TABLE OF RANGES.

BUCKNER.

Harvard University

Compliments of

H. A. Wise

Chief of Bureau of

Navy Ordnance.

May 8. 1865.

CALCULATED

TABLES OF RANGES

FOR

NAVY AND ARMY GUNS.

WITH

A METHOD OF FINDING

THE

DISTANCE OF AN OBJECT AT SEA.

BY

LIEUT. W. P. BUCKNER, U. S. N.

APPROVED BY THE ORDNANCE BUREAU NAVY DEPARTMENT.

NEW YORK:
D. VAN NOSTRAND, 192 BROADWAY.
1865.

BUREAU OF ORDNANCE, NAVY DEPARTMENT,
WASHINGTON CITY, February 8, 1865.

Lieut. W. P. BUCKNER, U. S. N., Navy Yard, New York:

SIR:—Your letter of the 14th ultimo, with enclosed Tables of Ranges of Navy Guns calculated by you, has been received.

The Tables have been carefully examined and approved by the Bureau.

The method of calculation is very simple and ingenious, and though not theoretically accurate, is yet sufficiently so for practical purposes, and it is believed that the Tables will prove of much value to the service.

Should you determine to publish them, the Bureau will take a thousand copies for distribution in the Navy.

I am, sir, your obedient servant,

H. A. WISE, *Chief of Bureau.*

N. B.—This letter has no reference to the Tables of Ranges of Army Guns hereto appended.

BUREAU OF NAVIGATION, NAVY DEPARTMENT,
WASHINGTON, March 21, 1864.

SIR:—It affords me pleasure to say, that I think your Table for finding the distance of an object at sea is suited to be very useful on board ship. I think the word "mast-head" should be substituted for "cross-trees."

Very respectfully, your obedient servant,

C. H. DAVIS,
Rear-Admiral and Chief of Bureau.

Lieut. W. P. BUCKNER, U. S. N.,
Ordnance Office, Navy Yard, N. Y.

PREFACE.

In publishing the following Tables of Ranges, the author does not pretend to say that they are theoretically exact. His attention was first called to a solution of the problem, in a general manner, by Commander W. N. Jeffers, of the Navy. After a patient search in all the books of reference at his disposal, he still found the problem covered with obscurity, and it struck him that the obscurity arose from the method of treating the subject: for instance, the resistance of the air to a shot passing through it is given in pounds, when I thought it should be given in terms of its velocity. The law usually assumed has been, that the resistance increases as the squares of the velocity; this is not strictly true, and I thought it more simple at once to deduce the retardation caused by the atmosphere. This put the problem in its simplest form, and is easily solved. It will be seen that in computing the horizontal range I have neglected the effect of gravity, for, since the horizontal ranges are given by experiment, the question of gravity does not enter into the problem at all. But, with regard to the angle of fall and the final velocity, I here introduce

the effect of gravity, combined with the resistance of the air. This I claim to be only an approximation to the truth. I have attempted to solve the problem in a strictly correct theoretical manner; but the Equations which it gave rise to were of so complex a form as to be utterly useless for practical purposes, and, in fact, transcendental in their character, and incapable of solution except by the method of approximation; so that I have resorted to this as the simplest solution, and the one best suited to the wants of the service. It will not be wondered at that I have stuck fast upon this problem in this respect, when I state that such minds as those of Newton, Bernoulli, Robbins, Hutton, Dr. Brooke, and many of the best French mathematicians, have failed to solve the problem in a satisfactory manner. On one occasion Dr. Keill proposed this problem to Bernoulli as one of the most difficult of solution. He solved it in the most general manner, but without giving satisfaction to the public in general, or in accordance with actual experiment. To quote the language of the *London Encyclopædia*, "We do not learn the ranges of a gun from theory, but the theory from the ranges of a gun;" it is this fact that I have based my calculations upon, and I believe them more accurate than any other Tables yet produced. Again it says: "All the solutions of this problem depend upon a particular law of resistance, assumed without proving that to be the law by which a body is resisted in its motion through the air; but even theory points out many causes of deviation from this law,

such as the pressure and condensation of the air in the case of very swift motion. And Mr. Robbins's experiments are sufficient to show that the resistance must be exceedingly great in such cases. Euler and subsequent writers have allowed it to be three times as great as squares of velocity, even in cases which frequently occur. And Euler gives a rule for ascertaining, with tolerable accuracy, what this increase and what the whole resistance may amount to."

I have tried to avoid these difficulties in determining the amount of retardation in terms of the velocity, for it is not the number of *pounds* of resistance a shot experiences that we wish to know, but the actual amount of retardation that this resistance causes. This I claim to have discovered, and from this I deduce the initial velocity, and, finally, the horizontal range. With regard to the time of flight of a shot, actual experiment shows it to be equal to the angle of elevation, varying, in extreme cases, a second or two from this rule. I have deduced a formula, based upon this fact, which gives the time of flight very nearly for all classes of guns, for since the theory must be discovered from the ranges, &c., of a gun, I believe that I am right in thus basing my calculations upon experiment. I have tried to avoid the difficulties which previous investigators have fallen into, and I think that I have succeeded in doing so, and if so, I hope that an indulgent public will not fail to appreciate it.

W. P. BUCKNER, *Lieutenant.*

EXPLANATION OF THE TABLES.

In the following Tables the height of the gun above the plane is assumed to be 16 feet, and the time of flight equal to the angle of elevation $+1''$. If we further assume that the retardation of the shot caused by the resistance of the air is in a certain proportion to its actual velocity, we have the following geometrical series expressing the range:

Let s = range.

r = ratio of retardation.

a = 1st term, or initial velocity.

Then we will have for s the following series:

$$s = a + ar + ar^2 + ar^3 + \ldots\ldots ar^{n-1};$$

or,

$$s = \frac{a(1-r^n)}{1-r}.$$

If then we take from any Table of Ranges two ranges actually obtained by experiment, we will have two equations involving two unknown quantities to find them. This gives rise to the following

PROBLEM.

Two ranges being given to find the retardation, initial velocity, and range of a gun.

Example.—To find the range of a 100-pounder Rifle; from a Table of Ranges, I take the range corresponding to

$$7° = 2853 \text{ yds} = \frac{a(1-r^8)}{1-r};$$

and

$$15° = 5030 \text{ yds} = \frac{a(1-r^{16})}{1-r}.$$

Finding the value of a in each, and equating, we have

$$\frac{2853-2853\,r}{1-r^8} = \frac{5030-5030\,r}{1-r^{16}}.$$

Clearing of fractions, transposing, and uniting, we have

$$2853\,r^{17}-2853\,r^{16}-5030\,r^9+5030\,r^8+2177\,r-2177 = 0;$$

dividing by $r-1$,

we have

$$2853\,r^{16}-5030\,r^8+2177 = 0;$$

and

$$r^{16}-\frac{5030}{2853}r^8 = \frac{-2177}{2853}.$$

Completing the square,

$$r^{16}-\frac{5030}{2853}r^8+\left(\frac{2515}{2853}\right)^2 = \frac{-2177}{2853}+\left(\frac{2515}{2853}\right)^2 = \frac{11424}{(2853)^2};$$

extracting the square root,

$$r^8-\frac{2515}{2853} = \frac{\pm 338}{2853};$$

transposing, we have

$$r^8 = 1 \text{ or } \frac{2177}{2853} = \cdot 76306;$$

$$r = \sqrt[8]{\cdot 76306} = \cdot 9668 = \text{nearly } \tfrac{29}{30};$$

hence, the retardation is $\frac{1}{30}$.

If now in the equation

$$a = \frac{2853 - 2853\,r}{1 - r^8},$$

we substitute the value of r thus found, we will have a or the initial velocity:

$$a = 401 \text{ yds} = 1203 \text{ feet.}$$

To find the range, we have simply to deduct $\frac{1}{30}$ of the velocity from the velocity, and add this quantity to the previous range, or thus:

0° = 401 yds.	401	5° = 2217
388	−13	328
1° = 789	388	6° = 2545
375	−13	317
2° = 1164	375	7° = 2862
363	−12	
3° = 1527	363	18° = 5736
351	−12	213
4° = 1878	351	19° = 5949
339	−12	206
5° = 2217	339	20° = 6155

and so on.

TO FIND THE ANGLE OF FALL.

WERE the shot to move in a vacuum it would strike the water at exactly the same angle as it was fired at, and the angle of fall would be exactly equal to the angle of elevation; but, owing to the resistance of the air, it strikes at a greater angle. The following method was used in constructing the Tables, which, though not strictly accurate in theory, is a sufficient approximation for all practical purposes. We see from the last example, that the remaining velocity of a 100-pounder shot, at 20° elevation and 21″ time of flight, was 206 yards. If we assume that the shot was one-half of this time in falling, say 10″, we would have for the velocity of the shot in falling, due to gravity alone, 108 yards, leaving out of consideration the resistance of the air to the falling body. But we have seen that a 100-pounder shot passing through the air experiences a resistance of $\frac{1}{10}$ of the velocity; hence the shot would not acquire 32·4 feet velocity at the end of the first second of time, but this quantity diminished by $\frac{1}{10}$, and so on. If then we call a the force of gravity, r the ratio, and n the number of seconds, we will have the following series, any term of which expresses the velocity at that time, viz.:

$$ar+2ar^2+3ar^3+4ar^4 \ldots\ldots +nar^n.$$

It is further evident that, as the resistance goes on increasing with the velocity, there must be a time when they will counterbalance each other, and at which time v, the velocity, will be a maximum, and afterwards remain constant or uniform.

To find when this takes place, we have the equation:

$$n a r^n = v.$$

To find when v is a maximum we differentiate this last equation, which gives

$$d n\, a r^n + r^n\, d n \log r\, n a = d v,$$

$$1 + \log r\, n = 0,$$

$$n = \frac{-1}{\log r}.$$

The logarithm here expressed is the Naperian. Now, if we assume

$$r = \frac{29}{30} \text{ Naperian log} = -\cdot 03390;$$

hence,

$$n = 29'' \, 5$$

for the time of falling, at which time v becomes a maximum and afterwards remains constant.

To find the velocity of fall at 10″ of time we have simply to solve the equation:

$$10\, a r^{10} = x:$$

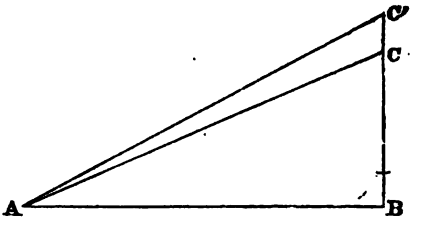
or thus:

$$\log 10\, a = 2\cdot 03342$$

$$\log r^{10} = 9\cdot 85280$$

$$x = 76\cdot 95 \text{ yds} = \log 1\cdot 88622$$

If we plot this example thus:



Lay off BAC = angle of elevation = 20°, and AC = remaining velocity = 206 yds.; then lay off CC′ = 76·9 yds. = velocity of fall; then will BAC′ = the angle of fall, and AC′ = final velocity. This may be more readily solved by Bowditch's Plane Table II.; for, if we enter the Table with 20° as a course, and 206 yds. as a distance, we take out AB = difference of latitude, and BC = departure; if, then, we add CC′ to the departure, we obtain BC′. Again, enter the Table and find AB and BC′ to correspond, the angle at the top of the page will be the angle of fall, if the difference of latitude is greater than the departure; otherwise the angle at the bottom of the page will be the required angle, and the distance corresponding will be the final velocity. Thus:

Elevation.	*Dist.*	*Diff. Lat.*	*Dept.*	*Dept.+76′ 9″.*
20°	206 yds.	193′ 6″	70′ 5″	147′ 4″

Now enter the Table again with 193′ 6″ difference of latitude and 147′ 4″ departure, we find them to correspond under 37° and opposite 243 yds.

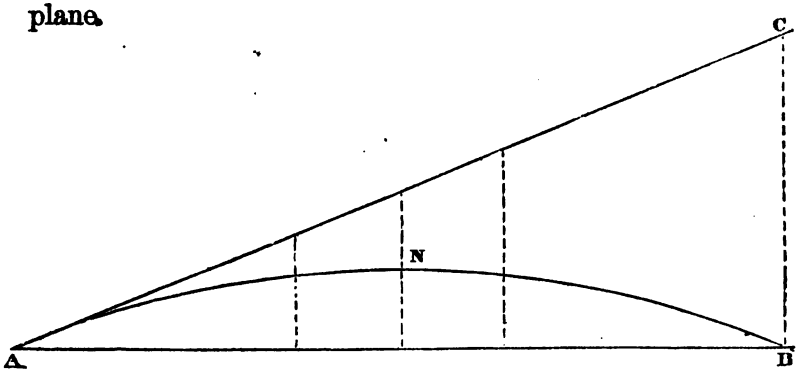
Then

Angle of Fall = 37°.

Final Velocity = 243 yds.

TIME OF FLIGHT.

As a shot fired from a gun moves through the air it experiences a certain amount of resistance: the amount of retardation has been found in the preceding pages. It is now proposed to find an expression for the time of flight. The time of flight is proved by experiment to be equal to the angle of elevation, when the gun is on the level of the plane.



In the figure, AC is the line of fire, AB the horizontal range, CB the distance the shot has to fall before reaching the plain, BAC the angle of elevation, ANB the actual path of the shot. The distance AC, that the shot would fly by the action of the charge, is expressed by the equation:

$$AC = \frac{a(1-r^t)}{1-r}.$$

The distance CB, that it would fall in the same time, by the force of gravity alone, would be expressed by the equation:

$$BC = \frac{g}{2}t + \frac{3g}{2}t^2 + \frac{5g}{2}t^3 + \frac{7g}{2}t^4 +, \text{ \&c.}$$

taking into consideration the resistance of the air to a falling body. But this last equation is equal to

$$CB = \frac{g}{2}\frac{(r+r^2-(2t+1)r^{t+1}+(2t-1)r^{t+2})}{(1-r)^2}.$$

But

$$CB = AB \sin A = Y,$$

and

$$Y = \frac{a(1-r^t)}{1-r}\sin A - \frac{g}{2}\frac{(r+r^2-(2t+1)r^{t+1}+(2t-1)r^{t+2})}{(1-r)^2}.$$

If we differentiate this last equation we obtain the value of t, that is:

$$t = \frac{a \sin A}{g r} - \frac{1}{\log r} - \frac{(1+r)}{2(1-r)}.$$

The logarithm of r, here expressed, is the Naperian, and is minus for a proper fraction, and

$$\frac{1}{\log r} = \frac{(1+r)}{2(1-r)};$$

hence

$$t = \frac{a \sin A}{gr}.$$

Now, since $\frac{a}{gr}$ is a constant, we can easily find its value for any angle of elevation, say 20°, for the time of flight of a shot fired at 20° elevation is equal to 20″.

Hence

$$\frac{20}{\sin 20^\circ} = \frac{a}{gr};$$

and

$$\log 20'' = 1{\cdot}30103$$
$$\log \sin 20^\circ = 9{\cdot}53405$$
$$\log \frac{a}{gr} = 1{\cdot}76698$$

If we then wish to find the time of flight for any other angle of elevation, say 10°, we have simply to add this log. of $\frac{a}{gr}$ to log. sin. 10°, the result will be the log. of the time of flight. Thus:

$$\log \frac{a}{gr} = 1{\cdot}76698$$
$$\log \sin 10^\circ = 9{\cdot}23967$$
$$t = 10''\tfrac{16}{160} = 1{\cdot}00665$$

But no gun is situated on the plane in firing, but at some distance above it, the average height being about 16 feet; so that we must add 1″ to the time thus obtained, and, instead of the time of flight at 10° being 10″, it will be 10+1, or 11″.

Calculated Ranges of Naval Guns.

Class of Gun—XX-inch.				Class of Gun—XX-inch.			
Charge of powder, 100 pounds. Projectile, Shot. Initial velocity, 400 yards. Retardation, $\frac{1}{60}$.				Charge of powder, 50 pounds. Projectile, Shell. Initial velocity, 350 yards. Retardation, $\frac{1}{40}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	400	1		0°	350	1	
1	793	2		1	691	2	
2	1179	3		2	1023	3	
3	1559	4		3	1347	4	
4	1933	5		4	1663	5	
5	2801	6	9°	5	1971	6	10°
6	2663	7		6	2271	7	
7	3019	8		7	2563	8	
8	3369	9		8	2848	9	
9	3713	10		9	3126	10	
10	4051	11	18°	10	3397	11	19°
11	4383	12		11	3661	12	
12	4709	13		12	3918	13	
13	5030	14		13	4169	14	
14	5346	15		14	4416	15	
15	5657	16	27°	15	4657	16	28°
16	5963	17		16	4892	17	
17	6264	18		17	5121	18	
18	6560	19		18	5344	19	
19	6851	20		19	5561	20	
20	7137	21	35°	20	5773	21	37°

Calculated Ranges of Naval Guns.

Class of Gun—XV-inch.				Class of Gun—XV-inch.			
Charge of powder, 60 pounds. Projectile, Shot. Initial velocity, 410 yards. Retardation, $\frac{1}{10}$.				Charge of powder, 50 pounds. Projectile, Cored Shot. Initial velocity, 400 yards. Retardation, $\frac{1}{18}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	410	1		0°	400	1	
1	799	2		1	778	2	
2	1169	3		2	1135	3	
3	1520	4		3	1472	4	
4	1853	5		4	1790	5	
5	2169	6	9°	5	2090	6	10°
6	2469	7		6	2373	7	
7	2754	8		7	2640	8	
8	3025	9		8	2892	9	
9	3282	10		9	3130	10	
10	3526	11	19°	10	3355	11	20°
11	3758	12		11	3568	12	
12	3978	13		12	3769	13	
13	4187	14		13	3959	14	
14	4386	15		14	4138	15	
15	4575	16	30°	15	4307	16	31°
16	4755	17		16	4467	17	
17	4926	18		17	4618	18	
18	5088	19		18	4761	19	
19	5242	20		19	4896	20	
20	5388	21	40°	20	5023	21	41°

Calculated Ranges of Naval Guns.

Class of Gun—XV-inch.				Class of Gun—XIII-inch.			
Charge of powder, 35 pounds. Projectile, Shell. Initial velocity, 343 yards. Retardation, $\frac{1}{14}$.				Charge of powder, 70 pounds. Projectile, Shot. Initial velocity, 400 yards. Retardation, $\frac{1}{10}$.			
Elevation..	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	343	1		0°	400	1	
1	661	2		1	790	2	
2	956	3		2	1170	3	
3	1230	4		3	1540	4	
4	1484	5		4	1901	5	
5	1720	6	11°	5	2253	6	9°
6	1939	7		6	2596	7	
7	2142	8		7	2930	8	
8	2330	9		8	3256	9	
9	2504	10		9	3574	10	
10	2665	11	22°	10	3884	11	18°
11	2814	12		11	4186	12	
12	2952	13		12	4480	13	
13	3080	14		13	4767	14	
14	3199	15		14	5047	15	
15	3309	16	35°	15	5329	16	27°
16	3411	17		16	5586	17	
17	3506	18		17	5845	18	
18	3594	19		18	6098	19	
19	3676	20		19	6345	20	
20	3752	21	47°	20	6586	21	35°

Calculated Ranges of Naval Guns.

Class of Gun—XIII-inch.				Class of Gun—XI-inch.			
Charge of powder, 50 pounds. Projectile, Shell. Initial velocity, 300 yards. Retardation, $\frac{1}{15}$.				Charge of powder, 20 pounds. Projectile, Shot. Initial velocity, 346 yards. Retardation, $\frac{1}{18}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	300	1		0°	346	1	
1	588	2		1	673	2	
2	865	3		2	982	3	
3	1131	4		3	1274	4	
4	1386	5		4	1550	5	
5	1631	6	11°	5	1811	6	10°
6	1866	7		6	2058	7	
7	2092	8		7	2291	8	
8	2309	9		8	2511	9	
9	2517	10		9	2719	10	
10	2717	11	22°	10	2915	11	21°
11	2909	12		11	3100	12	
12	3093	13		12	3275	13	
13	3270	14		13	3440	14	
14	3440	15		14	3596	15	
15	3603	16	33°	15	3743	16	32°
16	3759	17		16	3882	17	
17	3909	18		17	4013	18	
18	4053	19		18	4137	19	
19	4191	20		19	4254	20	
20	4323	21	43°	20	4365	21	44°

Calculated Ranges of Naval Guns.

Class of Gun—XI-inch. Charge of powder, 15 pounds. Projectile, Shell. Initial velocity, 339 yards. Retardation, $\frac{1}{17}$.				Class of Gun—X-inch. Charge of powder, 12½ pounds. Projectile, Shot. Initial velocity, 330 yards. Retardation, $\frac{1}{28}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	339	1		0°	330	1	
1	658	2		1	648	2	
2	958	3		2	954	3	
3	1240	4		3	1249	4	
4	1505	5		4	1533	5	
5	1754	6	10°	5	1807	6	10°
6	1988	7		6	2071	7	
7	2208	8		7	2325	8	
8	2415	9		8	2470	9	
9	2610	10		9	2706	10	
10	2794	11	22°	10	2934	11	21°
11	2967	12		11	3154	12	
12	3130	13		12	3366	13	
13	3283	14		13	3570	14	
14	3427	15		14	3767	15	
15	3563	16	33°	15	3957	16	31°
16	3691	17		16	4140	17	
17	3811	18		17	4316	18	
18	3924	19		18	4486	19	
19	4030	20		19	4650	20	
20	4130	21	45°	20	4808	21	41°

Calculated Ranges of Naval Guns.

Class of Gun—X-inch.				Class of Gun—IX-inch.			
Charge of powder, 12½ pounds. Projectile, Shell. Initial velocity, 332 yards. Retardation, 1/13.				Charge of powder, 13 pounds. Projectile, Shot. Initial velocity, 350 yards. Retardation, 1/11.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	332	1		0°	350	1	
1	648	2		1	683	2	
2	949	3		2	1000	3	
3	1235	4		3	1302	4	
4	1507	5		4	1590	5	
5	1765	6	10°	5	1864	6	10°
6	2010	7		6	2125	7	
7	2243	8		7	2374	8	
8	2465	9		8	2611	9	
9	2676	10		9	2837	10	
10	2876	11	21°	10	3052	11	21°
11	3065	12		11	3257	12	
12	3244	13		12	3452	13	
13	3414	14		13	3638	14	
14	3575	15		14	3815	15	
15	3727	16	33°	15	3984	16	31°
16	3871	17		16	4145	17	
17	4007	18		17	4298	18	
18	4135	19		18	4444	19	
19	4256	20		19	4583	20	
20	4370	21	43°	20	4715	21	42°

Calculated Ranges of Naval Guns.

Class of Gun—IX-inch. Charge of powder, 10 pounds. Projectile, Shell. Initial velocity, 335 yards. Retardation, $\frac{1}{15}$.				Class of Gun—VIII-inch. Charge of powder, 9 pounds. Projectile, Shot. Initial velocity, 340 yards. Retardation, $\frac{1}{20}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	335	1		0°	340	1	
1	648	2		1	663	2	
2	940	3		2	970	3	
3	1212	4		3	1262	4	
4	1466	5		4	1539	5	
5	1703	6	10°	5	1802	6	10°
6	1924	7		6	2052	7	
7	2130	8		7	2289	8	
8	2322	9		8	2514	9	
9	2501	10		9	2728	10	
10	2668	11	22°	10	2932	11	21°
11	2824	12		11	3126	12	
12	2970	13		12	3310	13	
13	3106	14		13	3485	14	
14	3233	15		14	3651	15	
15	3351	16	34°	15	3809	16	32°
16	3461	17		16	3959	17	
17	3564	18		17	4102	18	
18	3660	19		18	4238	19	
19	3750	20		19	4367	20	
20	3834	21	46°	20	4490	21	43°

Calculated Ranges of Naval Guns.

Class of Gun—VIII-inch.				Class of Gun—32-pdr.			
Charge of powder, 7 pounds. Projectile, Shell. Initial velocity, 310 yards. Retardation, $\frac{1}{16}$.				Charge of powder, 9 pounds. Projectile, Shot. Initial velocity, 430 yards. Retardation, $\frac{1}{8}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	310	1		0°	430	1	
1	600	2		1	812	2	
2	872	3		2	1152	3	
3	1127	4		3	1451	4	
4	1366	5		4	1722	5	
5	1590	6	12°	5	1961	6	10°
6	1800	7		6	2173	7	
7	1997	8		7	2361	8	
8	2182	9		8	2528	9	
9	2356	10		9	2676	10	
10	2519	11	24°	10	2808	11	24°
11	2672	12		11	2926	12	
12	2816	13		12	3031	13	
13	2951	14		13	3124	14	
14	3078	15		14	3207	15	
15	3197	16	36°	15	3281	16	38°
16	3309	17		16	3347	17	
17	3414	18		17	3406	18	
18	3513	19		18	3458	19	
19	3606	20		19	3504	20	
20	3693	21	48°	20	3545	21	53°

Calculated Ranges of Naval Guns.

Class of Gun—32-pdr. Charge of powder, 7 pounds. Projectile, Shell. Initial velocity, 440 yards. Retardation, $\frac{1}{8}$.				Class of Gun—32-pdr. Charge of powder, 6 pounds. Projectile, Shell. Initial velocity, 430 yards. Retardation, $\frac{1}{8}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	440	1		0°	430	1	
1	807	2		1	788	2	
2	1113	3		2	1086	3	
3	1368	4		3	1334	4	
4	1580	5		4	1541	5	
5	1757	6	10°	5	1713	6	11°
6	1905	7		6	1856	7	
7	2028	8		7	1975	8	
8	2130	9		8	2074	9	
9	2215	10		9	2156	10	
10	2286	11	26°	10	2224	11	26°
11	2345	12		11	2281	12	
12	2394	13		12	2329	13	
13	2435	14		13	2369	14	
14	2469	15		14	2402	15	
15	2497	16	46°	15	2429	16	46°
16	2520	17		16	2451	17	
17	2539	18		17	2469	18	
18	2555	19		18	2484	19	
19	2568	20		19	2496	20	
20	2579	21	67°	20	2506	21	67°

Calculated Ranges of Naval Guns.

Class of Gun—32-pdr. Charge of powder, 5 pounds. Projectile, Shell. Initial velocity, 420 yards. Retardation, $\frac{1}{8}$.				Class of Gun—32-pdr. Charge of powder, 4½ pounds. Projectile, Shell. Initial velocity, 412 yards. Retardation, $\frac{1}{8}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	420	1		0°	412	1	
1	770	2		1	755	2	
2	1062	3		2	1041	3	
3	1305	4		3	1279	4	
4	1507	5		4	1477	5	
5	1675	6	12°	5	1642	6	11°
6	1815	7		6	1780	7	
7	1932	8		7	1895	8	
8	2030	9		8	1991	9	
9	2112	10		9	2071	10	
10	2180	11	26°	10	2138	11	26°
11	2237	12		11	2194	12	
12	2285	13		12	2241	13	
13	2325	14		13	2280	14	
14	2358	15		14	2312	15	
15	2385	16	46°	15	2339	16	46°
16	2407	17		16	2361	17	
17	2425	18		17	2380	18	
18	2440	19		18	2396	19	
19	2452	20		19	2409	20	
20	2462	21	67°	20	2420	21	67°

Calculated Ranges of Naval Guns.

Class of Gun—32-pdr.				Class of Gun—24-pdr.			
Charge of powder, 4 pounds. Projectile, Shell. Initial velocity, 400 yards. Retardation, $\frac{1}{6}$.				Charge of powder, 2 pounds. Projectile, Shot. Initial velocity, 304 yards. Retardation, $\frac{1}{7}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	400	1		0°	304	1	
1	733	2		1	565	2	
2	1010	3		2	789	3	
3	1241	4		3	981	4	
4	1433	5		4	1146	5	
5	1593	6	11°	5	1288	6	12°
6	1726	7		6	1410	7	
7	1837	8		7	1515	8	
8	1929	9		8	1605	9	
9	2006	10		9	1682	10	
10	2070	11	27°	10	1748	11	29°
11	2123	12		11	1805	12	
12	2167	13		12	1854	13	
13	2204	14		13	1896	14	
14	2235	15		14	1932	15	
15	2261	16	46°	15	1963	16	48°
16	2283	17		16	1990	17	
17	2301	18		17	2013	18	
18	2316	19		18	2033	19	
19	2328	20		19	2050	20	
20	2338	21	67°	20	2065	21	65°

Calculated Ranges of Naval Guns.

Class of Gun—24-pdr.				Class of Gun—12-pdr.			
Charge of powder, 2 pounds. Projectile, Shell. Initial velocity, 320 yards. Retardation, $\frac{8}{9}$.				Charge of powder, 1 pound. Projectile, Shot. Initial velocity, 283 yards. Retardation, $\frac{1}{6}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	320	1		0°	283	1	
1	569	2		1	518	2	
2	762	3		2	716	3	
3	912	4		3	880	4	
4	1029	5		4	1017	5	
5	1120	6	14°	5	1131	6	13°
6	1191	7		6	1226	7	
7	1246	8		7	1305	8	
8	1289	9		8	1371	9	
9	1223	10		9	1426	10	
10	1249	11	37°	10	1472	11	33°
11	1269	12		11	1510	12	
12	1285	13		12	1542	13	
13	1297	14		13	1569	14	
14	1306	15		14	1591	15	
15	1313	16	69°	15	1609	16	57°
16	1318	17		16	1624	17	
17	1322	18		17	1636	18	
18	1325	19		18	1646	19	
19	1327	20		19	1654	20	
20	1329	21	84°	20	1661	21	75°

Calculated Ranges of Naval Guns.

Class of Gun—12-pdr.				Class of Gun—VIII-inch Rifle, Parrott.			
Charge of powder, 1 pound. Projectile, Shell. Initial velocity, 240 yards. Retardation, $\frac{1}{8}$.				Charge of powder, 16 pounds. Projectile, Shot or Shell. Initial velocity, 365 yards. Retardation, $\frac{1}{80}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	240	1		0°	365	1	
1	440	2		1	723	2	
2	607	3		2	1074	3	
3	746	4		3	1418	4	
4	862	5		4	1755	5	
5	959	6	15°	5	2085	6	9°
6	1040	7		6	2408	7	
7	1107	8		7	2724	8	
8	1163	9		8	3034	9	
9	1210	10		9	3338	10	
10	1249	11	36°	10	3636	11	19°
11	1281	12		11	3928	12	
12	1308	13		12	4214	13	
13	1330	14		13	4494	14	
14	1348	15		14	4768	15	
15	1363	16	60°	15	5037	16	28°
16	1375	17		16	5301	17	
17	1385	18		17	5560	18	
18	1393	19		18	5814	19	
19	1400	20		19	6163	20	
20	1406	21	76°	20	6407	21	37°

Calculated Ranges of Naval Guns.

Class of Gun—100-pdr. Rifle, Parrott.				Class of Gun—60-pdr. Rifle, Parrott.			
Charge of powder, 10 pounds. Projectile, Shot or Shell. Initial velocity, 401 yards. Retardation, $\frac{1}{30}$.				Charge of powder, 6 pounds. Projectile, Shot or Shell. Initial velocity, 400 yards. Retardation, $\frac{1}{25}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	401	1		0°	400	1	
1	789	2		1	784	2	
2	1164	3		2	1053	3	
3	1527	4		3	1407	4	
4	1878	5		4	1747	5	
5	2217	6	9°	5	2073	6	9°
6	2545	7		6	2386	7	
7	2862	8		7	2686	8	
8	3169	9		8	2974	9	
9	3466	10		9	3251	10	
10	3753	11	19°	10	3517	11	20°
11	4031	12		11	3772	12	
12	4300	13		12	4017	13	
13	4560	14		13	4252	14	
14	4811	15		14	4478	15	
15	5054	16	29°	15	4695	16	29°
16	5289	17		16	4903	17	
17	5516	18		17	5103	18	
18	5736	19		18	5295	19	
19	5949	20		19	5479	20	
20	6155	21	37°	20	5655	21	39°

Calculated Ranges of Naval Guns.

Class of Gun—30-pdr. Rifle, Parrott.				Class of Gun—20-pdr. Rifle, Parrott.			
Charge of powder, 3¼ pounds. Projectile, Shot or Shell. Initial velocity, 385 yards. Retardation, 1/10.				Charge of powder, 2 pounds. Projectile, Shot or Shell. Initial velocity, 383 yards. Retardation, 1/11.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	385	1		0°	383	1	
1	757	2		1	748	2	
2	1117	3		2	1096	3	
3	1465	4		3	1428	4	
4	1802	5		4	1744	5	
5	2128	6	9°	5	2045	6	10°
6	2443	7		6	2332	7	
7	2748	8		7	2605	8	
8	3033	9		8	2865	9	
9	3309	10		9	3113	10	
10	3576	11	20°	10	3349	11	20°
11	3834	12		11	3574	12	
12	4084	13		12	3788	13	
13	4326	14		13	3992	14	
14	4560	15		14	4086	15	
15	4786	16	30°	15	4271	16	30°
16	5005	17		16	4447	17	
17	5217	18		17	4606	18	
18	5422	19		18	4758	19	
19	5620	20		19	4903	20	
20	5812	21	39°	20	5042	21	41°

Calculated Ranges of Naval Guns.

Class of Gun—20-pdr. Rifle, Dahlgren.				Class of Gun—12-pdr. Rifle.			
Charge of powder, 2 pounds. Projectile, Shot or Shell. Initial velocity, 350 yards. Retardation, $\frac{1}{12}$.				Charge of powder, 1 pound. Projectile, Shot or Shell. Initial velocity, 360 yards. Retardation, $\frac{1}{8}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	350	1		0°	360	1	
1	671	2		1	675	2	
2	965	3		2	950	3	
3	1235	4		3	1191	4	
4	1483	5		4	1402	5	
5	1711	6	10°	5	1587	6	11°
6	1920	7		6	1749	7	
7	2112	8		7	1891	8	
8	2288	9		8	2015	9	
9	2449	10		9	2123	10	
10	2597	11	23°	10	2217	11	26°
11	2733	12		11	2299	12	
12	2858	13		12	2371	13	
13	2973	14		13	2434	14	
14	3078	15		14	2483	15	
15	3174	16	36°	15	2535	16	41°
16	3262	17		16	2576	17	
17	3343	18		17	2612	18	
18	3417	19		18	2643	19	
19	3485	20		19	2670	20	
20	3547	21	49°	20	2694	21	61°

Table for Finding the Distance of an Object at Sea.*

Yards distant.	Height of the Eye above the Sea.								
	20 ft.	30 ft.	40 ft.	50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
100	3 44	5 37	7 29	9 21	11 11	13 00	14 47	16 34	18 16
200	1 50	2 46	3 43	4 39	5 35	6 31	7 27	8 22	9 18
300	1 12	1 49	2 26	3 04	3 41	4 19	4 56	5 33	6 11
400	53	1 21	1 48	2 16	2 44	3 12	3 40	4 08	4 36
500	41	1 03	1 25	1 48	2 10	2 32	2 54	3 17	3 39
600	34	52	1 10	1 29	1 47	2 05	2 24	2 42	3 01
700	28	44	59	1 15	1 31	1 46	2 01	2 18	2 34
800	24	38	51	1 05	1 18	1 32	1 46	2 00	2 13
900	21	33	45	57	1 09	1 22	1 33	1 45	1 57
1000	18	29	40	50	1 01	1 12	1 23	1 34	1 45
1100	16	26	35	45	55	1 05	1 15	1 24	1 34
1200	15	23	32	41	50	59	1 08	1 17	1 26
1300	13	21	29	37	45	53	1 02	1 10	1 18
1400	12	19	27	34	42	49	57	1 04	1 12
1500	11	18	24	31	38	45	52	59	1 07
1600	9	15	21	27	35	42	48	55	1 02
1700	9	15	21	27	33	39	45	51	58
1800	8	14	19	25	31	36	42	48	54
1900	7	12	17	22	29	34	39	45	50
2000	7	12	17	22	27	32	37	42	47
2100	6	11	16	20	25	30	35	40	45
2200	6	10	15	19	24	28	33	38	42
2300	6	10	14	18	22	27	31	36	40
2400	5	9	13	17	21	25	29	34	38
2500	5	8	12	16	20	24	28	32	36
2600	4	8	11	15	19	23	26	30	34
2700	4	7	11	14	18	21	25	29	33
2800	4	7	10	14	17	20	24	28	31
2900	3	6	10	13	16	19	23	26	29
3000	3	6	9	12	15	19	22	25	28
4000	....	....	....	....	.....	.....	14	16	19
5000	....	....	....	....	.....	.....	10	11	13

* To Use the Table.—Measure the angle between the offing and the water-line of the object; with this angle enter the Table, and opposite, in the distance column, will be found the distance in yards.

Calculated Ranges of Army Guns.

Class of Gun—XV-inch Columbiad. Charge, 40 pounds. Projectile, Shell. Initial velocity, 293 yards. Retardation, $\frac{1}{13}$.				Class of Gun—X-inch Columbiad. Charge, 18 pounds. Projectile, Shot. Initial velocity, 417 yards. Retardation, $\frac{1}{10}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	293	1		0°	417	1	
1	573	2		1	792	2	
2	841	3		2	1128	3	
3	1098	4		3	1430	4	
4	1344	5		4	1702.	5	
5	1579	6	12°	5	1947	6	10°
6	1804	7		6	2167	7	
7	2019	8		7	2365	8	
8	2224	9		8	2543	9	
9	2420	10		9	2703	10	
10	2607	11	24°	10	2847	11	22°
11	2786	12		11.	2977	12	
12	2957	13		12	3094	13	
13	3120	14		13	3199	14	
14	3276	15		14	3293	15	
15	3425	16	35°	15	3378	16	36°
16	3568	17		16	3454	17	
17	3705	18		17	3522	18	
18	3836	19		18	3583	19	
19	3961	20		19	3638	20	
20	4080	21	46°	20	3687	21	50°

Calculated Ranges of Army Guns.

Class of Gun—X-inch Columbiad.				Class of Gun—X-inch Columbiad.			
Charge, 18 pounds. Projectile, Shell. Initial velocity, 472 yards. Retardation, $\frac{1}{3}$.				Charge, 15 pounds. Projectile, Shell. Initial velocity, 324 yards. Retardation, $\frac{1}{3}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	472	1		0°	324	1	
1	891	2		1	612	2	
2	1263	3		2	868	3	
3	1594	4		3	1095	4	
4	1843	5		4	1297	5	
5	2104	6	10°	5	1477	6	12°
6	2337	7		6	1637	7	
7	2544	8		7	1779	8	
8	2728	9		8	1905	9	
9	2892	10		9	2017	10	
10	3038	11	21°	10	2117	11	26°
11	3168	12		11	2206	12	
12	3284	13		12	2285	13	
13	3387	14		13	2355	14	
14	3479	15		14	2417	15	
15	3561	16	34°	15	2472	16	41°
16	3634	17		16	2521	17	
17	3699	18		17	2565	18	
18	3757	19		18	2604	19	
19	3809	20		19	2639	20	
20	3855	21	48°	20	2670	21	57°

Calculated Ranges of Army Guns.

Class of Gun—X-inch Sea-coast Howitzer. Charge, 12 pounds. Projectile, Shell. Initial velocity, 300 yards. Retardation, 1/10.				Class of Gun—VIII-inch Columbiad. Charge, 11 pounds. Projectile, Shell. Initial velocity, 332 yards. Retardation, 1/13.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	300	1		0°	332	1	
1	585	2		1	639	2	
2	856	3		2	922	3	
3	1113	4		3	1183	4	
4	1357	5		4	1424	5	
5	1589	6	12°	5	1646	6	12°
6	1809	7		6	1851	7	
7	2018	8		7	2040	8	
8	2207	9		8	2215	9	
9	2396	10		9	2377	10	
10	2576	11	23°	10	2527	11	23°
11	2747	12		11	2665	12	
12	2909	13		12	2792	13	
13	3063	14		13	2909	14	
14	3209	15		14	3017	15	
15	3348	16	35°	15	3117	16	32°
16	3481	17		16	3219	17	
17	3608	18		17	3304	18	
18	3729	19		18	3382	19	
19	3844	20		19	3454	20	
20	3953	21	45°	20	3520	21	49°

Calculated Ranges of Army Guns.

Class of Gun—VIII-inch Sea-coast Howitzer. Charge, 8 pounds. Projectile, Shell. Initial velocity, 400 yards. Retardation, 1/8.				Class of Gun—VIII-inch Sea-coast Howitzer, barbette. Charge, 4 pounds. Projectile, Shell. Initial velocity, 252 yards. Retardation, 1/8.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	400	1		0°	252	1	
1	720	2		1	454	2	
2	976	3		2	616	3	
3	1181	4		3	746	4	
4	1345	5		4	850	5	
5	1476	6	12°	5	933	6	16°
6	1581	7		6	999	7	
7	1665	8		7	1052	8	
8	1732	9		8	1094	9	
9	1786	10		9	1128	10	
10	1829	11	31°	10	1155	11	39°
11	1863	12		11	1177	12	
12	1890	13		12	1195	13	
13	1911	14		13	1210	14	
14	1928	15		14	1222	15	
15	1942	16	59°	15	1232	16	65°
16	1953	17		16	1240	17	
17	1962	18		17	1246	18	
18	1969	19		18	1251	19	
19	1975	20		19	1255	20	
20	1980	21	76°	20	1258	21	82°

Calculated Ranges of Army Guns.

Class of Gun—VIII-inch Siege Howitzer, siege carriage.				Class of Gun—42-pdr. Sea-coast Barbette.			
Charge, 4 pounds. Projectile, Shell. Initial velocity, 252 yards. Retardation, $\frac{1}{3}$.				Charge, 10½ pounds. Projectile, Shot. Initial velocity, 350 yards. Retardation, $\frac{1}{15}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	252	1		0°	350	1	
1	454	2		1	677	2	
2	616	3		2	982	3	
3	746	4		3	1267	4	
4	850	5		4	1533	5	
5	933	6	16°	5	1781	6	11°
6	999	7		6	2012	7	
7	1052	8		7	2228	8	
8	1094	9		8	2429	9	
9	1128	10		9	2617	10	
10	1155	11	39°	10	2792	11	23°
11	1177	12		11	2955	12	
12	1195	13		12	3107	13	
13	1210	14		13	3249	14	
14	1222	15		14	3382	15	
15	1232	16	65°	15	3506	16	34°
16	1240	17		16	3622	17	
17	1246	18		17	3730	18	
18	1251	19		18	3831	19	
19	1255	20		19	3925	20	
20	1258	21	82°	20	4013	21	45°

Calculated Ranges of Army Guns.

Class of Gun—32-pdr. Sea-coast Barbette. Charge, 8 pounds. Projectile, Shot. Initial velocity, 396 yards. Retardation, $\frac{1}{11}$.				Class of Gun—32-pdr. Field Howitzer. Charge, $2\frac{1}{2}$ pounds. Projectile, Shell. Initial velocity, 267 yards. Retardation, $\frac{1}{17}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	396	1		0°	267	1	
1	756	2		1	512	2	
2	1083	3		2	737	3	
3	1380	4		3	943	4	
4	1650	5		4	1132	5	
5	1895	6	12°	5	1305	6	13°
6	2118	7		6	1464	7	
7	2321	8		7	1610	8	
8	2506	9		8	1744	9	
9	2674	10		9	1867	10	
10	2827	11	22°	10	1980	11	27°
11	2966	12		11	2084	12	
12	3092	13		12	2179	13	
13	3207	14		13	2265	14	
14	3312	15		14	2344	15	
15	3407	16	35°	15	2416	16	42°
16	3493	17		16	2482	17	
17	3571	18		17	2542	18	
18	3642	19		18	2597	19	
19	3707	20		19	2647	20	
20	3766	21	47°	20	2693	21	55°

Calculated Ranges of Army Guns.

Class of Gun—32-pdr. Field Howitzer.				Class of Gun—24-pdr. Siege.			
Charge, 3¼ pounds. Projectile, Spherical Case. Initial velocity, 300 yards. Retardation, $\frac{1}{10}$.				Charge, 6 pounds. Projectile, Shot. Initial velocity, 416 yards. Retardation, $\frac{1}{8}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	300	1		0°	416	1	
1	570	2		1	780	2	
2	813	3		2	1098	3	
3	1032	4		3	1376	4	
4	1229	5		4	1619	5	
5	1406	6	13°	5	1832	6	11°
6	1565	7		6	2018	7	
7	1708	8		7	2181	8	
8	1837	9		8	2324	9	
9	1953	10		9	2449	10	
10	2057	11	26°	10	2558	11	24°
11	2151	12		11	2653	12	
12	2236	13		12	2736	13	
13	2312	14		13	2809	14	
14	2380	15		14	2873	15	
15	2441	16	42°	15	2929	16	37°
16	2496	17		16	2978	17	
17	2545	18		17	3021	18	
18	2589	19		18	3059	19	
19	2629	20		19	3092	20	
20	2665	21	55°	20	3121	21	53°

Calculated Ranges of Army Guns.

Class of Gun—24-pdr. Field Howitzer.				Class of Gun—24-pdr. Field Howitzer.			
Charge, 2 pounds. Projectile, Shell. Initial velocity, 297 yards. Retardation, $\frac{1}{3}$.				Charge, $2\frac{1}{2}$ pounds. Projectile, Spherical Case. Initial velocity, 300 yards. Retardation, $\frac{1}{10}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	297	1		0°	300	1	
1	556	2		1	570	2	
2	782	3		2	813	3	
3	980	4		3	1032	4	
4	1153	5		4	1229	5	
5	1304	6	13°	5	1406	6	13°
6	1436	7		6	1565	7	
7	1552	8		7	1708	8	
8	1654	9		8	1837	9	
9	1743	10		9	1953	10	
10	1821	11	29°	10	2057	11	26°
11	1890	12		11	2151	12	
12	1950	13		12	2236	13	
13	2002	14		13	2312	14	
14	2047	15		14	2380	15	
15	2086	16	47°	15	2441	16	41°
16	2121	17		16	2496	17	
17	2152	18		17	2545	18	
18	2179	19		18	2589	19	
19	2203	20		19	2629	20	
20	2224	21	63°	20	2665	21	56°

Calculated Ranges of Army Guns.

Class of Gun—18-pdr. Barbette.				Class of Gun—12-pdr. Field (Model 1857).			
Charge, 4½ pounds. Projectile, Shot. Initial velocity, 367 yards. Retardation, ⅛.				Charge, 2½ pounds. Projectile, Shot. Initial velocity, 362 yards. Retardation, 1/10.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	367	1		0°	362	1	
1	688	2		1	688	2	
2	969	3		2	981	3	
3	1215	4		3	1245	4	
4	1430	5		4	1483	5	
5	1618	6	12°	5	1697	6	11°
6	1782	7		6	1890	7	
7	1925	8		7	2064	8	
8	2050	9		8	2221	9	
9	2159	10		9	2362	10	
10	2254	11	26°	10	2489	11	23°
11	2337	12		11	2603	12	
12	2410	13		12	2706	13	
13	2474	14		13	2799	14	
14	2530	15		14	2883	15	
15	2579	16	42°	15	2959	16	38°
16	2622	17		16	3027	17	
17	2660	18		17	3088	18	
18	2693	19		18	3143	19	
19	2722	20		19	3192	20	
20	2747	21	59°	20	3236	21	52°

Calculated Ranges of Army Guns.

Class of Gun—12-pdr. Field (Model 1857).				Class of Gun—12-pdr. Field (Model 1857).			
Charge, 2 pounds. Projectile, Shell. Initial velocity, 357 yards. Retardation, $\frac{1}{7}$.				Charge, $2\frac{1}{2}$ pounds. Projectile, Spherical Case. Initial velocity, 291 yards. Retardation, $\frac{1}{8}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	357	1		0°	291	1	
1	663	2		1	532	2	
2	925	3		2	733	3	
3	1150	4		3	900	4	
4	1343	5		4	1039	5	
5	1508	6	12°	5	1155	6	14°
6	1650	7		6	1251	7	
7	1772	8		7	1331	8	
8	1877	9		8	1398	9	
9	1967	10		9	1454	10	
10	2044	11	27°	10	1501	11	33°
11	2110	12		11	1540	12	
12	2167	13		12	1573	13	
13	2216	14		13	1600	14	
14	2258	15		14	1622	15	
15	2289	16	49°	15	1640	16	56°
16	2316	17		16	1655	17	
17	2339	18		17	1667	18	
18	2359	19		18	1677	19	
19	2376	20		19	1685	20	
20	2391	21	65°	20	1692	21	74°

Calculated Ranges of Army Guns.

Class of Gun—12-pdr. Field Howitzer.				Class of Gun—12-pdr. Field Howitzer.			
Charge, 1 pound. Projectile, Shell. Initial velocity, 246 yards. Retardation, $\frac{1}{3}$.				Charge, $\frac{3}{4}$ pound. Projectile, Spherical Case. Initial velocity, 288 yards. Retardation, $\frac{1}{4}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	246	1		0°	288	1	
1	461	2		1	504	2	
2	649	3		2	666	3	
3	813	4		3	787	4	
4	956	5		4	878	5	
5	1081	6	14°	5	946	6	16°
6	1190	7		6	997	7	
7	1285	8		7	1035	8	
8	1372	9		8	1063	9	
9	1445	10		9	1084	10	
10	1509	11	32°	10	1100	11	47°
11	1565	12		11	1112	12	
12	1614	13		12	1121	13	
13	1657	14		13	1128	14	
14	1695	15		14	1133	15	
15	1728	16	50°	15	1137	16	75°
16	1757	17		16	1140	17	
17	1782	18		17	1142	18	
18	1804	19		18	1143	19	
19	1823	20		19	1144	20	
20	1840	21	65°	20	1145	21	89°

Calculated Ranges of Army Guns.

Class of Gun—12-pdr. Field (Model 1841).				Class of Gun—12-pdr. Field (Model 1841).			
Charge, 2½ pounds. Projectile, Shot. Initial velocity, 350 yards. Retardation, $\frac{1}{10}$.				Charge, 2½ pounds. Projectile, Spherical Case. Initial velocity, 300 yards. Retardation, $\frac{1}{8}$.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	350	1		0°	300	1	
1	665	2		1	550	2	
2	948	3		2	758	3	
3	1203	4		3	931	4	
4	1432	5		4	1075	5	
5	1638	6	12°	5	1195	6	14°
6	1823	7		6	1295	7	
7	1989	8		7	1378	8	
8	2138	9		8	1447	9	
9	2272	10		9	1504	10	
10	2393	11	24°	10	1552	11	32°
11	2502	12		11	1592	12	
12	2600	13		12	1625	13	
13	2688	14		13	1652	14	
14	2767	15		14	1675	15	
15	2838	16	39°	15	1694	16	55°
16	2902	17		16	1710	17	
17	2960	18		17	1723	18	
18	3012	19		18	1734	19	
19	3059	20		19	1743	20	
20	3101	21	52°	20	1750	21	74°

Calculated Ranges of Army Guns.

Class of Gun—12-pdr. Mountain Howitzer.				Class of Gun—6-pdr. Field.			
Charge, ½ pound. Projectile, Shell. Initial velocity, 300 yards. Retardation, ¼.				Charge, ¼ pound. Projectile, Shot. Initial velocity, 318 yards. Retardation, ⅛.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	300	1		0°	318	1	
1	525	2		1	583	2	
2	694	3		2	804	3	
3	821	4		3	988	4	
4	916	5		4	1141	5	
5	987	6	16°	5	1268	6	13°
6	1040	7		6	1374	7	
7	1080	8		7	1462	8	
8	1110	9		8	1535	9	
9	1132	10		9	1596	10	
10	1149	11	47°	10	1647	11	31°
11	1162	12		11	1689	12	
12	1172	13		12	1724	13	
13	1179	14		13	1753	14	
14	1184	15		14	1777	15	
15	1188	16	75°	15	1797	16	56°
16	1191	17		16	1814	17	
17	1193	18		17	1828	18	
18	1194	19		18	1840	19	
19	1195	20		19	1850	20	
20	1196	21	89°	20	1858	21	73°

Calculated Ranges of Army Guns.

Class of Gun—12-pdr. Field.				Class of Gun—12-pdr. Field.			
Charge, ¼ pound. Projectile, Spherical Case. Initial velocity, 300 yards. Retardation, ⅛.				Charge, ¼ pound. Projectile, Spherical Case. Initial velocity, 300 yards. Retardation, ⅛.			
Elevation.	Range.	Time of Flight.	Angle of Fall.	Elevation.	Range.	Time of Flight.	Angle of Fall.
	yds.	*sec.*			*yds.*	*sec.*	
0°	300	1		11	1396	12	
1	540	2		12	1417	13	
2	732	3		13	1434	14	
3	886	4		14	1448	15	
4	1009	5		15	1459	16	62°
5	1107	6	15°	16	1468	17	
6	1185	7		17	1475	18	
7	1248	8		18	1481	19	
8	1298	9		19	1486	20	
9	1338	10		20	1490	21	79°
10	1370	11	36°				