Shotgun barrels and ammunition: specifications & performance

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1. Shot diameter, mass, and designation

NOTE: English lead shot is presumed throughout this document unless stated otherwise. There is a mix of Imperial and SI units, so pay attention.

NOTE: If you print this document, be aware that it is set up for A4 paper.

The Imperial diameters in Table 1 are from Purdey[1], all other values in Table 1 were calculated by the author. Mass of shot and pellet counts are based on *pure* lead shot whereas most shot is lead alloyed with other metals which means that either:

- it will be of greater diameter for a given mass, or
- for a given diameter it will of greater mass.

Normal manufacturing tolerances means that what is marked as Number 6 shot may, in fact, be Number 5½ shot. The majority of the shot sizes given in Table 1 are not commercially loaded in ammunition.

Table 1: English shot sizes, mass per shot, shot counts per unit mass

Designation	Diameter		Mass		Number of shot	
↓	inch	mm	grains	grams	per oz	per 10g
LG	0.360	9.14	69.70	4.54	6.3	2.2
MG mould	0.347	8.81	62.42	4.07	7.0	2.5
SG	0.332	8.43	54.67	3.56	8.0	2.8
Special SG	0.298	7.57	39.53	2.58	11.1	3.9
SSG	0.269	6.83	29.08	1.90	15.0	5.3
SSSG	0.245	6.22	21.97	1.43	19.9	7.0
SSSSG	0.227	5.77	17.47	1.14	25.0	8.8
SSSSSG	0.214	5.44	14.64	0.95	29.9	10.5
AAA	0.203	5.16	12.50	0.81	35.0	12.3
AA	0.194	4.92	10.91	0.71	40.1	14.1
A	0.180	4.57	8.71	0.57	50.2	17.6
BBB	0.170	4.32	7.34	0.48	59.6	20.9
BB	0.161	4.09	6.23	0.41	70.2	24.6
B	0.154	3.91	5.46	0.36	80.2	28.1
1	0.143	3.63	4.37	0.28	100.1	35.1
2	0.135	3.43	3.68	0.24	119.0	41.7
3	0.128	3.25	3.13	0.20	139.6	49.0
4	0.120	3.05	2.58	0.17	169.5	59.4
5	0.110	2.79	1.99	0.13	220.0	77.1
5½	0.107	2.72	1.83	0.12	239.1	83.8
6	0.102	2.59	1.59	0.10	276.0	96.8
6½	0.099	2.51	1.45	0.09	301.8	105.8
7	0.095	2.41	1.28	0.08	341.6	119.8
7½	0.090	2.28	1.09	0.07	401.7	140.9
8	0.087	2.21	0.98	0.06	444.7	155.9
9	0.080	2.03	0.76	0.05	572.0	200.6
10	0.070	1.78	0.51	0.03	853.8	299.4

Table 2: Shot size equivalents: English –v– US and European (source: Eley[2])

I will be grateful to hear of any other foreign shot sizes that fill in the gaps in this table.

England	∅ mm	USA & Sweden	France	Belgium & Holland	Italy	Spain
LG	9.1	-	-	-	-	-
SG	8.4	00 Buck	-		9G	11/0
Sp.SG	7.6	1 Buck	C2	12G	9/0	-
SSG	6.8	3 Buck	C3	-	-	-
AAA	5.2	4 Buck	5/0	-	-	-
BB	4.1	Air rifle	1	00	00	1
1	3.6	2	3	-	1 or 2	3
3	3.3	4	4	-	3	4
4	3.1	5	5	-	4	5
5	2.8	6	6	5	5	6
6	2.6	-	-	6	6	-
7	2.4	7 ½	7	7	7½	7
8	2.2	-	8	8	-	8
9	2.0	9	9	9	9½	9

2. Number of shot in a charge – how many pellets are in my cartridge?

Whilst I know it does not make sense to talk of a charge of 9½ pieces of LG shot, I include the fractions in Table 3 for completeness. The smaller shot are shown in Table 4 on the next page.

Table 3: Number of shot in a charge – LG to BBB (source: the author)

Shot charge ↓		Size of shot →											
gram	ounce	LG	MG	SG	Sp. SG	SSG	SSSG	SSSSG	SSSSSG	AAA	AA	A	BBB
46.0	1 5/8	10.2	11.4	13.0	18.0	24.4	32.3	40.6	48.6	56.9	65.2	81.6	96.9
42.5	1 ½	9.5	10.5	12.0	16.7	22.5	29.9	37.5	44.9	52.5	60.2	75.3	89.4
36.0	1 ¼	7.9	8.8	10.0	13.9	18.8	24.9	31.3	37.4	43.8	50.1	62.8	74.5
34.0	1 3/16	7.5	8.3	9.5	13.2	17.8	23.6	29.7	35.5	41.6	47.6	59.6	70.8
32.0	1 1/8	7.1	7.9	9.0	12.5	16.9	22.4	28.1	33.6	39.4	45.1	56.5	67.1
30.0	1 1/16	6.7	7.4	8.5	11.8	15.9	21.1	26.6	31.8	37.2	42.6	53.3	63.3
28.5	1	6.3	7.0	8.0	11.1	15.0	19.9	25.0	29.9	35.0	40.1	50.2	59.6
26.5	1 5/16	8.3	9.2	10.5	14.6	19.7	26.1	32.8	39.2	45.9	52.6	65.9	78.2
25.0	7/8	5.5	6.1	7.0	9.7	13.1	17.4	21.9	26.2	30.6	35.1	43.9	52.2
23.0	1 3/16	7.5	8.3	9.5	13.2	17.8	23.6	29.7	35.5	41.6	47.6	59.6	70.8
17.5	5/8	3.9	4.4	5.0	6.9	9.4	12.4	15.6	18.7	21.9	25.1	31.4	37.3
16.0	9/16	3.5	3.9	4.5	6.2	8.4	11.2	14.1	16.8	19.7	22.6	28.2	33.5
12.5	7/16	2.8	3.1	3.5	4.9	6.6	8.7	10.9	13.1	15.3	17.5	22.0	26.1
9.0	5/16	2.0	2.2	2.5	3.5	4.7	6.2	7.8	9.3	10.9	12.5	15.7	18.6

Table 4: Number of shot in a charge – BB to No. 10 (source: the author)

Shot charge ↓		Size of shot →														
gram	ounce	BB	B	1	2	3	4	5	5 1/2	6	6 1/2	7	7 1/2	8	9	10
46.0	1 5/8	114	130	163	193	227	170	358	389	449	490	555	653	723	930	1387
42.5	1 ½	105	120	150	179	209	170	330	359	414	453	512	603	667	858	1281
36.0	1 ¼	88	100	125	149	175	170	275	299	345	377	427	502	556	715	1067
34.0	1 3/16	83	95	119	141	166	170	261	284	328	358	406	477	528	679	1014
32.0	1 1/8	79	90	113	134	157	170	248	269	311	340	384	452	500	644	961
30.0	1 1/16	75	85	106	126	148	170	234	254	293	321	363	427	472	608	907
28.5	1	70	80	100	119	140	170	220	239	276	302	342	402	445	572	854
26.5	1 5/16	92	105	131	156	183	170	289	314	362	396	448	527	584	751	1121
25.0	7/8	61	70	88	104	122	170	193	209	242	264	299	351	389	501	747
23.0	1 3/16	83	95	119	141	166	170	261	284	328	358	406	477	528	679	1014
17.5	5/8	44	50	63	74	87	170	138	149	173	189	214	251	278	358	534
16.0	9/16	39	45	56	67	79	170	124	134	155	170	192	226	250	322	480
12.5	7/16	31	35	44	52	61	170	96	105	121	132	149	176	195	250	374
9.0	5/16	22	25	31	37	44	170	69	75	86	94	107	126	139	179	267

3. Definition of choke – inside the barrel

The term *choke* has two definitions which, in a perfect world, would be in total agreement with one another. From the perspective of the gun, the degree of choke refers to the constriction (if any) at the muzzle compared to the internal diameter of the bore measured 9 inches ahead of the breech. By definition, therefore, a cylinder bored barrel has no choke. The other perspective of choke is the distribution of shot at the target (see later). The shooter is concerned with the latter: the gun maker the former. The English system of choke notation is detailed in the table below.

Table 5: English specifications for choke in barrels

Name of choke	Nominal constriction (inches)
True cylinder	none
Improved cylinder	0.005
¼ choke	0.010
½ choke	0.020
¾ choke	0.030
Full choke	0.040

NOTE 1: A barrel can be bored to any degree of choke, including 'negative choke' i.e. a flared muzzle.

There is no guarantee that a barrel bored to '¼ choke' will throw ¼ choke patterns with any particular brand of cartridge. The only way to determine how a barrel behaves is to pattern it (fire it at a patterning plate). Just because a barrel is *marked*, say full choke, does not mean that it is *bored* to full choke. A previous owner may have had the choke opened up. Hence the only way to be sure is to measure the barrel at both ends with the proper tools and/or test the patterns it throws – see next subject.

Some European gun barrels (esp. Italian) bear 'star' markings to indicate the degree of choke, as shown in Table 6 on the next page. Again, these markings are indicative of dimensions only, and do not guarantee that the patterns thrown will be of corresponding density and diameter.

Table 6: Choke markings on European barrels (source: GT[3])

Name of choke	Marking	Nominal constriction
True cyl	CL	
Improved cyl.	****	0.2-0.3 mm
¼ choke		
½ choke	***	0.4-0.6 mm
¾ choke	**	0.7-0.8 mm
Full choke	*	0.9-1.0 mm

4. Definition of choke – on the target

Density of shot on the target

The second way of defining choke is to consider the nature of the pattern thrown by a given barrel and ammunition combination. If the barrel throws 70% of the shot inside a 30 inch circle at a measured 40 yards from the shooter, then it throws *full choke* patterns and hence can be considered a full choke barrel *regardless of the actual boring*. (It is a full choke barrel with *that* ammunition, and may well behave differently with different ammunition.) The definitions of choke according to the patterns thrown are given in the tables below.

Table 7: Percentage patterns for all borings at all distances in **yards** (source: GT)

Boring of barrel ↓	Range in *yards* → 30	35	40	45	50	55	60
True cyl	60	49	40	33	27	22	18
Improved cyl.	72	60	50	41	33	27	22
¼ choke	77	65	55	46	38	30	25
½ choke	83	71	60	50	41	33	27
¾ choke	91	77	65	55	46	37	30
Full choke	100	84	70	59	49	40	32

Table 8: Percentage patterns for all borings at all distances in **metres** (source: Eley)

Boring of barrel ↓	Range in *metres* → 20	25	30	35	40	45	50	55
True cyl	75	63	53	43	35	28	22	18
Imp. cyl.	85	74	64	53	43	34	27	22
¼ choke	90	80	70	58	48	39	31	25
½ choke	97	86	76	64	54	43	34	27
¾ choke	100	93	83	70	58	47	38	30
Full choke	100	100	90	74	62	51	41	32

NOTE: All shotguns of a given choke specification – regardless of gauge – should throw the same *percentage* of shot inside the 30 inch circle and have the same diameter of pattern. The total *number* of pellets will vary according to gauge and load, but not the percentage of shot nor diameter of pattern.

Distribution of shot across the pattern

One of the quirks of a heavily choked barrel is that, not only is the overall diameter reduced compared to less choke, but more choke tends to concentrate the shot density *to the centre of the pattern* rather than merely uniformly across a smaller diameter. This can be illustrated by dividing the 30 inch circle into two concentric circles, one 30 inch diameter and the other 20 inch diameter. The 20 inch circle occupies an area which is only 45% that of the 30 inch circle. Given a uniform distribution of shot, therefore, the inner circle should be struck by 45% as many shot as strike the total area inside the 30 inch circle. Does this happen in reality? No. It has been found that as the degree of choke increases the degree of concentration inside the 20 inch circle increased disproportionately (although the effect lessens with distance.)

Table 9: Percentage of total shot strikes inside a 20 inch circle (source: GT)

Boring of barrel	Percentage of pellets inside 20 inch circle
True cyl	46-51
Improved cyl.	48-54
½ choke	52-57
Full choke	57-62

The implications of this are that a bird hit squarely in the centre of the pattern from a full choked barrel at medium range (e.g. 30 yards) is likely to be struck by an excessive number of shot, thus incurring the wrath of the cook. It also means that more birds will be missed at close to medium ranges.

Diameter of pattern

The diameter of the pattern is another measure of performance. In short, the wider the diameter produced by a barrel, the less accurate the shooter has to be (provided the density is adequate – and therein lies the compromise). The narrower the pattern, the more accurate we must be. So too much choke is a bad thing for most forms of shooting in Britain. Table 10 and Table 11 below give the pattern diameter that is covered by the bulk of the shot charge at various distances according to the stated degree of choke of the barrel.

Table 10: Diameter of spread in centimetres for distances in **metres** (source: Eley)

Boring of barrel ↓	Range in *metres* → 10	15	20	25	30	35
True cyl	54	71	88	105	122	140
Imp. cyl.	38	55	72	89	106	124
1/4 choke	34	49	64	80	97	115
1/2 choke	31	44	58	73	90	108
3/4 choke	27	39	52	66	82	101
Full choke	23	33	45	59	75	94

Table 11: Diameter of spread in inches for distances in **yards** (GT)

Boring of barrel ↓	Range in *yards* → 10	15	20	25	30	35	40
True cyl	20	26	32	38	44	51	58
Imp. cyl.	15	20	26	32	38	44	51
1/4 choke	13	18	23	29	35	41	48
1/2 choke	12	16	21	26	32	38	45
3/4 choke	10	14	18	23	29	35	42
Full choke	9	12	16	21	27	33	40

The reason for many 'unexplained' misses at close to medium distances with a heavily choke barrel is obvious from the above. One only needs to compare the cylinder boring at 20-30 yards to the full choke at 35-40 yards. The heavily choked barrel is only really suitable for shooting where most of the shots are taken at 40+ yards.

Patchiness of pattern

A typical pattern produced on the flat patterning plate will include some areas through which a bird can 'escape'. Many people consider that an empty 5 inch disc represents a 'missed bird' (but see later). GT reported that the number of non-overlapping 5 inch circles (the vital area of our pheasant) in which there were no shot strikes on a normal 12 gauge 30 inch pattern were as follows.

Table 12: Non-overlapping empty 5 inch circular patches on typical patterns

No. of shot in 30 inch circle	No. of 5-inch vacant patches
50	13-19
100	8-11
150	4-7
200	2-5
250	0-3
300	0-2

Of course, the pattern plate is 2-dimensional but the shot pattern in the air is 3-dimensional, and shaped like a large sausage or melon. Approximately *half* the shot is in the front *third* of the sausage. The 5-inch vacant patch represents a 'tube' along the length of the pattern. Unless our bird is flying directly up that tube, he will be hit by several shot – so the reality is better than the pattern plate might have us believe. ☺ Some manufacturers measure the quality of their patterns only by the presence or absence of the 5-inch vacant discs.

5. Ballistics – velocities and energies

Striking velocities

The 'observed velocity' of shotgun ammunition is the average velocity of the shot charge over the first 20 yards of flight. An observed velocity of 1070 feet/second is approximately equal to a muzzle velocity of 1320 feet/second.

Using the Eley 'standard' cartridge (e.g. *Grand Prix*) with an observed velocity of 325 m/s (1070 f/s), the striking velocities are given below. The Eley 'high velocity' cartridges are approximately 5-10% faster but the difference at normal shooting distances is, in fact, negligible.

Table 13: Striking velocities in metres/second for Eley standard velocity cartridges

Shot size ↓	Range in *metres* → 20	25	30	35	40	45
BB	284	269	254	238	226	212
3	272	253	236	219	203	188
4	269	249	231	214	197	181
5	265	244	224	205	188	171
6	261	239	219	199	180	163
7	257	234	212	191	172	154
9	247	220	196	171	150	128

NOTE: To convert metres to yards, multiply by 1.09361. I do not have the data for yards and foot-pounds. Any offers?

Striking energy of shot

Kinetic energy is calculated from the pellet's mass and velocity, and expressed here in foot-pounds. The *striking* energies of individual shot with an observed velocity of 1070 feet/second (muzzle velocity of 1350f/s) are given in Table 14 below.

Table 14: Striking energies in foot-pounds for individual shot (source: GT)

Size of shot ↓	Range in yards → 30	35	40	45	50	55	60
3	4.48	3.92	3.43	2.99	2.59	2.23	1.94
4	3.54	3.08	2.66	2.3	1.97	1.68	1.42
5	2.6	2.23	1.9	1.61	1.36	1.14	.93
6	2.03	1.71	1.44	1.2	1.01	.82	.67
7	1.52	1.27	1.06	.86	.7	.57	.45

NOTE: To convert foot-pounds to joules, multiply by 1.3558. I do not have the data for metres and joules. Any offers?

Eley indicate that the minimum requirements for a clean kill on certain types of bird are:

- small birds e.g. snipe – 2 pellets each having striking energy of at least 0.5 ft-lb
- medium birds e.g. grouse – 3 pellets each having striking energy of at least 0.85 ft-lb
- large birds e.g. goose – 4 pellets each having a striking energy of at least 1.5 ft-lb.

Therefore, from Table 14 we can select the appropriate size of shot for the quarry at the distance at which we expect to shoot. We then need to consider the density of pattern thrown by our gun-ammunition combination to determine at what distances we can realistically shoot that quarry. This has already been done for us.

What pattern and shot size is required for each quarry species?

Using the above percentage patterns and ballistics, the suitability of a given barrel and shot charge can be compared to the minimum patterns required for given quarry species at typical shooting distances. If, for example, a 1 oz charge delivers too few shot then one must step up the shot charge (or reduce the distance at which shots are taken). The minimum patterns required on a 30 inch patterning plate at 40 yards to be reasonably confident of a clean kill of the various quarry species is given below. The numbers in column 3 are the number of pellets that must strike a 30 inch target to ensure that sufficient pellets strike our quarry to kill it cleanly.

Table 15: Minimum patterns required for given quarry species

Game	Shot size	Min pattern in 30" circle
Snipe	8	270
Woodcock	7	150
Squirrel	7	180
Partridge	6	130
Grouse	6	130
Pheasant	6	120
Pigeon	6	130
Rabbit	5	120
Teal	6 or 7	150
Duck	4	80
Hare	4	100

Goose	3	70

Velocities and forward allowance

One shooting technique is to aim ahead of the bird, giving it *forward allowance* so the shot and bird will arrive at the same point in space at the same time. In effect, you aim off ahead of the bird, and fire. Eley standard game cartridges have a nominal observed velocity of 1070 f/s (325 m/s). Eley 'high velocity' game cartridges have a nominal velocity of 1120 f/s (340 m/s). The difference in forward allowance between the two is negligible. (So what is the point you might ask, especially as the high velocity cartridge may deliver inferior patterns?) The forward allowance for a bird crossing at 40 mph (65 kmh) using #6 shot is given below.

Table 16: Forward allowance for Eley cartridges (source Eley)

Range/yards →	30	35	40	45	50
forward allowance	5' 6"	6' 8"	8'	9' 6"	11'

Range/metres →	30	35	40	45	50
forward allowance	1.9 m	2.3 m	2.7 m	3.3 m	4 m

[1] *The Shot Gun* by TDS Purdey and Capt. JA Purdey, 1936

[2] *The Eley Shooter's Diary 1992*, published by Eley

[3] *Gough Thomas' Gun Book, Gough Thomas' Second Gun Book, Shotgun Facts & Fancies* and *Shotguns and Cartridges for Clays and Game* by Gough Thomas Garfield