CALCULATION OF RANGES, ETC., OF ELONGATED PROJECTILES.

FROM time to time it has been suggested to me that some reduction in the coefficients of resistance deduced from my experiments made in 1867-68, is required to adapt them for use in connection with the improved guns of more recent times. I do not agree with those suggestions. My coefficients were most carefully deduced from experiments made with ogival-headed shot fired at very low elevations so as to secure ranges of about 500 or 600 yards, and the observations were made near the gun. The 5-inch gun was a remarkably good gun, and from the numerous records it gave had a preponderating effect on the final result; while an unsteady shot cut only a few screens, and had a very trifling influence. It seems, therefore, that the coefficients were derived from shot moving very nearly in the direction of their axes. I have applied these coefficients to calculate ranges for comparison with Commander May's (R.N.) range-table for the 12-inch muzzle-loading gun (based on practice 1885); muzzle velocity, 1892 f.s.; "jump," 6 minutes.

Elevation		1°	2°	3°	4°	
Exp. range	...	1200	2267	3200	4057	yards.
Calc. range	...	1206	2249	3192	4039	,,
Difference	...	+6	−18	−8	−18	,,

I will now do the same for the 4-inch breech-loading gun, which was the gun chosen by the authorities to be used in testing my coefficients on a long range; muzzle velocity, 1900 f.s.; range-table founded on experiments made in 1884; "jump," 6 minutes.

Elevation		1°	2°	3°	4°	
Exp. range	...	1086	1811	2400	2917	yards.
Calc. range	...	1049	1817	2410	2895	,,
Difference	...	−37	+6	+10	−22	,,

Thus it appears that my coefficients give very satisfactory results when applied under the conditions of the original experiments. Commander May's table stops at a range of 4000 yards. As the elevation of the 4-inch gun was gradually increased, the calculated ranges fell shorter and shorter of the experimental ranges. At an elevation of 15° the calculated range was 6364 yards, and the experimental range 6608 yards, giving a difference of 244 yards. The explanation of this seems to me to be as follows:—

When an elongated shot is fired from a rifled gun at high elevations, the shot endeavours to preserve the parallelism of its axis. This causes the axis of the shot to become sensibly inclined to the direction of the motion of its centre of gravity. Thus the pressure of the air acts from below and raises the shot bodily, so as to give its trajectory an increased elevation. This would naturally increase the range of the shot. After a short time the shot inclines sideways, as explained by Magnus, and the shot continues to move with its axis inclined to the direction of its motion, which is the cause of the lateral "drift" of the shot. This shot having had its axis so much inclined to the direction of its motion, would encounter a greater resistance from the air than another shot fired at a lower elevation, because this latter would move with its axis more nearly in the direction of its motion.

Hence it is clear that, in order to apply any rational correction to the calculated ranges for high elevations, it would be necessary slightly to *increase* both (1) the elevation, and (2) the values of the coefficients of resistance.

Major Mackinlay, R.A., warns us that the published range-tables are not to be "blindly followed," a very necessary caution, when it is considered that we cannot be quite certain about the muzzle velocity, the "jump," the elevation, and the precise form of the head. The height of the barometer is seldom mentioned. My only surprise is that such good agreement between calculation and experiment should be found as above. The only question seems to be whether it is worth while to trouble about the correction of calculated ranges for high velocities and high elevations, when the reason for some little discrepancy is so evident. But to *reduce* coefficients would be to make matters worse.

Having been requested to calculate the range of a 9·2-inch shot weighing 380 pounds, fired at an elevation of 40° with a muzzle velocity of 2360 f.s., I could not feel satisfied till I had completed the calculation of a range-table for elevations 0° to 45° on a horizontal plane 27 feet below the muzzle. I give the result. Gravity and the temperature of the air were considered constant. The air was supposed to be at rest, and the shot was assumed to move in the direction of its axis; head ogival, struck with a radius of 1½ diameter. When the results of experiment are published I shall be ready to discuss the matter, but there are so many things uncertain at heights of 10,000, 15,000 feet, &c., that I doubt whether any theoretical advantages will result. It will, however, be interesting to know what can be done in an extremity.

It will be seen that the ranges go on increasing up to an elevation of 45°, and would probably go on beyond an elevation of 50° before reaching a maximum.

Elevation.	Range,	Height of Vertex.	Time of Flight.	Angle of Descent.	Striking Velocity.	Horizontal Striking Velocity.
°	Yards.	Feet.	Seconds.	° ′	f.s.	y.s.
0	969	0	1·3	1 4	2,154	718
1	2,115	25	3·0	1 35	1,931	643
2	3,416	94	5·1	2 47	1,708	569
3	4,611	237	7·1	4 20	1,528	508
4	5,600	343	9·4	5 52	1,399	464
5	6,475	517	11·4	7 38	1,291	426
6	7,271	716	13·4	9 30	1,200	395
7	7,999	937	15·3	11 28	1,128	368
8	8,669	1,180	17·1	13 28	1,075	349
9	9,291	1,445	18·9	15 28	1,040	334
10	9,876	1,731	20·6	17 23	1,022	325
11	10,430	2,036	22·3	19 9	1,015	320
12	10,952	2,360	23·9	20 54	1,009	314
13	11,448	2,703	25·5	22 38	1,003	309
14	11,922	3,065	27·0	24 21	998	303
15	12,379	3,443	28·5	26 2	993	297
16	12,804	3,835	30·0	27 40	990	292
17	13,217	4,242	31·5	29 15	987	287
18	13,618	4,663	33·0	30 48	985	282
19	14,007	5,099	34·4	32 19	984	277
20	14,385	5,550	35·9	33 48	984	273
21	14,750	6,015	37·3	35 15	985	268
22	15,103	6,489	38·8	36 40	987	264
23	15,445	6,970	40·2	38 3	990	260
24	15,775	7,459	41·6	39 24	993	256
25	16,092	7,956	43·0	40 41	996	252
26	16,398	8,461	44·4	41 54	1,000	248
27	16,691	8,974	45·7	43 2	1,004	245
28	16,973	9,494	47·1	44 6	1,009	242
29	17,242	10,022	48·4	45 7	1,014	239
30	17,501	10,558	49·7	46 5	1,019	236
31	17,747	11,102	51·0	47 1	1,025	233
32	17,981	11,654	52·2	47 56	1,031	230
33	18,203	12,214	53·5	48 50	1,037	228
34	18,413	12,782	54·7	49 43	1,044	225
35	18,612	13,357	56·0	50 35	1,051	222
36	18,799	13,941	57·2	51 27	1,058	220
37	18,973	14,534	58·5	52 18	1,065	217
38	19,136	15,136	59·7	53 8	1,072	214
39	19,287	15,747	61·0	53 58	1,079	212
40	19,426	16,368	62·2	54 47	1,086	209
41	19,553	17,001	63·4	55 36	1,092	206
42	19,668	17,646	64·7	56 24	1,099	203
43	19,772	18,302	65·9	57 11	1,105	200
44	19,864	18,969	67·1	57 57	1,111	197
45	19,944	19,648	68·3	58 43	1,117	193

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