130	0.0508938	0.919584583	18.06869568	3.50"

Lead #2, .15	4.9742	0.035342917	0.4455462	12.60637881	2.25"
Steel B, .17	5.1271	0.045396013	0.572037871	12.60105972	2.25"
Steel BB, .18	6.0868	0.0508938	0.641722628	12.60905313	2.25"
Steel BBB, .19	7.1584	0.056705747	0.714817371	12.60573062	2.25"
Steel #2, .15	3.5356	0.035342917	0.368712571	10.43243181	1.75"
Steel#1, .16	4.2909	0.040212385	0.419282228	10.42669388	1.75"
Steel #3, .14	2.8637	0.030787608	0.2875973	9.341333045	1.50"
Steel #2, .15	3.5223	0.035342917	0.330089828	9.3396317	1.50"
Lead #5, .12	2.5468	0.022619467	0.2113844	9.345242308	1.50"
Steel #2, .15	3.5356	0.035342917	0.299012919	8.46033506	1.30"
Steel#1, .16	4.2909	0.040212385	0.340207071	8.460348756	1.30"

Regardless of the size, weight, or momentum, (and most likely-composition) for all pellets that will penetrate to the same depth, there is a relation between frontal surface area, and momentum. (I have also discovered that using the entire surface area, or even the cross sectional area works, it just yields a different constant. If you use the cross sectional area, 1.1 and 2.7 must be doubled, if you use the whole surface area, 1.1 and 2.7 must be halved).

When the penetration is zero, the projectile could still have momentum (all objects in motion that have mass, have momentum, that doesn't mean it's enough to penetrate ballistics gel). So there is a nonzero momentum/area value for when penetration is zero inches.

This table shows that for every ¼ inch the penetration increases the momentum/area constant increases by 1.1. The row in bold was a gap filling educated guess, an extrapolation.

Momentum/ Area Value	Penetration
9.3	1.5
10.4	1.75
11.5	2
12.6	2.25

By subtracting ¼ inch from the penetration until it equals zero, and subtracting 1.1 from the momentum/area constant that same number of times, we are left with the minimum momentum/area ratio for there to be any penetration at all.

$$1.5 - .25 - .25 - .25 - .25 - .25 - .25 = 0 \rightarrow 1.5 - (.25(6)) = 0$$

$$9.3 - 1.1 - 1.1 - 1.1 - 1.1 - 1.1 - 1.1 = 2.7 \rightarrow 9.3 - (1.1(6)) = 0$$

So the minimum momentum/area value for 0 inches of penetration is 2.7. For penetration greater than 0 inches the momentum/area constant has to be greater than 2.7.

$$\frac{(\text{momentum/area constant} - 2.7)}{\text{penetration}} = \text{required momentum/area constant for 1 inch of penetration}$$

$$\frac{(12.6 - 2.7)}{2.25} = 4.4$$

$$\frac{(9.3 - 2.7)}{1.5} = 4.4$$

That can be rearranged to calculate the required momentum/area value you need for a desired amount of penetration like so

$$\text{required } \frac{\text{momentum}}{\text{area}} \text{ value for 1 inch of penetration} \times \text{desired penetration} + 2.7 = \\ \text{required } \frac{\text{momentum}}{\text{area}} \text{ value for that desired penetration in inches}$$

So...

$$(4.4 \times \text{desired penetration in inches}) + 2.7 \\ = \text{required } \frac{\text{momentum}}{\text{area}} \text{ value for that desired penetration}$$

Ex: $(4.4 \times 2.25) + 2.7 = 12.6$

If you take it a step further you can rearrange the basic formula to figure out the minimum impact velocity you need to get a desired amount of penetration

So starting with the basic equation:

$$\text{Penetration} = \frac{\left(\frac{\text{Impact Momentum}}{1/2 \text{ Pellet Surface Area}} - 2.7 \right)}{1.1} \times .25$$

Rearranged to solve for impact velocity:

$$\text{Impact velocity} = \frac{\left(\left(\left(\frac{\text{Penetration}}{.25} \times 1.1 \right) + 2.7 \right) \times 1/2 \text{ Pellet surface area} \right) \times 7000}{\text{Pellet weight}}$$

From there with a round ball or shotgun pellet ballistics calculator you can figure out the maximum range of a given load to reach that penetration depth, given the initial velocity, or the

required initial velocity of a load to achieve that required velocity for a desired penetration at a given distance.

Now that I've rambled for a bit I'll apply it to the example I had on page 4, to demonstrate just how much of a difference an extra 400fps at the muzzle makes at 40 yards. So, 1200fps and 1600fps muzzle velocities, #4 chilled lead shot, and 40 yards velocities for each. I'll be using the penetration formula for this.

$$1200\text{fps: Penetration} = \frac{\left(\frac{(734 \times 3.23) \div 7000}{.13 \times \pi \times .065} - 2.7\right)}{1.1} \times .25$$

$$\text{Penetration} = 2.28''$$

$$1600\text{fps: Penetration} = \frac{\left(\frac{(825 \times 3.23) \div 7000}{.13 \times \pi \times .065} - 2.7\right)}{1.1} \times .25$$

$$\text{Penetration} = 2.64''$$

You get .36" more penetration by increasing starting velocity 400fps, just for comparisons sake I did the math to show what happens if you go up a shot size instead.

By my formula, for #3 chilled lead shot (4.03gr/pellet) at 1200fps muzzle velocity (40 yard velocity of 757fps): 2.60" of penetration. Nearly identical penetration, and not nearly enough of a difference to significantly impact pellet performance. Keep in mind that the minimum recommended penetration for pheasant (according to Ed Lowry), is 1.75", and even at 1200fps #4 lead exceeds that at 40 yards.

That said, there is a 20% reduction in pellet count between #4, and #3. 122 pellets/ 1 1/8oz load of #3 lead vs 152 pellets to the 1 1/8oz load of #4 lead. Whether that's significant depends almost entirely on your pattern and the needs of your hunting situation.

Using the formula to establish minimum impact velocity, and using the desired penetration of 1.75" at 40 yards, the minimum impact velocity for 1.75" of penetration is 600fps for #4 chilled lead. Using the ballistic calculator I determined the minimum starting velocity of a load of #4 chilled lead pellets to have that velocity at 40 yards. The starting velocity needs to be a minimum of 924fps. Fairly slow by most standards.

In my mind, if you're looking for more penetration it's more practical to increase the shot size by one number than to push the load faster. In loads of equivalent charge weights the recoil will not change, and if you find yourself with a shortage of pellets more can usually be added. 1 1/8oz of lead can be run at 1600fps and be at the upper limit of shotgun pressure, 1 1/2oz of lead can be run at 1200fps and be at that same limit.

Now that you know the minimum impact velocity to penetrate 1.75", you can use a ballistics calculator to determine the range the pellet will have a velocity of 600fps if it has a muzzle velocity of 1200fps, and 1600fps. According to the ballistics calculator I used, at a muzzle velocity of 1200fps the #4 chilled pellet will penetrate 1.75" at 58 yards, and at a muzzle velocity of 1600fps the #4 chilled pellet will penetrate 1.75" at 69 yards.

The following pages are calculated penetration tables. Tables missing a final row are missing it because the pellet would not have enough momentum to penetrate ballistics gel whatsoever at that range. I believe the tables are accurate to +/- 1 yard, and +/-5 fps. Keep in mind my data for velocity comes from a ballistics calculator, actual velocities may vary. All tables are calculated for 1000 feet above sea level and 66 degrees Fahrenheit.

Lead

#2

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1000	3.94
10	906	3.52
15	865	3.32
20	826	3.15
25	791	2.99
30	755	2.82
35	721	2.67
40	688	2.52
45	655	2.31
50	624	2.23
75	480	1.57

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 49, 67, 78

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	4.39
10	984	3.87
15	934	3.64
20	889	3.43
25	850	3.25
30	813	3.09
35	777	2.92
40	743	2.77
45	709	2.61
50	675	2.46
75	524	1.77

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 57, 75, 86

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	4.85
10	1035	4.10
15	985	3.87
20	935	3.64

25	890	3.44
30	850	3.25
35	813	3.09
40	777	2.92
45	743	2.77
50	709	2.61
75	553	1.90

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 62, 80, 91

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	5.31
10	1085	4.33
15	1024	4.05
20	972	3.81
25	924	3.59
30	880	3.39
35	842	3.22
40	806	3.05
45	770	2.89
50	735	2.73
75	575	2.00

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 66, 84, 95

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	5.76
10	1142	4.59
15	1062	4.22
20	1003	3.95
25	954	3.73
30	908	3.52
35	866	3.33
40	828	3.15
45	793	3.00
50	758	2.84
75	595	2.09

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 69, 87, 98

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	6.22
10	1201	4.85
15	1102	4.40

20	1036	4.10
25	982	3.86
30	932	3.63
35	890	3.44
40	851	3.26
45	814	3.09
50	777	2.92
75	612	2.17

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 72, 90, 101

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	6.67
10	1266	5.15
15	1150	4.62
20	1066	4.24
25	1010	3.98
30	960	3.76
35	913	3.54
40	871	3.35
45	832	3.17
50	796	3.01
75	629	2.25

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 75, 93, 103

End of #2

#4

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1000	3.33

10	894	2.91
15	846	2.72
20	804	2.56
25	763	2.40
30	724	2.24
35	686	2.09
40	647	1.94
45	611	1.80
50	577	1.66
75	421	1.04

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 37, 46, 56

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	3.73
10	966	3.20
15	912	2.98
20	864	2.80
25	822	2.63
30	780	2.46
35	739	2.30
40	700	2.15
45	662	2.00
50	626	1.85
75	462	1.21

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 40, 53, 63

Distance (Yards)	Velocity (fps)	Penetration (inches)
0	1200	4.12
10	1019	3.41
15	960	3.17
20	907	2.96
25	860	2.78
30	816	2.61
35	775	2.44
40	734	2.28
45	695	2.13
50	658	1.98
75	489	1.31

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 41, 58, 67

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	4.52
10	1066	3.59

15	998	3.32
20	942	3.10
25	889	2.89
30	844	2.72
35	803	2.55
40	762	2.39
45	721	2.23
50	683	2.08
75	509	1.39

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 44, 61, 70

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	4.91
10	1110	3.77
15	1033	3.46
20	971	3.22
25	917	3.00
30	871	2.82
35	826	2.64
40	783	2.48
45	744	2.32
50	704	2.16
75	527	1.46

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 47, 64, 73

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	5.31
10	1169	4.00
15	1067	3.60
20	1003	3.34
25	943	3.11
30	893	2.91
35	848	2.73
40	805	2.56
45	762	2.39
50	723	2.24
75	543	1.53

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 49, 66, 76

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	5.70

10	1230	4.24
15	1107	3.75
20	1030	3.45
25	970	3.21
30	915	3.00
35	867	2.81
40	825	2.64
45	782	2.47
50	741	2.31
75	559	1.59

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 52, 69, 78

#4 End

#5

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1000	3.03
10	886	2.61
15	836	2.43
20	791	2.27
25	746	2.10
30	703	1.94
35	664	1.80
40	623	1.65
45	585	1.51
50	549	1.38
75	386	0.79

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 20, 36, 45

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	3.39
10	957	2.87
15	901	2.67
20	851	2.48
25	805	2.32
30	761	2.16
35	716	1.99
40	676	1.85
45	636	1.70
50	596	1.55
75	425	0.93

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 27, 43, 51

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	3.76
10	1009	3.06
15	948	2.84
20	890	2.63
25	841	2.45
30	796	2.28
35	751	2.12
40	709	1.97
45	668	1.82
50	628	1.67
75	450	1.027

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 31, 47, 56

Distance (Yards)	Velocity (fps)	Penetration (Inches)
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0	1300	4.12
10	1055	3.23
15	984	2.97
20	923	2.75
25	870	2.55
30	824	2.39
35	778	2.22
40	734	2.06
45	692	1.90
50	652	1.76
75	470	1.10

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 34, 50, 59

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	4.49
10	1097	3.38
15	1019	3.10
20	955	2.86
25	896	2.65
30	847	2.47
35	801	2.30
40	757	2.14
45	713	1.98
50	673	1.84
75	488	1.16

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 36, 52, 61

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	4.85
10	1142	3.55
15	1051	3.21
20	982	2.96
25	921	2.74
30	868	2.55
35	823	2.38
40	777	2.21
45	733	2.05
50	691	1.90
75	503	1.22

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 39, 55, 64

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	5.22
10	1209	3.79
15	1088	3.35
20	1008	3.06
25	947	2.83
30	892	2.63
35	841	2.45
40	796	2.28
45	752	2.12
50	709	1.97
75	517	1.27

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 41, 57, 66

#5 end

#6

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1000	2.73
10	875	2.31
15	824	2.14
20	775	1.98
25	727	1.82
30	682	1.67
35	638	1.52
40	596	1.38
45	556	1.24
50	517	1.11
75	348	0.55

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 11, 27, 35

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	3.06
10	947	2.55
15	888	2.35
20	833	2.17
25	785	2.01
30	736	1.85
35	691	1.70
40	645	1.54
45	603	1.40
50	564	1.27
75	384	0.67

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 17, 32, 41

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	3.40
10	998	2.72
15	930	2.50
20	873	2.30
25	821	2.13
30	771	1.96
35	724	1.81
40	678	1.65
45	635	1.51
50	593	1.37
75	408	0.75

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 21, 36, 45

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	3.73
10	1037	2.85
15	965	2.61
20	902	2.40
25	848	2.22
30	798	2.05
35	751	1.90
40	704	1.74
45	659	1.59
50	615	1.44
75	427	0.81

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 24, 39, 48

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	4.07
10	1081	3.00
15	998	2.72
20	933	2.51
25	873	2.30
30	820	2.13
35	773	1.97
40	726	1.81
45	679	1.66
50	635	1.51
75	443	0.87

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 26, 41, 50

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	4.40
10	1124	3.15
15	1029	2.83
20	958	2.59
25	897	2.39
30	844	2.21
35	792	2.03
40	745	1.88
45	698	1.72
50	654	1.57
75	458	0.92

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 28, 43, 52

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	4.74
10	1186	3.35
15	1062	2.94
20	984	2.68
25	922	2.47
30	864	2.27
35	812	2.10
40	764	1.94
45	717	1.78
50	671	1.63
75	471	0.96

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 30, 45, 54

#6 End

#7

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1000	2.42
10	864	2.01
15	808	1.84
20	755	1.68
25	705	1.52
30	654	1.37
35	609	1.23
40	563	1.09
45	520	.966
50	479	.842
75	305	0.31

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 4, 17, 25

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	2.72
10	935	2.22
15	869	2.02
20	812	1.85
25	759	1.69
30	709	1.54
35	659	1.38
40	612	1.24
45	567	1.10
50	524	.978
75	339	0.41

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 9, 23, 31

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	3.03
10	985	2.37
15	913	2.16
20	852	1.97
25	794	1.79
30	743	1.64
35	692	1.48
40	642	1.33
45	596	1.19
50	552	1.09
75	361	0.48

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 12, 26, 34

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	3.33
10	1023	2.49
15	947	2.26
20	879	2.05
25	824	1.89
30	769	1.72
35	718	1.56
40	667	1.41
45	621	1.27
50	575	1.13
75	378	0.53

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 15, 29, 37

Note: While it is an uncommon shot size, #7 American shot is equivalent to #6 English shot, a popular size for hunting pheasants in the late 1800's as I understand it. It was the shot size mentioned in Ralph Galleyway's "The Merits of Cokes and Cylinders". He mentions dropping pheasants at 50 yards with it, it seemed worth including because of its size and the average velocity of the loads then. Notice that at none of the muzzle velocities probable at the time will #7 lead shot penetrate the recommended 1.75" at 50 yards. Payloads seem to have been generally 1oz or 1 1/8oz, something to consider for the gentleman who requires 1 3/4oz of #5 shot, at 1330fps to put down his birds. Though personally I'm partial to #4 lead for Grouse, so to each his own.

End of #7

#7 ½

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1000	2.27
10	859	1.86
15	800	1.69
20	746	1.53
25	692	1.38
30	640	1.23
35	592	1.09
40	545	0.95
45	502	0.83
50	459	0.71
75	281	0.19

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: <1, 13, 20

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	2.56
10	929	2.06
15	861	1.87
20	802	1.70
25	745	1.53
30	694	1.38
35	641	1.23
40	593	1.09
45	546	0.96
50	502	0.83
75	313	0.29

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 5, 18, 26

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	2.84
10	973	2.19
15	900	1.98
20	838	1.80
25	782	1.64
30	727	1.48
35	673	1.32
40	623	1.18
45	575	1.04
50	530	0.91
75	334	0.35

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 8, 21, 29

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	3.13
10	1015	2.31
15	938	2.09
20	868	1.89
25	809	1.72
30	753	1.55
35	698	1.40
40	648	1.25
45	599	1.11
50	551	0.97
75	351	0.39

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 11, 23, 31

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	3.42
10	1049	2.41
15	964	2.16
20	893	1.96
25	832	1.78
30	774	1.62
35	720	1.46
40	669	1.31
45	618	1.17
50	570	1.03
75	365	0.44

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 13, 25, 33

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	3.71
10	1093	2.54
15	994	2.25
20	921	2.04
25	855	1.85
30	794	1.67
35	740	1.52
40	687	1.36
45	635	1.21
50	588	1.08
75	378	0.47

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 15, 27, 35

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	4.00
10	1135	2.66
15	1023	2.33
20	944	2.11
25	873	1.90
30	813	1.73
35	757	1.57
40	704	1.41
45	653	1.27
50	604	1.12
75	391	0.51

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 16, 29, 37

End of #7 ½

#8

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	2.39
10	921	1.90
15	852	1.71
20	788	1.53
25	729	1.37
30	675	1.22
35	622	1.08
40	572	0.94
45	523	0.81
50	478	0.69
75	287	0.17

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 2, 13, 21

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	2.66
10	965	2.02
15	890	1.81
20	827	1.64
25	766	1.47
30	707	1.31
35	653	1.16
40	601	1.02
45	552	0.89
50	505	0.76
75	307	0.22

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 5, 16, 24

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	2.93
10	1007	2.13
15	922	1.90
20	853	1.71
25	792	1.54
30	733	1.38
35	678	1.23
40	625	1.09
45	574	0.95
50	527	0.82
75	322	0.26

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 7, 19, 26

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	3.20
10	1040	2.22
15	953	1.98
20	881	1.79
25	816	1.61
30	757	1.45
35	699	1.29
40	645	1.14
45	594	1.00
50	544	0.87
75	337	0.30

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 9, 20, 28

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	3.48
10	1082	2.34
15	982	2.06
20	903	1.85
25	838	1.67
30	776	1.50
35	718	1.34
40	663	1.19
45	612	1.05
50	561	0.91
75	349	0.33

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 11, 22, 30

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	3.75
10	1121	2.44
15	1011	2.14
20	926	1.91
25	856	1.72
30	795	1.55
35	735	1.39
40	680	1.24
45	627	1.09
50	576	0.95
75	361	0.37

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 12, 24, 31

End of #8

#9

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	2.05
10	900	1.56
15	828	1.39
20	760	1.22
25	695	1.07
30	636	0.92
35	578	0.78
40	524	0.65
45	474	0.53
50	425	0.41

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: Na, 5, 11

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	2.29
10	947	1.68
15	863	1.47
20	794	1.31
25	731	1.15
30	667	1.00
35	607	0.85
40	553	0.72
45	500	0.59
50	450	0.47

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: <1, 8, 14

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	2.53
10	981	1.76
15	894	1.55
20	823	1.38
25	756	1.21
30	691	1.06
35	630	0.91
40	573	0.77
45	520	0.64
50	470	0.52

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 2, 10, 16

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	2.77
10	1019	1.85
15	923	1.62
20	845	1.43
25	779	1.27
30	714	1.11
35	653	0.96
40	594	0.82
45	538	0.69
50	487	0.56

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 4, 12, 18

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	3.02
10	1049	1.92
15	950	1.68
20	866	1.48
25	797	1.31
30	733	1.16
35	669	1.00
40	611	0.86
45	554	0.72
50	502	0.60

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 5, 13, 19

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	3.26
10	1082	2.00
15	978	1.75
20	892	1.54
25	817	1.36
30	751	1.20
35	687	1.05
40	627	0.90
45	570	0.76
50	516	0.63

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 7, 14, 20

End of #9 Damn!

Steel

BBB

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	4.69
10	1070	3.75
15	1003	3.48
20	948	3.25
25	899	3.05
30	854	2.87
35	813	2.70
40	772	2.53
45	734	2.38
50	696	2.22
75	524	1.52

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 49, 66, 77

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	5.10
10	1116	3.94
15	1038	3.62
20	982	3.39
25	927	3.17
30	878	2.97
35	836	2.79
40	794	2.62
45	755	2.46
50	718	2.31
75	543	1.60

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 52, 69, 79

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	5.51
10	1177	4.19
15	1074	3.77
20	1010	3.51
25	954	3.28
30	904	3.07
35	856	2.88
40	816	2.71
45	776	2.55
50	737	2.39
75	560	1.67

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 54, 72, 81

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	5.91
10	1239	4.44
15	1115	3.93
20	1038	3.62
25	981	3.39
30	927	3.17
35	878	2.91
40	836	2.79
45	794	2.62
50	755	2.46
75	575	1.73

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 57, 74, 83

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1700	6.32
10	1305	4.71
15	1164	4.13
20	1072	3.76
25	1005	3.48
30	950	3.26
35	900	3.06
40	855	2.87
45	813	2.70
50	773	2.54
75	590	1.79

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 59, 76, 85

End of BBB

BB

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	4.17
10	1061	3.29
15	992	3.03
20	932	2.81
25	882	2.63
30	834	2.45
35	791	2.29
40	748	2.14
45	709	1.99
50	669	1.84
75	491	1.19

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 36, 53, 62

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	4.54
10	1104	3.45
15	1026	3.16
20	964	2.93
25	909	2.73
30	859	2.54
35	815	2.38
40	771	2.22
45	730	2.07
50	690	1.92
75	509	1.26

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 39, 56, 65

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	4.90
10	1161	3.66
15	1060	3.28
20	991	3.03
25	935	2.82
30	881	2.62
35	836	2.46
40	791	2.29
45	750	2.14
50	708	1.99
75	525	1.31

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 42, 58, 67

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	5.27
10	1221	3.88
15	1098	3.42
20	1022	3.14
25	961	2.92
30	903	2.71
35	855	2.53
40	810	2.36
45	767	2.21
50	726	2.05
75	541	1.37

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 44, 60, 69

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1700	5.64
10	1285	4.11
15	1143	3.59
20	1050	3.25
25	983	3.00
30	928	2.80
35	876	2.61
40	829	2.43
45	787	2.28
50	744	2.12
75	554	1.42

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 46, 62, 72

End of BB

#B

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	4.12
10	1055	3.23
15	984	2.97
20	923	2.75
25	870	2.56
30	824	2.39
35	778	2.22
40	734	2.06
45	692	1.91
50	652	1.76
75	470	1.10

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 34, 50, 59

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	4.49
10	1097	3.38
15	1019	3.10
20	955	2.87
25	896	2.65
30	847	2.47
35	801	2.30
40	758	2.15
45	713	1.98
50	673	1.84
75	488	1.02

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 36, 53, 61

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	4.85
10	1142	3.55
15	1052	3.22
20	982	2.96
25	921	2.74
30	868	2.55
35	823	2.38
40	777	2.22
45	733	2.06
50	691	1.90
75	503	1.22

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 39, 55, 64

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	5.22
10	1209	3.79
15	1088	3.35
20	1008	3.06
25	947	2.84
30	892	2.64
35	841	2.45
40	796	2.29
45	753	2.13
50	703	1.95
75	518	1.27

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 41, 57, 66

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1700	5.58
10	1272	4.02
15	1131	3.51
20	1040	3.18
25	973	2.93
30	914	2.72
35	862	2.53
40	815	2.35
45	770	2.19
50	726	2.03
75	532	1.32

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 43, 59, 68

End of #B

#1

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	3.85
10	1041	2.96
15	974	2.73
20	912	2.52
25	857	2.33
30	808	2.16
35	759	1.99
40	714	1.84
45	670	1.69
50	628	1.54
75	442	0.90

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 27, 42, 51

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	4.20
10	1087	3.12
15	1008	2.85
20	939	2.61
25	883	2.42
30	830	2.24
35	781	2.07
40	737	1.92
45	692	1.76
50	648	1.61
75	459	0.96

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 29, 45, 53

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	4.54
10	1130	3.27
15	1035	2.94
20	965	2.70
25	904	2.49
30	851	2.31
35	802	2.14
40	756	1.98
45	710	1.82
50	668	1.68
75	473	1.01

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 32, 47, 56

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	4.89
10	1194	3.49
15	1068	3.06
20	995	2.80
25	929	2.58
30	871	2.38
35	823	2.21
40	775	2.05
45	729	1.89
50	685	1.74
75	488	1.06

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 34, 49, 58

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1700	5.23
10	1255	3.70
15	1107	3.19
20	1021	2.89
25	954	2.66
30	892	2.45
35	840	2.27
40	793	2.11
45	745	1.94
50	702	1.80
75	501	1.11

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 36, 51, 60

End of #1

#2

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	3.57
10	1032	2.71
15	958	2.47
20	895	2.27
25	840	2.09
30	787	1.92
35	739	1.76
40	692	1.61
45	645	1.46
50	601	1.32
75	409	0.70

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 20, 35, 42

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	3.90
10	1075	2.85
15	991	2.58
20	922	2.35
25	865	2.17
30	812	2.00
35	762	1.84
40	712	1.68
45	665	1.53
50	621	1.38
75	425	0.75

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 23, 37, 46

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	4.22
10	1116	2.98
15	1022	2.68
20	951	2.45
25	885	2.24
30	832	2.06
35	780	1.90
40	730	1.74
45	683	1.58
50	639	1.44
75	439	0.80

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 24, 39, 48

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	4.54
10	1164	3.14
15	1054	2.78
20	976	2.53
25	909	2.31
30	852	2.13
35	800	1.96
40	748	1.79
45	702	1.65
50	656	1.50
75	453	0.84

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 26, 41, 49

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1700	4.86
10	1235	3.36
15	1090	2.90
20	1001	2.61
25	933	2.39
30	871	2.19
35	817	2.02
40	766	1.85
45	718	1.70
50	673	1.55
75	465	0.88

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 28, 43, 51

End of #2

#3

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	3.30
10	1022	2.46
15	946	2.24
20	877	2.03
25	822	1.86
30	767	1.70
35	713	1.53
40	665	1.39
45	616	1.24
50	571	1.10
75	373	0.51

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 15, 28, 35

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	3.60
10	1057	2.57
15	978	2.33
20	906	2.11
25	846	1.93
30	788	1.76
35	737	1.60
40	684	1.44
45	637	1.30
50	590	1.16
75	388	0.55

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 16, 30, 38

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	3.91
10	1102	2.71
15	1008	2.42
20	931	2.19
25	865	1.99
30	808	1.82
35	755	1.66
40	705	1.51
45	655	1.36
50	608	1.22
75	402	0.59

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 18, 32, 40

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	4.21
10	1146	2.84
15	1033	2.50
20	955	2.26
25	888	2.06
30	827	1.88
35	775	1.72
40	723	1.56
45	671	1.41
50	624	1.26
75	414	0.63

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 20, 34, 41

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1700	4.51
10	1199	3.00
15	1065	2.59
20	979	2.33
25	911	2.13
30	846	1.93
35	792	1.77
40	740	1.61
45	687	1.45
50	540	1.01
75	427	0.67

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 22, 35, 43

End of #3

#4

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	3.02
10	1010	2.21
15	927	1.98
20	861	1.79
25	798	1.62
30	742	1.46
35	687	1.31
40	634	1.16
45	585	1.02
50	537	0.89
75	335	0.32

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 9, 21, 28

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	3.30
10	1044	2.31
15	958	2.07
20	886	1.86
25	821	1.68
30	763	1.52
35	708	1.36
40	655	1.22
45	604	1.07
50	555	0.94
75	349	0.36

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 11, 23, 30

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	3.58
10	1086	2.42
15	987	2.15
20	909	1.93
25	843	1.74
30	785	1.58
35	728	1.42
40	672	1.26
45	621	1.12
50	572	0.98
75	361	0.39

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 13, 24, 32

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	3.86
10	1127	2.54
15	1017	2.23
20	932	1.99
25	865	1.80
30	804	1.63
35	745	1.47
40	690	1.31
45	638	1.17
50	587	1.03
75	373	0.43

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 14, 26, 34

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1700	4.14
10	1175	2.67
15	1047	2.31
20	960	2.07
25	884	1.86
30	823	1.69
35	764	1.52
40	707	1.36
45	654	1.21
50	602	1.07
75	384	0.46

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 16, 28, 35

End of #4

#5

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	2.74
10	997	1.96
15	911	1.74
20	840	1.55
25	775	1.38
30	714	1.23
35	656	1.08
40	601	0.93
45	549	0.80
50	499	0.67
75	293	0.14

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 4, 14, 21

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	3.00
10	1030	2.04
15	941	1.81
20	863	1.61
25	798	1.44
30	735	1.28
35	676	1.13
40	621	0.99
45	568	0.85
50	517	0.72
75	306	0.17

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 6, 16, 23

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	3.26
10	1061	2.12
15	964	1.87
20	885	1.67
25	820	1.50
30	757	1.34
35	696	1.18
40	637	1.03
45	584	0.89
50	533	0.76
75	317	0.20

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 8, 17, 25

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	3.52
10	1107	2.24
15	992	1.94
20	907	1.73
25	837	1.54
30	775	1.38
35	712	1.22
40	654	1.07
45	599	0.93
50	547	0.80
75	328	0.23

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 10, 19, 26

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1700	3.77
10	1150	2.35
15	1021	2.02
20	929	1.78
25	858	1.60
30	790	1.42
35	731	1.27
40	670	1.11
45	615	0.97
50	561	0.83
75	339	0.26

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 11, 20, 27

End of #5

#6

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	2.47
10	976	1.70
15	888	1.49
20	817	1.32
25	745	1.15
30	681	1.00
35	620	0.85
40	563	0.72
45	508	0.59
50	457	0.47

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 2, 8, 18

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	2.71
10	1014	1.79
15	917	1.56
20	839	1.37
25	768	1.21
30	703	1.05
35	642	0.91
40	581	0.76
45	526	0.63
50	474	0.51

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 3, 10, 20

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1500	2.94
10	1044	1.86
15	944	1.62
20	860	1.42
25	789	1.26
30	722	1.10
35	658	0.94
40	597	0.80
45	541	0.67
50	488	0.54

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 5, 12, 21

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	3.18
10	1076	1.94
15	966	1.68
20	881	1.47
25	807	1.30
30	740	1.14
35	676	0.99
40	615	0.84
45	557	0.70
50	503	0.58

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 6, 13, 23

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1700	3.42
10	1112	2.02
15	994	1.74
20	901	1.52
25	827	1.35
30	758	1.18
35	691	1.02
40	631	0.88
45	573	0.74
50	517	0.61

Yardage for 2.25", 1.75", and 1.5" of penetration respectively: 8, 14, 24

End of #6 Steel

Required Impact Velocity to Penetrate 1.5”, 1.75”, and 2.25”

For Chilled Lead:

Size	1.5”	1.75”	2.25”
2	465.87	521.23	628.47
4	537.33	600.04	724.89
5	582.22	651.42	785.44
6	634.00	709.35	855.29
7	698.63	781.65	942.47
7.5	735.59	823.02	992.35
8	777.43	869.83	1048.79
9	876.36	980.51	1182.24

For Steel:

Size	1.5”	1.75”	2.25”
BBB	519.97	581.77	701.46
BB	576.67	645.21	777.96
B	581.95	651.12	785.08
1	617.15	690.50	832.56
2	658.32	736.56	888.10
3	703.80	787.45	949.46
4	757.90	846.35	1022.44
5	821.58	919.23	1108.35
6	839.99	1000.24	1206.03

It seems that for all steel loads with initial velocities of 1400fps or higher, and all lead loads with initial velocities of 1100fps or higher, lethal pellet range is extended by 2-3 yards for every 100fps the muzzle velocity is increased. Going up one size of shot increases lethal range by roughly 10 yards for lead, and 8-11 yards for steel, that is equivalent to a 400fps muzzle velocity increase.

Lead Distance

Assuming a maximum flight speed of 60km/hr. or 88fps for waterfowl as a safe maximum, without a tail wind, increases in steel shot velocity between 1300fps, 1500fps, and 1700fps will change 40 yard lead by the following for shot sizes BBB through 6

Size	1300fps Lead (Feet)	Lead Reduction (Feet)	1500fps Lead (Feet)	Lead Reduction (Feet)	1700fps Lead (Feet)
BBB	11.00	.72	10.28	.78	9.50
BB	11.26	.79	10.47	.71	9.76
B	11.35	.79	10.56	.71	9.85
1	11.52	.79	10.73	.70	10.03
2	11.70	.70	11.00	.71	10.29
3	11.96	.79	11.17	.70	10.47
4	12.32	.80	11.52	.70	10.82
5	12.67	.79	11.88	.71	11.17
6	13.11	.79	12.32	.80	11.52

Increased muzzle velocity does reduce lead, but marginally, and with steel shot sizes BBB-6 not an amount I consider significant. Between 1300fps, and 1700fps lead is reduced only 1.5 feet (18 inches) with BBB, and 1.59 feet (19 inches) with #6. I don't find these numbers significant because they are 13%, and 12% (respectively), of the total lead required for a crossing shot at 40 yards. That coupled with the fact that the pellet spread at 40 yards would be in excess of 30 inches, (22%, and 19% of the lead), leads me to believe that the reduction in lead distance is inconsequential.

Buckshot

#4

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	900	5.94
10	850	5.57
20	804	5.24
30	760	4.92
40	717	4.60
50	676	4.31
75	579	3.60
100	490	2.95

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1000	6.67
10	940	6.23
20	885	5.83
30	836	5.47
40	791	5.14
50	747	4.82
75	643	4.07
100	549	3.38

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	7.39
10	1021	6.82
20	958	6.36
30	900	5.94
40	850	5.57
50	804	5.24
75	696	4.45
100	597	3.73

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	8.12
10	1084	7.28
20	1008	6.72
30	947	6.28
40	891	5.87
50	841	5.51
75	731	4.71
100	628	3.96

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	8.85
10	1149	7.75
20	1053	7.05
30	984	6.55
40	925	6.12
50	871	5.73
75	757	4.90
100	652	4.13

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	9.58
10	1253	8.51
20	1098	7.38
30	1018	6.80
40	955	6.34
50	897	5.92
75	779	5.06
100	673	4.28

End of #4 Buck

#3 Buck

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	900	6.23
10	852	5.86
20	808	5.53
30	765	5.13
40	724	4.89
50	684	4.58
75	590	3.87
100	504	3.22

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1000	6.99
10	942	6.55
20	889	6.14
30	841	5.78
40	797	5.44
50	755	5.12
75	655	4.36
100	564	3.67

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	7.75
10	1024	7.17
20	962	6.70
30	907	6.28
40	858	5.91
50	813	5.57
75	708	4.77
100	612	4.04

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	8.51
10	1088	7.66
20	1016	7.11
30	953	6.63
40	900	6.23
50	850	5.85
75	743	5.03
100	644	4.28

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	9.27
10	1154	8.16
20	1059	7.44
30	991	6.92
40	933	6.48
50	881	6.08
75	770	5.24
100	668	4.46

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	10.03
10	1232	8.75
20	1105	7.79
30	1027	7.19
40	963	6.71
50	908	6.29
75	793	5.41
100	689	4.62

End of #3

#2 Buck

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	900	6.76
10	855	6.39
20	814	6.05
30	775	5.73
40	736	5.41
50	699	5.11
75	610	4.38
100	529	3.72

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1000	7.58
10	946	7.13
20	896	6.72
30	852	6.36
40	811	6.03
50	771	5.70
75	677	4.93
100	590	4.22

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	8.40
10	1029	7.81
20	971	7.34
30	918	6.90
40	872	6.53
50	830	6.18
75	731	5.37
100	641	4.63

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	9.21
10	1094	8.35
20	1025	7.78
30	967	7.31
40	915	6.88
50	869	6.50
75	767	5.67
100	673	4.90

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	10.03
10	1163	8.91
20	1070	8.15
30	1006	7.63
40	949	7.16
50	900	6.76
75	794	5.89
100	698	5.10

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	10.85
10	1243	9.57
20	1119	8.55
30	1041	7.91
40	983	7.44
50	928	6.99
75	818	6.08
100	720	5.28

End of #2

#1 Buck

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	900	7.59
10	859	7.21
20	823	6.89
30	786	6.55
40	751	6.23
50	717	5.92
75	635	5.17
100	560	4.49

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1000	8.50
10	951	8.05
20	905	7.63
30	864	7.26
40	827	6.92
50	790	6.58
75	704	5.80
100	623	5.06

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	9.41
10	1035	8.82
20	983	7.52
30	933	7.89
40	890	7.50
50	850	7.13
75	760	6.31
100	676	5.55

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	10.32
10	1102	9.43
20	1036	8.83
30	984	8.35
40	934	7.990
50	890	7.50
75	796	6.64
100	709	5.85

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	11.23
10	1174	10.09
20	1086	9.28
30	1023	8.71
40	971	8.23
50	924	7.81
75	823	6.89
100	735	6.08

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	12.15
10	1256	10.83
20	1140	9.78
30	1061	9.06
40	1004	8.54
50	955	8.09
75	848	7.11
100	758	6.29

End of #1 Buck

#0 Buck

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	900	8.14
10	862	7.77
20	827	7.43
30	793	7.10
40	760	6.78
50	728	6.46
75	650	5.71
100	579	5.02

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1000	9.11
10	954	8.66
20	911	8.25
30	872	7.87
40	836	7.52
50	801	7.117
75	719	6.38
100	643	5.64

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	10.08
10	1038	9.48
20	989	9.00
30	943	8.56
40	900	8.14
50	862	7.77
75	776	6.93
100	696	6.15

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	11.06
10	1107	10.15
20	1045	9.55
30	993	9.04
40	946	8.59
50	905	8.19
75	813	7.29
100	731	6.49

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	12.03
10	1180	10.86
20	1095	10.04
30	1035	9.45
40	984	8.96
50	939	8.52
75	841	7.56
100	757	6.75

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	13.00
10	1264	11.68
20	1151	10.58
30	1074	9.83
40	1018	9.29
50	969	8.81
75	866	7.81
100	780	6.97

End of #0

#00

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	900	9.26
10	864	8.86
20	831	8.50
30	799	8.15
40	768	7.81
50	737	7.47
75	664	6.67
100	595	5.91

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1000	10.35
10	957	9.88
20	916	9.43
30	878	9.01
40	843	8.63
50	811	8.28
75	734	7.43
100	660	6.62

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	11.45
10	1041	10.80
20	994	10.29
30	950	9.80
40	910	9.37
50	873	8.96
75	791	8.06
100	714	7.21

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	12.55
10	1111	11.57
20	1051	10.91
30	1001	10.36
40	957	9.88
50	916	9.43
75	828	8.47
100	749	7.60

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	13.64
10	1186	12.39
20	1103	11.48
30	1043	10.82
40	996	10.31
50	951	9.81
75	857	8.78
100	776	7.90

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	14.74
10	1271	13.33
20	1161	12.12
30	1087	11.31
40	1030	10.68
50	983	10.17
75	883	9.07
100	799	8.15

End of #00

#000

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	900	9.23
10	867	8.87
20	834	8.51
30	804	8.18
40	775	7.86
50	745	7.53
75	675	6.77
100	610	6.06

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1000	10.32
10	959	9.87
20	920	9.45
30	885	9.06
40	851	8.69
50	820	8.35
75	746	7.54
100	667	6.68

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	11.42
10	1046	10.83
20	999	10.31
30	957	9.85
40	918	9.43
50	883	9.04
75	804	8.18
100	731	7.38

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	12.51
10	1118	11.61
20	1057	10.95
30	1009	10.42
40	966	9.95
50	927	9.52
75	842	8.59
100	766	7.76

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	13.60
10	1192	12.42
20	1110	11.53
30	1053	10.90
40	1005	10.38
50	963	9.92
75	871	8.91
100	794	8.07

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	14.70
10	1277	13.35
20	1175	12.24
30	1097	11.38
40	1042	10.78
50	995	10.27
75	898	9.21
100	817	8.32

End of #000

#0000

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	900	9.78
10	868	9.41
20	837	9.05
30	809	8.73
40	780	8.39
50	752	8.07
75	686	7.31
100	622	6.57

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1000	10.93
10	961	10.48
20	924	10.06
30	889	9.65
40	858	9.29
50	828	8.95
75	757	8.13
100	689	7.34

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	12.09
10	1048	11.49
20	1003	10.97
30	964	10.52
40	927	10.09
50	892	9.69
75	816	8.81
100	746	8.00

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	13.24
10	1121	12.33
20	1062	11.65
30	1016	11.12
40	975	10.64
50	938	10.22
75	854	9.25
100	782	8.42

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1300	14.40
10	1197	13.21
20	1119	12.31
30	1061	11.64
40	1015	11.11
50	974	10.63
75	885	9.60
100	809	8.73

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1400	15.58
10	1283	14.20
20	1184	13.06
30	1106	12.16
40	1053	11.55
50	1008	11.03
75	912	9.92
100	833	9.00

End of #0000

Single Round Balls

.729

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	26.09
10	1155	25.08
20	1118	24.26
30	1085	23.53
40	1057	22.90
50	1034	22.39
75	979	21.17
100	929	20.05

.690

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1200	24.51
10	1153	23.53
20	1112	22.67
30	1080	22.00
40	1052	21.41
50	1027	20.89
75	970	19.70
100	919	18.63

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1600	32.89
10	1519	31.19
20	1442	29.58
30	1371	28.09
40	1304	26.69
50	1246	25.48
75	1124	22.92
100	1047	21.31

End of .690

Triple Ball (.600)

Distance (Yards)	Velocity (fps)	Penetration (Inches)
0	1100	19.28
10	1065	18.64
20	1035	18.10
30	1007	17.59
40	981	17.12
50	956	16.67
75	899	15.64
100	849	14.66

Other Considerations

The formula I created used data from table posted online created by the KPY ballistics program. The tables are at these links: <http://www.randywakeman.com/LeadVSteelPenetration.jpg>.

http://s1324.photobucket.com/user/ksfowler166/media/BC8600x153_zps89f1afdd.jpg.html

<http://s148.photobucket.com/user/derbyacresbob/media/SHTGUN%20BALis%202.jpg.html>

I used the data in those tables to make up the formula.

The link to the SAAMI recoil equation

<http://www.saami.org/PubResources/GunRecoilFormulae.pdf>

The ballistics calculator used was created by Dr. Stephen C Wardlaw, this would not have been possible without it. He was also kind enough to provide me with the source code for the application so that I could modify it as I needed to. He runs the website <http://www.ctmuzzleloaders.com/>. It's a very interesting site with stuff not necessarily exclusive to muzzleloaders, and it's well worth looking at. I want you to know that I am receiving nothing in return for mentioning Dr. Wardlaw's application, or his website. I mention his website because I find it interesting and worth reading. Without both he and his application I could not have written this, the least I can do is give credit where credit is due.

All tables were calculated for 1000 feet above sea level (I live at 900 feet above sea level) and 66 degrees Fahrenheit, the lead ballistic tables were calculated for chilled shot.

I recognize that Ed Lowry's penetration recommendations are guidelines, and are not necessarily guarantees in terms of performance. I do not know what the calculated density of the gel used in the online tables is. Changes in gel density will likely yield a different momentum/area constant. It is something that could stand to be factored into my formula.

Feathers impact pellet performance in unpredictable ways as do bones, and they affect smaller pellets more than larger ones, so less penetration than projected should be expected on game, and even less with smaller pellets.

I have to consider shot strings, pellets at the front have more velocity than those in the rear, the pellets are not traveling at exactly the same speed (therefore the momentum is not evenly distributed). However I am unaware of how great a difference that would make in terms of penetration. I doubt it would be significant.

Some data sets do not form perfect patterns, there are in some cases extraneous decimals that I did not account for, in other cases I rounded slightly. For the data of ranges for a given penetration, velocity drops by several feet per second every yard, and those values were rounded to the nearest yard that would produce that penetration.

The main purpose of this paper is to accurately represent how increases in muzzle velocity impact the downrange performance of shotgun pellets. No one should pay 45\$ a box for a concept without proof of the results.

This also dispels any hard and fast rule of 2, 3 or 4, when going between steel and lead shot. The rule of X varies between shot sizes and initial velocities.

High velocity, and heavy charges of lead shot will deform more on firing, will decelerate faster, and penetrate less than shown in the tables. The patterns will be different for every load, for every shooter, for every gun. You mileage may vary.

I'm quite certain that if this gets circulated enough I'm going to incur the wrath of every person who has ever spoke to the merits of high velocity shotgun loads. While I'm not a fan of them, I do think in some cases that some increase in muzzle velocity is practical, but not to the extents it is advertised.

While I cannot refute tested data, or personal experience, I consider the average shooter to be very superstitious, and it's not a habit of mine to take their words at face value. I believe that a full scale test should be conducted on actual birds to better examine penetration, with modern loads of all sizes, velocities, and from all angles. That would be the best representation of pellet performance, but it has to be done by an independent body. It will be very expensive, but qualitative examinations are never cheap.

I have great respect for shotgunning writers, but my trust in them is limited. I think in some cases their conclusions are questionable, and ambiguous. So long as the magazines they write for are supported by monetary contributions from the companies who make the products they write about, my faith in their work will remain limited. My apologies to the magazines and writers that have integrity.

There is likely a correlation between impact kinetic energy and penetration, I think there almost certainly is. I haven't got the time to find it. If someone else has the time I encourage them to discover it.

Pellets of different materials and compositions will deform differently on firing, and impact, resulting in different amounts of penetration, and different downrange velocities.

My formula is also applicable to round balls, such as those used in muzzleloaders.

This paper took about 31 hours to write up. I started writing it April 7th of 2017

If you made it this far, thanks for reading. Please pass this along.

June 21st, 2017