REPORT

OF

EXPERIMENTS ON GUNPOWDER,

MADE AT

WASHINGTON ARSENAL,

IN

1843 AND 1844.

BY

CAPTAIN ALFRED MORDECAI,

OF THE ORDNANCE DEPARTMENT.

WASHINGTON:

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ORDNANCE OFFICE,

WASHINGTON, FEB. 13, 1845.

Hon. WM. WILKINS, *Secretary of War.*

SIR: In the year 1839, this Department proposed the construction of a Ballistic Pendulum for the purpose of prosecuting, in an accurate manner, many experimental enquiries essential to the advancement of the science of gunnery, and to acquiring a knowledge of the principles which should govern, in determining the proper proportions of length and weight, in the construction of cannon, and the best mode of fabrication of gunpowder for artillery purposes, and introduced in its estimate an item for that purpose.

This measure was approved by Mr. Secretary Poinsett, and the sum asked for was appropriated, but owing to the absence of the greater part of the Officers composing the Ordnance Board, on a visit to Europe, the construction of, and experiments with, the Pendulum were not commenced until the year 1842. This duty was then assigned to Capt. Mordecai, who has, since that time, been engaged therein under the direction of this office. Having completed the construction of, and a course of experiments with, the Cannon pendulum, to which was subsequently added a Musket pendulum, for the determination of similar principles in reference to small arms and powder therefor, Capt. Mordecai has now presented his first report, shewing the nature of his experiments, so far as they have been carried, and their results. This report exhibits great skill, industry and scientific knowledge on the part of that officer, and contains a mass of facts highly important to be known generally in the service. I, therefore, submit the report for your examination, and propose, with your sanction, to cause it to be printed and distributed for general information—the expense of which may be defrayed from a balance of the appropriation for the Pendulum yet remaining.

While on this subject I may remark that there is, in possession of this Department, much other valuable information, the knowledge of which would be of great advantage to the military service of the country, and which it is proposed to digest and prepare for publication from time to time.

I am, sir, very respectfully,

Your obedient servant,

(Signed) G. TALCOTT,

Lt. Col. Ordn.

Having examined the Report of Experiments referred to in the above communication, and believing that the work is of a nature to be highly interesting and useful to the military service, I approve of its publication. The Chief of the Ordnance Department will, therefore, take measures to have the Report printed under the immediate superintendence of Capt. Mordecai.

(Signed) WM. WILKINS,

Sec'y of War.

War Dept., *Feb'y* 13, 1845.

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ERRATA.

P. 30, 11th line from the bottom, after the word *whence* for v read V.

P. 34, 5th line from the bottom, after the word *hence* for v read v'.

INTRODUCTION.

In the summer of 1842, I received from the Ordnance Office instructions to erect at Washington Arsenal a ballistic pendulum, and a gun pendulum, to serve for experiments in gunnery and also for the proof of gunpowder.

The iron work for these pendulums was prepared at the West Point foundry, and it was received at the Arsenal in December, 1842, at which time the piers and sheds for the pendulums had also been completed; but, in consequence of the intervention of other duties, the erection of the pendulums was not commenced until the end of January, 1843. The adjustment of them and some preliminary trials for testing the accuracy and the stability of the work, were made during the favorable weather in the winter and spring. In the beginning of May the apparatus was reported ready for use, and a programme of the proposed experiments on gunpowder was submitted to the chief of the Ordnance Department and adopted.

In the course of the experiments, a minute journal of all the operations was carefully made, and is preserved at the Arsenal. That journal will be presented almost verbatim in this report, the principal alteration in it being that required for bringing together all the experiments of each kind, for the sake of facilitating a reference to them.

By this course, all the circumstances which have an influence on the results of the experiments will be presented in detail, so that those results may at any time be verified, and an estimate may be formed of the value of the authority from which they are derived. The candor and minuteness with which Hutton has rendered an account of his experiments have been commended by all subsequent writers on the same subject, and his example is worthy of imitation by those engaged in the like pursuit.

The journal contains, for each day on which experiments were made, an extract from the Meteorological Register kept at the Hydrographical Office in Washington, and an abstract of these observations is appended to this report. Other causes of variation, in the results of such experiments as the present, are so much more influential than those arising from changes in the state of the atmosphere or of the weather, that no attempt is here made to correct those results for a normal meteorological condition; but this register will furnish the elements for such correction, if in the course of a long series of experiments it should be found that there are variations which may be fairly attributed to atmospheric influence. With few exceptions, the experiments have been made in favorable, pleasant weather.

When I was first charged with the direction of these experiments, I suggested to the chief of the Ordnance Department to endeavor to procure, through the legation of the United States in France, copies of the reports which might have been made of the experiments on gunpowder at Metz, as such reports would be highly valuable for the purpose of comparing and verifying the results obtained in the experiments which we proposed to make. In pursuance of this suggestion, application was made to the War Department of France, and through the great kindness and liberality of the Minister of War, Marshal Soult, a manuscript copy of a very elaborate report of experiments on gunpowder was furnished to the Ordnance Department. That report was received in July, 1843; it embraces experiments of a kind similar to those proposed in my programme, and extends also to other points of practical importance in such investigations. Some of its conclusions will be alluded to in discussing the results of the present experiments.

I take pleasure in acknowledging my obligations to Major Symington, the commanding officer at Washington Arsenal, for the facilities extended to me in making these experiments: to several of the workmen employed at the arsenal, and especially to the master armorer, Mr. Fisher, I am also indebted for the zeal and intelligence displayed in perfecting the mechanical arrangements of the various apparatus, and in executing my designs.

PART FIRST.

1. PROGRAMME OF THE EXPERIMENTS.

In order to establish a standard of proof by means of the ballistic pendulum, it was first necessary to compare the strength and other qualities of the various kinds of gunpowder now in service; and it was thought advisable, also, to extend the comparison to other kinds of powder, differing from these in the mode of manufacture, the proportions of the composition, the size of grain, density, &c. In the course of the experiments, other varieties of powder, not embraced in the original programme, were subjected to trial.

It was proposed to try many of these varieties of powder by the ballistic pendulum, with various charges, with both shot and shells, and to compare the indications of the strength of powder given by the pendulum with those of the common mortar eprouvette, and of the eprouvettes used in the British and French services. This comparison was subsequently extended to a trial with small arms, by means of a musket pendulum established on the same principles as the cannon pendulum.

It was further proposed to compare other physical qualities of the several kinds of powder, by ascertaining their density, relative quickness of burning, tendency to absorb moisture, &c.

The apparatus used for these several trials and comparisons are described, and the results set down, under their appropriate heads.

The natures of all the varieties of powder are exhibited in the subjoined tabular view, to which the requisite explanatory remarks are annexed.

	Designation.	Kind of grain.		COMPOSITION.			Kind of coal.	Chlorides in the saltpetre.	MANUFACTURE.				RECEIVED AT WASHINGTON ARSENAL.			Remarks.	
				Saltpetre.	Charcoal.	Sulphur.			Mode of incorporation, &c.	Glazing.	Place.	Date.	Whence.	When.	Quantity.		
															lbs.		
1	*a*	Cannon	Uneven	76	14	10	Cylinder; brown.	$\frac{1}{14,000}$	3 hours in dust barrels; 1 hour under heavy rollers, running on a charge of 50 lbs; not pressed.	Glazed	Dupont's mills; near Wilmington, Delaware.	1836	Little Falls magazine, near Washington.	Ap'l, 1843	200	Sent to the magazine in 1836.	1
2	A											July, 1837	Frankford Arsenal, near Philadelphia.	June, 1843 & Mar., 1844	500		2
3	A. 1		Large														3
4	A. 2		Medium												500		4
5	A. 3		Small					$\frac{1}{41,000}$									5
6	A. 4	Musket										1839		Mar., 1844	100		6
7	A. 5	Rifle										1844	Dupont's mills	June, 1844	2	In tin canisters.	7
8	A. 0	Very large	Even									Aug., 1843		Sep., 1843	50		8
9	A. m	Mealed										1836	Frankford Arsenal.				9
10	B	Cannon	Uneven	76	13.7	10.3	Cylinder; black.	$\frac{1}{4,140}$	Mixed in dust barrels; incorporated with light rollers; pressed.	Glazed	Garesché, Eden park; near Wilmington, Delaware.	July, 1837		June, 1843	500		10
11	B. 1		Large														11
12	B. 2		Medium														12
13	B. 3		Small														13
14	C		Uneven	76	15	9	Cylinder; brownish-black.	$\frac{1}{314}$	16 hours under heavy rollers, running on a charge of 300 lbs; part of the cake pressed.		Loomises, Hazzard, and Co.; Enfield, Connecticut.	1837	Watervliet Arsenal, near Albany, N York.		500		14
15	C 1		Large														15
16	C. 2		Medium														16
17	C. 3		Small					$\frac{1}{590}$									17
18	C. 5	Rifle										1838			100		18
19	C. 6	Sporting							Do. charge 100 lbs.						$\frac{1}{4}$	From a canister.	19
20	D	Cannon	Uneven	75	15	10	Cylinder; jet black.	$\frac{1}{141}$	48 hours in rolling barrels, with a charge of 200 lbs.; pressed.		Masters, Swift, & Co.; Scaghticoke, N. York.	1837	Watervliet Arsenal.		500		20
21	D. 1		Large														21
22	D. 2		Medium														22
23	D. 3		Small														23
24	E		Uneven	76	14	10	Cylinder; brown.		4 hours in dust barrels; $\frac{3}{4}$ hour under heavy rollers; 6 hours pounding mill; pres'd very hard; fracture slaty.		Dupont's mills	Jane, 1843	Dupont's mills	July, 1843			24
25	E. 1		Large												100		25
26	E. 2		Medium												100		26
27	E. 3		Small														27
28	E. 5	Rifle													100		28
29	F	Cannon	Uneven	75	12.5	12.5			14 hours pound'g mill; not pressed; grain soft and friable.	Rough					200		29
30	F. 1		Large												200		30
31	F. 2		Medium												200		31
32	F. 0	Very large	Even												50		32
33	G. 1	Cannon	Large	77	13	10	Cylinder; reddish-brown.	$\frac{1}{62,000}$	5 hrs. dust barrels; 4 hrs. heavy rollers; not pressed; grain very hard.	Highly glazed.					200	Same as Eagle canister powder.	33
34	G. 6	Sporting													200		34
35	H	Cannon	Uneven	75	15	10	Alder; Cylinder.		Heavy rollers; pressed	Glazed	Waltham Abbey, England.	August, 1812	Boston	Ap'l, 1844	90	Captured in the "Lady Johnson," 1813.	35

	Designation.	Kind of grain.		Composition. Saltpetre.	Charcoal.	Sulphur.	Kind of coal.	Manufacture. Mode of incorporation, &c.	Glazing.	Place.	Date.	Received at Washington Arsenal. Whence.	When.	Quantity.	Remarks.	
														lbs.		
36	K. 1, r.		Large	75	12.5	12.5	Pit burnt; black.	14 hours pounding mill; Not pressed.	Rough					100		36
37	K. 1, g.													100		37
38	L. 1							24 hours do. do.						100		38
39	M. 1			76	14	10		14 hours do. do.						100		39
40	N.	Cannon	Uneven	75	12.5	12.5		Like A.		Dupont's mills	May, 1844	Dupont's mills		100		40
41	R. 15′		Large	76	14	10	Cylinder; brown.	15 minutes } Under heavy rollers; not pressed.						25		41
42	R. 30′							30 "					June, 1844	25		42
43	R. 60′							60 "						25		43
44	R. 90′							90 "						25		44
45	S	Blasting	Uneven	70	15	15	Large wood.	2 hours dust barrels; ¾ hour heavy rollers;						25		45
46	T	Ditto	Large				Kiln burnt		Glazed	Sumaney town, Pennsylvania.		Philadelphia		25	Crude saltpetre.	46
47	W	Cannon	Uneven					Pounding mill; pressed hard.		Bussard's mills, near Washing'n	1824 to 1828.	Little Falls magazine.			In current use.	47
48	X	Cannon	Uneven	76	14	10	Cylinder	Like A.		Dupont's mills	Oct., 1844	Dupont's mills	Nov. 1844	25		48
49	X. p.							Like X, but pressed in thick cakes.						25		49
50	X. p, 4	Musket						Dust from X. p; worked 1 hour with the rollers, and pressed.						25		50
51	X. p, 5	Rifle												25		51
52	English.	Cannon	Uneven	75	15	10	Cylinder; brown.	Heavy rollers; pressed.		Waltham Abbey.	Sept., 1838	British Ordn'ce Department.	1841	2	In glass bottles, corked & sealed.	52
53		Musket									Mar., 1839			2		53
54		Rifle									May, 1836			2		54
55		Sporting								J. Hall & Sons, Dartford.				¼	From a canister.	55
56	French.	Cannon	Uneven	75	12.5	12.5	Pit; black.	11 hours pounding mill; not pressed; grain soft.	Rough	Bouchet	2d quarter 1838.	French War Department.	1841	2	In tin canisters; corked, not seal'd.	56
57		Musket												2		57
58		Sporting		76	14	10	Cylinder; brown.	Heavy rollers.	Glazed	Esquerdes	1838			2		58
59	Swedish	Musket						Grain very hard; fracture slaty.	Glazed			Stockholm		2	In glass; sealed.	59
60	Old cartridges.	Ditto						Pounding mill; grain soft.	Rough							60

Remarks explanatory of the foregoing Table.

The figures 0, 1, 2, 3, 4, 5, 6, attached to the letters which designate the different kinds of powder, denote the several sizes of grain of each kind.

A. 0, & F. 0, are samples of very large grains of powders A & F, containing no grains which will pass through the coarsest sieve for cannon powder.

No 4 denotes musket grain; No. 5, rifle; and No. 6, sporting.

Nos. 1, 2, 3, denote three different sizes of grain obtained by sifting cannon powder with sieves corresponding with the regulation gauges for the inspection of powder; the diameters of the holes in these sieves are:

	Inch.
Maximum - - -	0.100
Medium - - -	0.085
Minimum - - -	0.070

No. 1 denotes the size of grain between the maximum and medium sieves; No. 2, between the medium and minimum; and No. 3, that which passes through the minimum.

In the powders E, F, G, K, L, M, R, the separation of the different sizes of grain was made at the powder works; the powders A, B, C, D, were sifted at the Arsenal. The following table shows the proportions of the several sizes of grain in these powders, obtained by sifting one sample; and it also shows the proportions of the different sizes which are required by the regulation for the inspection of powder:

Samples of cannon powder sifted, August 11th, 1843.

Powder sifted.		Quantity remaining on sieve No. 1.	Between No. 1 & 2.		Between No. 2 & 3.		Through No. 3.	
Kind.	Quantity.		Designation.	Quantity.	Designation.	Quantity.	Designation.	Quantity.
	lbs.	Per cent.		Pr. ct.		Pr. ct.		Pr. ct.
A	42.223	2.08	A. 1	35.52	A. 2	24.86	A. 3	37.54
B	30.869	0.23	B. 1	26.62	B. 2	25.53	B. 3	47.62
C	32.345	0.58	C. 1	31.33	C. 2	19.83	C. 3	48.26
D	35.293	8.23	D. 1	42.10	D. 2	19.	D. 3	30.67
By regulation.		Not more than 6.25	Not less than 37.5		Not more than 37.5		Not more than 18.75	

Of these powders, sample A alone agrees pretty nearly with the regulation; samples B and C contain too little of large grain and too much of small grain, which also is too fine, as will be seen by the number of grains in a given weight stated in a future part of the Report; sample D is nearer to the proper size of grain, but there is too much inequality in it.

Of these four kinds of powder a considerable quantity was procured for the Ordnance Department in 1837 and 1838, and they constitute the principal part of the stock now in the magazines. Nearly all the other kinds used in these experiments (except the foreign powders) were prepared expressly for this purpose.

In procuring some powder in 1837, from the powder mills at Nitre Hall, near Philadelphia, I found that, in consequence of the great density and hardness imparted to it by the press, (although incorporated by the pounding mill,) the coarse grain, or cannon powder, gave so low a range with the mortar eprouvette, (180 to 200 yards,) that it could not be received, under the regulations, although the fine grain or rifle powder, sifted from the same, gave an uncommonly high range. I thought it would be interesting to test this powder with large charges in the cannon, and as the Nitre Hall mills were not in operation, I had similar powder prepared at Dupont's mills. This is the powder designated by the letter E, in which the hardness and density of the grain are undoubtedly carried to excess.

In contrast with this very hard grain is the powder F, which is made according to the French process, in all respects except in the kind of coal; *cylinder coal*, or coal made by the distillation of the wood, having been used instead of that burnt in pits. This powder, not being pressed or glazed, is very light and soft grained, and in these respects it presents an extreme case of an opposite nature to that offered by the powder E. The error in the kind of coal used was corrected in making the powder K, which differs from the common French war powder only in being worked 14 hours instead of 11 hours.

G. 1 is a sample of cannon powder made from the same cake as the fine canister sporting powder designated by G. 6.

H is a sample of English government powder, captured in 1813, and placed probably at that time in the magazine near Boston, belonging to the State of Massachusetts. The appearance of the powder affords satisfactory evidence of its being the kind indicated by the marks on the barrel; it is in excellent order, free from lumps and containing very little dust.

T is a sample of such powder as is commonly sold for blasting rocks; it is made of crude Calcutta saltpetre and common charcoal, and is probably incorporated by pounding in large mortars.

W is the powder used for ordinary service at Washington Arsenal, having been longer in the magazine than the other kinds. The mills where it was made being no longer in existence, the particulars of the mode of manufacture could not be accurately ascertained.

The samples of English and French government powders were obtained directly from the War Departments of the respective countries, and the packages are carefully marked with the description and proof of the powder contained in them, as follows:

ENGLISH POWDER.

Cannon powder. Made of willow charcoal; stoved at Waltham Abbey, 22d September, 1838; proved 4th October, 1838; mean vibration of the gun eprouvette 22°.3; weight of 1 cubic foot, 54½ lbs. (872 oz.)

Musket powder. Made of willow coal; stoved 23d March, 1839; proved 25th March, 1839; mean vibration 26°.4; weight of a cubic foot 52¾ lbs. (844 oz.)

Rifle powder. Made of dogwood coal; stoved 5th May, 1836; proved 9th July, 1836; mean vibration of gun eprouvette 28°.1; weight of a cubic foot 51¼ lbs. (820 oz.)

FRENCH POWDER.

Cannon powder. Made at Bouchet, between the 1st April and 30th September, 1838; range with the mortar eprouvette 249 metres, (272 yds.;) gravimetric density 804.

Initial velocity, by musket pendulum, 516 metres, (1,694 feet;) the proof charge being 10 grammes = 154 grains troy.

Musket powder. Made at Bouchet, between the 1st April and 30th September, 1838; range with the mortar eprouvette, 246 metres, (269 yds.;) gravimetric density 830.

Initial velocity, by musket pendulum, 508 metres, (1,667 ft.)

Sporting powder, (Poudre Royale.) Made at Esquerdes in 1838. Proof by musket pendulum: charge 5 grammes, (77 grains troy;) ball 0.02562 kil., (395.4 grs.;) initial velocity 398 metres, (1,306 feet.)

The Swedish powder is a sample sent by Baron Wahrendorf, the proprietor of the cannon foundry of Åker.

The particulars of the composition and mode of manufacture of most of the powders mentioned in the foregoing table were obtained from the manufacturers themselves. The composition of the samples A, B, C, and D, has been verified or corrected, and the purity of the saltpetre tested, by an analysis made for me in the course of some comparative experiments with these powders in 1838.

None of these powders have been subjected to transportation by land for any considerable distance; they are therefore generally clean and free from dust, with the exception of the *unglazed* powders which will not bear ordinary handling or sifting without creating a good deal of dust.

They have been well preserved in good dry magazines, except the samples *a* and W, which were taken from the magazine at the Little Falls of the Potomac, about six miles above Washington Arsenal. This magazine is in a low, damp situation, but it cannot be said that the powder received from it has suffered any deterioration which is apparent on mere inspection.

II. EXPERIMENTS WITH THE CANNON PENDULUM AND ITS BALLISTIC PENDULUM.

DESCRIPTION OF THE PENDULUMS.—*Plate* 11.

The order for the construction of these pendulums directed that they should be made on the plan of those recently erected at Metz, in France, of which a description, with drawings, had been procured by Messrs. E. J. Dupont & Co., of Delaware, and obligingly communicated to the Ordnance Department. This plan was accordingly followed, with some modifications in the details, most of which modifications had been suggested by experience in the use of the pendulums constructed at Metz.

Conditions to be fulfilled.

The principal conditions to be fulfilled in the arrangement of these pendulums were:

1st. That the pendulum block should be capable of sustaining, without injury, the impact of balls of large calibre, moving with great velocity; as it was proposed to use in the experiments a 24-pounder gun, with a charge of $\frac{1}{2}$ the weight of the shot, and a 32-pounder, with a charge of $\frac{1}{4}$, or even $\frac{1}{3}$.

2d. That the *core* or part of the block which receives the impact of the ball, should be susceptible of being easily and quickly renewed after each fire.

3d. That the frame of the gun pendulum should be capable of receiving guns of various calibres.

4th. That arrangements should be made in each pendulum for adjusting the height of its centre of oscillation, so as to make it coincide with that of the line of fire, in order to prevent violent shocks on the axis of motion.

5th. That the apparatus should not be liable to be affected by hygrometric changes in the atmosphere.

These conditions were fulfilled in the following manner:

The pendulum block.

The pendulum block is of cast iron, in the form of a hollow frustrum of a cone, with a hemispherical bottom. In order to give it the requisite strength, the block is closely hooped with wrought iron over all the conical part, except in the places where it is embraced by the suspension straps; for this purpose the block was first turned, and the hoops were accurately reamed in a lathe, and then shrunk on to their places, using in this operation only heat enough to set the hoops closely to the cast iron.

In order to facilitate the adjustment of the centre of oscillation of the pendulum, by throwing the weight as far as possible from the axis of motion, the block was made thicker on the lower side than on the upper, by placing the core of the hollow part above the centre of figure, thereby bringing the centre of gravity of the block 0.5 in. below its axis. This object would have been better effected by placing the axis of the core, instead of that of the exterior of the block, in the line of fire.

The opening in the face of the block is partially closed by an iron plate, which is held fast by bolts set in the block, and which serves to retain the sand used for filling the hollow of the block. In the centre of this plate is a circular opening 16 inches in diameter, through which the ball passes, and the point struck by the ball is marked by the hole made in a sheet of lead, (of about $3\frac{1}{2}$ lbs. to the square foot,) which is placed over the opening in the plate and retained by a washer, or smaller iron plate, bolted to the large one; vertical and horizontal scales, drawn on the face of the small plate, serve, by means of an easy reference, to measure the position of the point struck by the centre of the ball.

Manner of forming the core of the pendulum block.

The hemispherical bottom of the core is formed of a block of lead, which serves to counterpoise the weight of the front part of the pendulum block, and facilitates the adjustment of the axis in a horizontal position, by bringing the centre of gravity of the system nearly in the middle point between the suspension straps; this lead forms also a sort of cushion, to receive the impact of the balls, and to prevent them from striking against the cast iron, in case they should penetrate through the sand which forms the chief part of the core of the pendulum block.

The sand which receives the impact of the balls is contained in cases made of strong leather stretched over iron frames; the frame consists of two wrought iron hoops, connected together by ribs of the same material; the diameter of each hoop is 0.75 in. less than that of the core, at the place which it is to occupy; each hoop is made in three segments, and the corresponding segments of the two hoops which form one frame, are connected together, each pair, by three ribs of square iron welded to the hoops. The leather which covers these frames is brought over the outer faces of the hoops and secured there by rivets, the sections of each hoop being connected together by the leather covering only. When the sand is compressed by the ball, the case or bag expands laterally, until it is supported by the sides of the pendulum block.

The ends of these cases are closed with boards of soft wood, about $\frac{3}{8}$ in. thick; those which form the bottom, or smaller end of the case, rest on iron pins which are set on the inside of the smaller hoop; and those which form the head, or larger end, are kept in place by small nails driven into wooden plugs in holes on the inside of the large hoop.

In order to fill the case or bag, it is placed on its small end and the boards forming the bottom are laid down on the pins intended to support them; if there are any openings through which the sand might escape, they are closed with shavings, &c. The sand is then put in and settled with a small rammer, such as a piece of an implement staff; when nearly filled, the bag is placed on the platform of a balance, and its weight properly adjusted, after which the head is fastened in as before mentioned.

Four of these bags form a set for filling the pendulum block: the first or smallest one is 15 inches high; the second, 14 inches; the third and fourth, each, 12 inches; an interval of about 3 inches is thus left at the mouth of the block, which serves to admit any compensating weights that may be required to make up the proper charge. These weights are in the form of large rings, made of iron of different sizes, according to the weight required. The vacant space in the mouth of the block is requisite also for containing the sand displaced by the shot. A small portion of this sand escapes through the hole made by the ball in the sheet of lead on the face of the block.

The placing of the sand bags in the block, is facilitated by the use of a pair of large hooks, or tongs, attached to a tackle and fall, suspended from the roof of the pendulum shed and hanging just in front of the block; when not in use they are drawn aside, out of the way of the pendulum, and hung on a hook driven into the frame of the shed.

Manner of suspending the pendulum block.

The block is suspended by means of four straps of wrought iron attached to a horizontal shaft of the same material.

The shaft terminates at each end in knife edges, made of hardened steel welded to the iron. These knife edges are rounded on a radius of 0.06 in.; inside of the knife edges, the shaft has cylindrical bearings which are turned with great care; the lower lines of the knife edges are in the surface of these cylinders produced, and consequently the axes of motion, at the two extremities of the shaft, are in the same right line.

The suspension straps terminate, at their upper ends, in collars which are accurately bored to fit the cylindrical bearings on the shaft. In the lower parts of these collars are *slots*, which fit on corresponding projections on the shaft and prevent the straps from turning; the collars of the straps are also pressed firmly, by means of keys, against the shoulders of the shaft. The two inner straps, from each end of the shaft, pass to the front end of the pendulum block; the outer ones, to the rear end. The inner straps are straight, from the collars on the shaft to a point near the block where they take a direction perpendicular to the axis of the block, which they embrace between the shoulders provided for them. The outer straps are curved just below the shaft, so that at the distance of about 5 feet from the axis, the two straps from each end of the shaft are brought into the same plane, passing nearly through the axis of the block.

The work should be fitted together in such a manner that the line joining the centres of the two collars for the pendulum block, which are thus formed by the two pairs of straps, shall be in a plane perpendicular to the axis of the shaft at its middle point, and shall be also perpendicular to a plane passing through the axis of the shaft and the middle point of the line in question, which line coincides with the axis of the block. In the construction of the suspension frames, the direction of the vertical planes passing through the axes of the gun and of the pendulum block, was not perfectly accurate in either system; and in order to make these planes coincide, so that the line of fire should pass through the centre of the block, it was found necessary to adjust their direction, by inserting a washer between the collars of the straps on one end of each shaft, which had the effect of drawing the breech of the gun and of the block towards that end of the shaft.

The pair of straps which embrace the front part of the block approach, above and below the block, within 8 inches of each other, and are kept apart by iron transoms which terminate at each end in bolts that pass through the straps and are held by nuts on the outside. The other pair of straps come together within 2 inches, and the bolts which serve to press them against the block pass through the flattened heads of two large transverse bolts, the other ends of which are cut with a screw thread. The ends of these bolts pass through holes in the transoms of the front pair of straps, and the bolts have strong screw threads cut on their whole length, for a purpose which will be hereafter explained.

Between the pendulum block and the shaft, the two straps from each end of the shaft are firmly connected together by two pairs of flat braces, having shoulders which bear against the edges of the straps; the upper braces are bolted to the straps and they are connected together by a large cross bolt which passes through the middle of each; the lower braces are connected with the straps, and with each other, by means of cross bolts. All of these cross bolts have bevel washers against their shoulders inside, and under the nuts, outside of the braces.

Supports of the pendulum.

The knife edges of the shaft rest in V's formed in dies of hardened steel, which are set in cast iron seats; these seats are bolted down to large cast iron plates, resting on the tops of two stone piers to which the plates are secured by long bolts let into the stone. On the upper sides of the plates there are projecting ledges between which the seats for the V's are placed, and the position of these seats is regulated by means of wedges inserted between them and the projections on the plates. The bolt holes in the seats are made of an oblong form, in order to admit of adjustment, so that the two V's of each pair shall be in the same horizontal line, and that these lines, in the two pendulums, shall be parallel to each other.

The bottom parts of the V's are rounded on a radius of $\frac{1}{10}$th of an inch; and the inclination of the sides is so arranged, with reference to that of the planes of the knife edges, as to allow the pendulum to vibrate through an arc of 30°.

The parallelism of the two shafts is verified by means of two plumb lines, suspended to the ends of a needle attached to each shaft in a direction perpendicular to its axis. Four other plumb lines are suspended in the axis of the gun and block, (on the front and rear of each,) and when the adjustment is perfect, these eight plumb lines should hang in the same plane.

Measurement of the arc of vibration.

The vibration of the pendulum is measured on a brass limb, placed under the axis of the block and supported by wrought iron chairs set in stone posts. A slider, also of brass, moves on this limb, and is held at any point by the pressure of a light spring; the slider is moved by an index attached to a bar connected with the lower ends of the suspension straps. The limb is graduated in degrees and minutes, and the slider has a vernier which reads to two seconds. The *zero* of the arc is placed in the vertical plane passing through the axis of motion, and the face of the index is also in this plane when the axis of the block is horizontal, or situated in the line of fire. In order to have the means of verifying the adjustment of the limb, at any time, if necessary, two hollow centres are screwed into the under side of the shaft, near each end, for the purpose of suspending two plumb lines that shall hang in the vertical plane through the axis of motion.

Shed for covering the pendulum.

The whole apparatus is protected from the weather by a wooden shed, which has large openings in the sides and scuttles in the roof, to permit the escape of the smoke and to prevent injury from the blast of the gun.

Gun pendulum.

The suspension frame, the supports, and the general arrangement of the gun pendulum, are similar to those of the ballistic pendulum, and it is therefore necessary to describe only the manner of attaching the gun to the frame.

In order to provide for mounting guns of any calibre below a 32-pounder, the diameter of the circular parts of the suspension straps is sufficiently large to admit collars of cast iron which may be adapted to the gun and made to fit on the trunnions, having shoulders to receive the straps; but the 32 and 24-pounder guns, heretofore attached to the pendulum, having been made for the purpose, the projecting pieces, to form the shoulders for the straps, were cast on the guns. In order to facilitate the adjustment of the centre of oscillation of the pendulum, and also to have a gun which shall be perfectly safe to use, with any charge up to $\frac{1}{2}$ the weight of the shot, the 24-pounder has been made on the same model as the 32-pounder, and the trunnions are omitted, as the piece is designed for use with the pendulum exclusively.

When the piece is to be changed, the gun is supported by a scaffold placed under it; the bolts and keys are then loosened, and the straps detached, after which the gun is removed, another put in its place, and the straps again driven up. In replacing the straps, it is necessary that the cross bolts of the lower set of braces, and the bolts of the transoms in the front straps, should be entered at the same time; all the other parts can be put together after the straps are in place.

Adjustment of the centre of gravity and of the centre of oscillation.

The two systems being nearly symmetrical, with reference to the vertical planes through the axis of motion and the axis of the gun or block, the centre of gravity of each pendulum was found nearly in the intersection of these vertical planes, when the axis of the gun or block is horizontal; it is therefore necessary to provide only for correcting the deviations caused by variations in the charge of the gun, or of the block. For this purpose, adjusting weights are placed on the large screw bolts which connect the front and rear straps above and below the gun and the block; by sliding these weights backwards or forwards, the position of the vertical line containing the centre of gravity is easily adjusted. These weights effect another very important purpose, in the adjustment of the centre of oscillation of the system, so as to make it coincide with the axis of the gun or block.

The weight of the gun and block being very great, in comparison with that of the suspension frame, the centres of oscillation were found to be nearly at the proper height, and the adjustment of them was readily effected by placing weights on the lower screw bolt, which has the effect of lowering the centre of oscillation; the upper screw bolt would be made use of in the same manner, in case the centre of oscillation should be found, by any change of circumstances, to be too low. These screw bolts are flattened, or planed off, at the sides, in order to allow the weights to slide on them more readily. The weights are cylinders of various heights, having slits of the thickness of the screw bolt, to facilitate placing and removing them. The slits are lined with thick sheet iron to prevent the weight from being cut by the screw, and the height of the slit is so regulated (for convenience in calculation) as to bring the centre of gravity of the weight in the axis of the bolt on which it rests. The weights are made of lead, with about 6 per cent. of tin; they are moved on the bolt, and are also held in place when set, by means of large nuts with handles, of which there are two on each bolt. To prevent these nuts from being pressed into the weights by their reaction in the recoil of the pendulum, broad iron washers are placed between the weights and the nuts, and the front weight for each pendulum is made of a shell of cast iron $\frac{1}{2}$ inch thick, filled with lead.

Weight of the pendulums.

Before the frames were put together, the weights of the several parts, and also of the gun and block, were carefully determined and verified by means of different balances; and the weight of each system was thus ascertained to be as follows:

	lbs.
Weight of the 4 straps of the gun frame -	481; $479\frac{1}{2}$; $489\frac{1}{2}$; $483\frac{1}{2}$.
" shaft of do. - -	403
" of 4 straps of the pendulum block frame	500; $496\frac{1}{4}$; $492\frac{1}{4}$; 491.
" of the shaft of do. do. -	395
" gun frame complete - - -	2,811
" 32-pounder gun - - - -	7,689
Total of gun pendulum -	10,500
" ballistic pendulum frame complete -	2,847
" pendulum block, (empty) - -	6,368
" face plates and bolts for do. -	143
Total ballistic pendulum -	9,358

Position of the centres of gravity of the pendulums.

The position of the centre of gravity of each system was determined by balancing the frame complete on the edge of a square steel bar, placed parallel to the axis of the shaft. The place of the centre of gravity of the gun and the block being known, that of the whole system is easily calculated.

The results of this calculation were verified by actually balancing, in a horizontal position, the whole pendulum, with the gun and block in place; and the two operations were performed at different places and by different persons:

	Gun.	Block.
	Inches.	Inches.
Distance from the axis of motion to the centre of gravity of the frame - - - - - -	112.8	114.13
Distance to the centre of gravity of the gun or pendulum block, (empty) - - - - -	195	195.5
Distance to centre of gravity of the system (by calculation) $\frac{112.8 \times 2{,}811 + 195 \times 7{,}689}{10{,}500}$ - - - =	172.994	
$\frac{2{,}847 \times 114.13 + 6{,}368 \times 195.5 + 143 \times 195}{9{,}358}$ - =	-	170.737
Distance to centre of gravity of the system, by trial -	172.8	170 8
Do. mean; taken as the true distance - -	172.9	170.8

The height of the centre of gravity of each pendulum in this condition being known, it is easy to make the necessary correction for the addition of the adjusting weights, and for the weight of the core of the block. For this purpose it is sufficient to observe that the centre of gravity of the adjusting weights, being in the axis of the lower screw bolts, is, in the gun pendulum, at 215 inches from the axis of motion, and in the ballistic pendulum, at 219 in. The centre of gravity of the hemisphere of lead in the bottom of the pendulum block is in the axis of the block, or 195 in. from the axis of motion; and that of the conical part of the core is 0.66 in. above the the axis of the block, or 194.34 in. from the axis of motion.

In the gun pendulum, when adjusted for use with the 32-pounder gun, a weight of 667 lbs. was placed on the lower screw bolt.

In the ballistic pendulum there were:

	lbs.
a hemisphere of lead in the block, weighing -	$626\frac{1}{2}$
an oak board over the lead - - -	$9\frac{1}{2}$
a sheet of lead on the face - - -	8
4 sand bags - - - - -	965
adjusting weights on the lower screw bolt -	789

Under these circumstances, the distance of the centre of gravity of the gun pendulum from the axis, is

$$\frac{10,500\times 172.9+667\times 215}{11,167}=\frac{1,958,963}{11,167}=175.41 \text{ in.}$$

and that of the centre of gravity of the ballistic pendulum,

$$\frac{9,358\times 170.8+643\times 195+975\times 194.34+789\times 219}{11,756 \text{ lbs.}}=\frac{2,084,162.5}{11,756}=177.29 \text{ in.}$$

The results of these calculations and measurements may be at any time verified, and in case of a change in the pendulums, they may be corrected, by practically ascertaining the moment of the system, *i. e.* the product of the weight into the distance of its centre of gravity from the axis of motion; and this moment is a factor which enters into the formula for the computation of the initial velocity of the ball. To ascertain the moment of the pendulum without dismounting it, it is sufficient to determine by trial the weight which, acting at a given distance from the axis, will sustain the system, out of a vertical position, at such an angle that the direction in which this weight acts shall be perpendicular to the line drawn from the centre of the axis of motion to the centre of gravity of the system. If a be the angle which this latter line then makes with the vertical; w the weight which balances the system, and d the distance at which it acts from the centre of motion, then will the moment of the pendulum be:

$$\frac{w\,d}{\sin. a}=p\,g$$

Position of the centre of oscillation.

The lengths of pendulums being to each other as the squares of the times of ibration, or vinversely as the squares of the number of vibrations in a given time, the distance of the centre of oscillation from the axis of motion is determined by observing the number of vibrations made by the pendulum in any given time, or the number of seconds required for a given number of vibrations of the pendulum.

In the present instance this was determined by observing, with a chronometer which beats half seconds, the time required for 500 vibrations of the pendulum, commencing in an arc of about one degree and a half. The length of the seconds pendulum at Washington, (latitude 38° 53′ 23″,) being 39.1 in., the distance of the centre of oscillation of a pendulum vibrating 500 times in n seconds, will be

$$L = \frac{n^2 \times 39.1}{500^2}$$

and in order that L shall be equal to 195 in., or that the centre of oscillation shall be in the line of fire of the pendulum gun, n must be $=$ 1,116.5 seconds.

In the gun pendulum, this adjustment of the time of vibration is effected by placing an additional weight of 667 lbs. on the lower screw bolt, as above mentioned in ascertaining the position of the centre of gravity. In the ballistic pendulum, when ready for use and loaded as above stated, the time required for 500 vibrations is 1,116 seconds, and the position of the centre of oscillation is at 194.8 in. from the axis.

When the position o' of the centre of oscillation is accurately ascertained, for any given condition of the system, the additional weight W, requisite to bring that centre into any other position, o may be computed very nearly by the formula

$$W = \frac{p\,g\,(o - o')}{d\,(d - o)}$$

$p\,g$ being the actual moment of the pendulum, and d the distance of the additional weight from the axis of motion.

In consequence of the lightness of the frames, in proportion to the whole weight of the pendulums, they are found to possess a great degree of sensibility; when vibrating in an arc of 14°, they lose about 36″ in one vibration; in an arc of 4°, about 25″. When set in motion in an arc of 12°, the gun pendulum continued to vibrate about 24 hours, and the pendulum block (empty) about 30 hours.

Distance between the pendulums.

In order to ascertain the least distance at which the pendulum could be placed from the gun without being too much affected by the blast, a rude experiment was made by suspending a 24-pounder gun to a rod 20 feet long, and attaching to the muzzle of the gun a disc 34 inches in diameter. Against this disc, blank cartridges were fired from a 32-pounder gun; a screen, with a hole of 12 inches diameter, being interposed between the gun and the disc. In this manner it was ascertained that, at the distance of 48 feet from the muzzle of the gun, the pendulum would be but slightly affected by the blast, and it was therefore determined to place the axes of the two pendulums 55 feet apart.

In order to intercept the blast of the gun as much as possible, a fixed screen of 2 in. oak plank is placed 17 feet in front of the face of the pendulum block, having a hole in it 12 inches diameter for the passage of the ball. The protection afforded by this screen is such, that with a blank charge of $\frac{1}{3}$ from the 32-pounder gun, the vibration of the pendulum block does not exceed 45″; which vibration, if produced by the impact of a ball, would require a velocity of only 0.85 ft.

The penetration of the 32-pounder balls, in the sand of the pendulum block, is about 4 feet. It is found that, in consequence of the great and sudden compression of the sand, produced by balls moving with great velocities, the penetration does not increase with the charge; but the pressure against the sides and bottom of the block is necessarily greater with higher charges, and under these circumstances, the mass of lead in the bottom of the block is so much compressed and battered as to make it inexpedient to fire with high charges ($\frac{1}{4}$ or $\frac{1}{3}$) from the 32-pounder gun, without filling the block with some material affording a greater resistance than sand.

SERVICE OF THE PENDULUMS.

Open all the doors and windows of the sheds, and fasten them back; observe whether the nuts of the several connecting bolts are screwed up tight, and whether the shoulders of the knife edges swing clear of the seats. Wipe out the V's and oil them with a small quantity of clear oil.

1*st. The ballistic pendulum.*

Load the pendulum block with the sand bags, driving them in with handspikes, so as to make them bear on each other; put on the face plates with the sheet of lead previously adjusted between them.

Adjust, if requisite, the position of the centre of oscillation of the pendulum, and in order to maintain this adjustment, let the sand bags be always filled to the same weight as at first. If this cannot be done, make up the correct total weight by placing some of the iron rings within the mouth of the block.

Wipe the graduated arc and move the adjusting weights on the lower screw bolt, so that, the pendulum being at rest, its index shall be in contact with the slider when the latter stands at *zero*; in this position the axis of the block is horizontal: see that the nuts on the screw bolts are set firmly against the adjusting weights.

After the gun is fired, two men stop the vibrations of the pendulum block, checking them gradually with the hand, (or with a rope thrown over the breech,) and taking care not to displace the slider on the arc.

Note the arc of vibration.

Bring up a truck cart under the mouth of the block to receive the sand when it is withdrawn. Take off the face plates and ascertain the position of the point struck by the centre of the ball, by referring the extremities of the vertical diameter of the hole made by the ball to the graduated scales on the outer plate. If necessary, note also the lateral deviation of the shot. Withdraw the sand and the ball, &c.; clean out the block with the rake and brush provided for the purpose, and take the sand, with the bags, to the filling shed.

2nd. The gun pendulum.

The centre of oscillation is supposed to have been properly adjusted.

Wipe out the gun, insert the cartridge, push it home with the rammer, and measure the length which it occupies in the bore by means of the graduated brass scale set in the rammer staff for that purpose; insert the shot, ram it home and measure in the same manner the height of the whole charge; prick the cartridge, and prime with a tube having a short piece of quick match inserted in the cup, in order to give time for withdrawing the linstock before the gun recoils. A quill or paper tube is preferable for priming with, as the metal tubes are driven with considerable force against the sides, or the roof, of the shed.

Wipe the graduated arc and adjust the index of the pendulum as before, taking care that the nuts on the screw bolt are set firmly against the adjusting weights.

Before giving the order to fire, be sure that both pendulums are at rest and in their true positions.

After the discharge, note the arc of recoil.

Two men stop the vibrations of the pendulum by throwing a rope over the breech of the gun against the suspension frame; in this manner they are less apt to twist the frame than when acting directly with the hands against the gun. Clean out the gun and prepare for another charge. During the firings the pendulums should be carefully observed to see if any derangement occurs in the position of the shafts in their V's, or in the stability of the frames, the tightness of the nuts, &c.

Nine men are required for the regular service of the pendulums, *viz:* two at the gun, who also have time to assist in charging the pendulum block; three at the pendulum block; and four to fill and wheel the sand bags. With this number of men the 32-pounder gun can be fired at the rate of about 4 rounds an hour.

Position of the pendulums.

The place occupied by the pendulums, and the direction of the line of fire, are shown in the sketch of the Arsenal grounds represented in Plate 1.

The axis of the gun is situated 17.06 feet above the surface of the wharf which is crossed by the line of fire, and on which a target was erected for some preliminary experiments. The surface of the wharf is about 8 feet above the level of ordinary low water in the river.

FORMULÆ FOR COMPUTING THE VELOCITY OF THE BALL FROM THE RECOIL OF THE PENDULUMS.

1. *By the ballistic pendulum.*

The formula for the velocity with which the ball strikes the pendulum block is:

$$v = \frac{2 \sin. \tfrac{1}{2} A \sqrt{(pgo + bi^2)(pg + bi)G}}{bi}$$

where v is the required velocity of the ball in a second;

p the weight of the pendulum;

g the distance of its centre of gravity
o the distance of its centre of oscillation
i the distance of the point of impact
} from the axis of motion;

b the weight of the ball;

A the angle of first vibration of the pendulum;

G the measure of the force of gravity, $= 32.155$ ft., at Washington.

The demonstration of the correctness of this formula is given by Hutton in his Mathematical Tracts, (34th Tract,) and is to be found also in many of the elementary works on Mechanics. It is here repeated for the satisfaction of those who may not have such works at hand for reference.

The weight of the ball being represented by b, its mass or quantity of matter is $\frac{b}{G}$ and its quantity of motion before the impact is $\frac{b\,v}{G}$.

The moment of this quantity of motion, with reference to the axis of suspension of the pendulum, is $\frac{b\,v\,i}{G}$.

The quantity of motion communicated to an element $d\,m$ of the mass of the pendulum, situated at a distance r from the axis of motion, is $V\,r\,d\,m$, V being the angular velocity of the pendulum after the impact. The moment of this quantity of motion with reference to the axis is $V\,r^2\,d\,m$, and the sum of all such moments, or the moment of the pendulum, is $V\int r^2\,d\,m$, which is $= \frac{V\,p\,g\,o}{G}$, since $o = \frac{G\int r^2\,d\,m}{p\,g}$.

After the impact, the ball partakes of the motion of the pendulum; its quantity of motion is therefore $\frac{b\,V\,i}{G}$, and its moment with reference to the axis is $\frac{b\,V\,i^2}{G}$. Hence the sum of the moments after the impact is $\frac{V}{G}(p\,g\,o + b\,i^2)$, and this being equal to the moment of the quantity of motion of the ball before the impact, we have:

$$\frac{b\,v\,i}{G} = \frac{V\,(p\,g\,o + b\,i^2)}{G};$$

consequently $V = \frac{b\,v\,i}{p\,g\,o + b\,i^2}$ - - - (1)

Again, in the recoil of the pendulum, its centre of gravity rises through the height of the versed sine of the angle of vibration, which is represented by

$$g - g \cos. A = g\,(1 - \cos. A) = 2\,g \sin.^2 \tfrac{1}{2} A;$$

also, the ball at the distance i from the axis rises through the height $i - i \cos. A = 2 i \sin.^2 \frac{1}{2} A$. Hence the quantity of action exerted by the force of gravity on the pendulum and the ball united, during the recoil, is

$$2 \sin.^2 \tfrac{1}{2} A \frac{(p\,g + b\,i)\,G}{G} = 2 \sin.^2 \tfrac{1}{2} A\,(p\,g + b\,i);$$

but the living force of the system is $\frac{V^2\,(p\,g\,o + b\,i^2)}{G}$, and this force being double the quantity of action, we have:

$$\frac{V^2\,(p\,g\,o + b\,i^2)}{G} = 4 \sin.^2 \tfrac{1}{2} A\,(p\,g + b\,i);$$

whence, $v = 2 \sin. \frac{1}{2} A \sqrt{\frac{(p\,g + b\,i)\,G}{p\,g\,o + b\,i^2}}$.

Substituting this value for V in the equation (1) it becomes:

$$\frac{b\,v\,i}{p\,g\,o + b\,i^2} = 2 \sin. \tfrac{1}{2} A \sqrt{\frac{(p\,g + b\,i)\,G}{p\,g\,o + b\,i^2}}.$$

Therefore, $v = 2 \sin. \frac{1}{2} A \frac{\sqrt{(p\,g\,o + b\,i^2)\,(p\,g + b\,i)\,G}}{b\,i}$, as above.

In our pendulums the axis of the gun and that of the pendulum block are adjusted on the same horizontal line, when the pendulums are at rest; therefore the ball strikes very near to the axis of the block, and in order to prevent any shock on the axis of suspension, the centre of oscillation of the system is made to coincide also very nearly with the axis of the pendulum block, and this adjustment is maintained by renewing the core of the block and restoring the pendulum after each shot to its original condition; hence the values of o and i in the above formula are very nearly equal, and the quantity $p\,g$ being very great in comparison with $b\,i$, no sensible error will be caused by assuming $i = o$ in the first term under the radical sign; the formula then becomes

$$v = 2 \sin. \tfrac{1}{2} A \frac{(p\,g + b\,i)\sqrt{G\,o}}{b\,i}$$

Moreover, in practice with balls of the same kind and calibre, the variations in the value of b are confined within narrow limits. On this account, and in consideration of the great inequality between the terms $p\,g$ and $b\,i$, we may, in the case just mentioned, assign to $b\,i$, in the numerator of the above expression, a constant value equal to the mean weight of the balls multiplied by the mean distances of the points struck from the axis of suspension. By this assumption the whole term $(p\,g + b\,i)\sqrt{G\,o}$ becomes constant for one set of experiments, and the formula is perfectly adapted to logarithmic computation.

In making the calculations of the velocity for a case of extreme variation in the value of $b\,i$, it was found that the error produced by the above transformation of the formula, and by assuming a constant mean value for $p\,g + b\,i$, did not exceed $\frac{4}{10}$ths of a foot, in a velocity of 1,350 feet; and in ordinary cases the error is so small that it may safely be disregarded.

Since $2 \sin. \frac{1}{2} A =$ chord of A, it is obvious from the formula, that, all other circumstances being equal, the velocity of the ball is proportional to the chord of the arc of vibration of the pendulum.

2. *Computation of the velocity of the ball by the recoil of the gun pendulum.*

For the formula for this purpose, I am indebted to the Report of experiments on gunpowder at Metz, heretofore mentioned. The formula is:

$$v' = \frac{2 \sin. \frac{1}{2} A' \frac{p' g' \sqrt{G o'}}{i'} - c N}{b' \frac{D^2}{d^2} + \frac{c'}{2}} \text{; in which}$$

v' is the required initial velocity of the ball;
p' the weight of the gun pendulum;
g' the distance of its centre of gravity
o' the distance of its centre of oscillation
i' the distance of the axis of the gun } from the axis of suspension;
A' the angle of vibration of the pendulum;
b' the weight of the ball and wad;
D the diameter of the bore of the gun;
d the diameter of the ball;
c the weight of the charge of powder;
c' the weight of the cartridge, including the bag;
G the force of gravity $= 32.155$ ft.;
N a constant factor, of the same kind as g', G, &c., to be determined by experiment.

This formula may be deduced thus:

Denoting by V' the angular velocity of the gun pendulum, the moment of its quantity of motion is, as in the ballistic pendulum, $\frac{V' p' g' o'}{G}$; also, the quantity of action of gravity, during the recoil of the pendulum, is $= 2 \sin.^2 \frac{1}{2} A' \times p' g'$, and the living force is $V'^2 \frac{p' g' o'}{G} = 4 \sin.^2 \frac{1}{2} A' \times p' g'$;

therefore, $$V' = 2 \sin. \frac{1}{2} A' \sqrt{\frac{G}{o'}}.$$

Substituting this value of V' in the expression for the moment of the quantity of motion of the pendulum, it becomes

$$2 \text{ sin. } \tfrac{1}{2} A' p' g' \sqrt{\frac{o'}{G}}.$$

As the ball and wad together leave the muzzle of the gun with the velocity v', their quantity of motion is $\frac{b'v'}{G}$; but the expansive force of the fired gunpowder, which produces this quantity of motion, may be considered as acting on a surface equal to the area of a great circle of the ball, whilst it reacts on the gun pendulum (so far as respects its recoil) on a surface equal to that of the cross section of the bore. Its action on the pendulum will therefore be greater than that on the ball, in proportion as the area of the bore is greater than that of the ball, or in other words, in the proportion of the square of the diameter of the bore to the square of the diameter of the ball. The quantity of motion of the pendulum from this cause will therefore be $\frac{b'v'}{G} \times \frac{D^2}{d^2}$, and its moment with reference to the axis of suspension is $\frac{b'v'i'}{G} \times \frac{D^2}{d^2}$.

Again, on the supposition that all the gaseous fluid produced by the inflammation of the charge of powder occupies the space in the bore behind the ball, we may assume, with Hutton, (Problem 19; 37th Tract,) that the mean velocity of the fluid at the moment that the ball leaves the gun is half that of the ball, or $\frac{1}{2} v'$; and on the hypothesis that the charge is not too great to become wholly inflamed in the bore of the gun, the weight of the elastic gas is the same as that of the charge. The greater part of the cartridge bag being also expelled from the gun, I have supposed one-half of it to partake of the velocity of the ball, or the whole of it to move with half the velocity of the ball, and its weight is therefore included with that of the charge of powder in the quantity c'. The quantity of motion of the inflamed powder is therefore represented by $\frac{1}{2} v' \frac{c'}{G}$, and its moment, with reference to the axis of suspension, is $\frac{1}{2} v' i' \frac{c'}{G}$. Moreover, after the ball has left the gun, this elastic fluid continues to expand, and, in consequence of the resistance of the air, to react on the pendulum and increase its recoil. It is difficult to assign a value for the quantity of motion produced by this cause, but it may be considered proportional to the quantity of powder in the charge, and it may therefore be approximately represented by the factor $\frac{c\,N}{G}$; N being a constant linear quantity representing the velocity communicated to the pendulum by a unit of the charge c. The moment of the quantity of motion produced by this action of the charge is therefore $\frac{c\,N i'}{G}$, the resultant of all of these forces being supposed to coincide with the axis of the gun.

The sum of all the moments resulting from the action of the charge is therefore

$$\frac{b' v' i'}{G} \cdot \frac{D^2}{d^2} + \tfrac{1}{2} v' i' \frac{c'}{G} + \frac{c\,N i'}{G} = 2 \sin. \tfrac{1}{2} A' p' g' \sqrt{\frac{o'}{G}};$$

the second member of the equation being the moment of the pendulum before obtained from its recoil.

$$\text{Hence, } v = \frac{2 \sin. \frac{1}{2} A' \dfrac{p' g' \sqrt{G o'}}{i'} - c\,N}{b' \dfrac{D^2}{d^2} + \dfrac{c'}{2}} \text{ as above stated.}$$

There are obvious causes of error and uncertainty which may prevent the results of this calculation of the velocity from coinciding in all cases with those obtained by means of the ballistic pendulum, even after allowance is made for the loss of velocity occasioned by the resistance of the air whilst the ball is passing from the gun to the pendulum block. The principal one of these causes is the uncertainty of the value $\frac{1}{2}v'$, assumed for the mean velocity of the inflamed gunpowder in the bore of the gun. It is certain also that a considerable portion of the elastic fluid escapes through the windage of the ball, and therefore the mass of fluid behind the ball is less than that of the charge of powder; but this loss of fluid is in some measure compensated by the greater velocity of the part which passes by the ball. The effect now under consideration must likewise be modified by the quality of the gunpowder and the quantity of the charge, even within the usual limits of practice, and these circumstances probably exert a still greater influence on the value of the quantity N in the term $c\,N$. In the French Report, from which the formula was obtained, the value of 420 metres (or 1,400 feet) is assigned to N, but I have found that the results of my experiments with the 32-pounder and 24-pounder guns, are more accurately represented by giving to N a mean value of 1,600 ft., and it is with this value that the formula has been used in the calculations of those experiments. It will be seen hereafter that the same value of N does not appear to apply equally well to the computation of the velocities of balls of very small calibre, and this result might have been anticipated; for the intensity of the heat, and consequently the elastic force of the fluid, generated by the combustion of the charge, probably increase in a greater proportion than the direct ratio of the quantity of powder, and the value of N must therefore vary with the charge of powder, and also with the length and calibre of the gun and the density of the ball. However, as in ordinary practice with the cannon pendulum, the variations in the value of N cannot be great, and as the quantity $c\,N$ is much smaller in value than the other term in the numerator of the formula for the velocity, no considerable error arises from assigning to that co-efficient a constant mean value, as above stated. Accordingly it will be seen, that there is, in most cases, a remarkable coincidence in the velocities of the ball as indicated by the two pendulums.

In order to facilitate the verification (and perhaps the improvement) of the accuracy of this formula, I have given in each experiment, under the head of *Moment of the gun pendulum*, the value of the term

$$2 \sin. \tfrac{1}{2} A' \frac{p' g' \sqrt{G o'}}{i'} = 2 \sin. \tfrac{1}{2} A' p' g' \sqrt{\frac{G}{i'}};$$

since, by the adjustment of the centre of oscillation in the axis of the gun, $o' = i'$. We must not, however, regard this quantity as a measure of the relative force of recoil, without taking into consideration the weight and windage of the ball, as well as the weight of the charge of powder.

With regard to the measurement of the angles of vibration of the pendulums, it may here be remarked that, in conformity with the practice of Hutton and others who have conducted similar experiments, I denote by A and A' the arcs of vibration indicated by the position of the slider on the graduated limb of the instrument, although strictly speaking these angles would seem to require correction; for the ball lying in the gun in rear of the vertical plane passing through the axis of suspension of the gun pendulum, and being deposited, after the discharge, in a similar position with regard to the vertical plane through the axis of the ballistic pendulum, it follows that the recoil of the former pendulum is accelerated and that of the latter retarded, in consequence of the change in the place of the ball, and that the observed angle of vibration should therefore be diminished in the former case and increased in the latter, in order to obtain the true arc of recoil. This correction would, however, be very inconsiderable, and it is also difficult to note with accuracy, in consequence of a slight movement of the adjusting weights on the pendulums, which it is almost impossible to prevent, and which alone often produces a greater change in the position of the centre of gravity of the system than that caused by the displacement of the ball.

This source of error is pointed out by M. Maguin in his notice of the pendulums constructed at Esquerdes.*

MANNER OF LOADING THE GUN.

Of the balls.

The shot and shells used in these experiments were selected in the first place by means of the large shot gauge of the calibre, and an intermediate gauge between that and the small gauge; that is to say, the diameters of the balls were:

For the 32-pounder gun, between 6.235 in. and 6.27 in.; and for the 24-pounder gun, between 5.66 in. and 5.70 in.

The exact diameter of each ball was determined by means of other intermediate gauges differing so little from each other as to make the possible error of measurement very small.

It was intended to use no shot of less weight than the nominal calibre of the gun, but in selecting those of a suitable diameter it became necessary to make use of a few that were under that weight.

With the exception of some of the first 32-pounder shot, those used in the experiments were hammered shot, sufficiently smooth and nearly spherical. Each shot was floated in mer-

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* In the manuscript copy of the French Report from which I derived the formula for the velocity of the ball by the recoil of the gun pendulum, there occurred an error of the transcriber, for the detection of which and also for the investigation of the formula itself, I am indebted to my friend Professor Ed. H. Courtenay, of the University of Virginia, a graduate of the U. S. Military Academy.

cury, and the upper extremity of the axis passing through its centre of gravity was marked with a centre punch. This point was determined by suspending over the ball a plummet, at the bottom part of which is a horizontal disk; the under surface of this disk being covered with paint, its point of contact with the ball when at rest in the mercury is easily marked. For the sake of brevity, the axis of the ball which passes through the centre of gravity will be designated as the *principal axis.*

Of the wads.

The wads ordinarily used in the experiments are *grommets*, or rings formed of a single strand of packing yarn, about $\frac{1}{2}$ in. thick, such as is used for the packing of pistons in machinery; this yarn is soft and very slightly twisted. The diameter of the grommet is a little less than that of the ball, to which it is attached by four leather straps about $\frac{3}{8}$ in. wide, each pair crossing the other at right angles and being tied on the ball with twine strings; the grommet has also a cross of twine to assist in placing it and to preserve its form. The thickness of the leather straps is nearly equal to half the windage of the ball. The average weight of a grommet with straps is, for the 32-pounder ball, 0.1 lb.; for the 24-pounder, 0.08 lb. They were made as light as possible, being intended only to retain the ball in its proper position in the gun and to prevent it from rolling forward.

The grommet is placed on the lighter hemisphere of the ball, in a direction perpendicular to its principal axis.

Of the cartridges.

The cartridge bags are made of closely woven twilled woollen stuff; they are cut with a circular bottom like those for field service, and are sewed on a cylindrical former of the regulation size, the diameter of the former being for the 32-pounder gun 5.9 in., and for the 24-pounder 5.35 in.

The charge of powder was settled in the usual manner in the bag, which was then tied down close to the powder, and the superfluous part cut off to a uniform length. The weight of the cartridge was then again ascertained by weighing together several (3 or 4) of those of the same kind. The accuracy of these weighings is demonstrated by the regularity in the excess of the weight of the cartridge over that of the powder, and even by the apparent anomalies in the weights of cartridges containing the same quantity of powders of different densities. In some cases the variations in the weights of similar cartridges are due to differences in the thickness of the material, which being procured at different times, was not perfectly uniform in quality.

The cartridges were generally filled on the day on which they were used, or on the day before, and they were kept in budge barrels, in the magazine or in the laboratory, until required for use.

The balance with which the balls and cartridges are weighed is a small French platform balance, (of the capacity of 100 lbs.,) in which the proportion of the weight on the platform to that in the scale pan is 10 to 1. A set of weights consisting of pounds and decimal parts of a pound, down to $\frac{1}{10000}$ lb., was used for this balance, and the results are expressed accordingly in decimals, instead of being given in the usual divisions of the pound. This arrangement facilitates both the operation of weighing and the calculations.

Of the manner of loading.

The cartridge being inserted, it is pressed firmly with the rammer against the bottom of the bore, and its height is measured by means of the graduation on the rammer staff. The ball is then placed with one of the leather straps resting on the lower side of the bore, the grommet outside, so that the heavier hemisphere of the ball is next to the powder. The leather straps are designed not only to retain the grommet, but also to support the ball nearly in the centre of the bore, so that its principal axis may coincide with the axis of the gun. It was hoped by this arrangement to remove one cause of irregularity in the motion of the ball as it passes out of the gun, and from the accuracy of direction of the shot and the smoothness of the bore, after firing a considerable number of rounds, there is reason to believe that the object was in a great measure accomplished.

In order to prevent the ball from being detached from the grommet, it was found necessary to push it to its place with the end of the rammer staff, which, acting below the centre of gravity of the ball, causes it to slide on the bottom of the bore instead of rolling; the rammer being then turned, the height of the whole charge is measured. The difference between the height of the cartridge and that of the whole charge is less than the diameter of the ball, because the centre of the ball lies above the neck of the cartridge, and consequently the bottom of the ball passes beyond the tie of the cartridge and rests against the powder.

After the discharge the gun is cleaned with a cylindrical brush made of stiff bristles, and then wiped out with a common woollen sponge. The gun is washed after each series of rounds with the same powder, (generally after 3 rounds,) and is then wiped with a dry sponge.

Note.—I may here mention some circumstances observed on the impact of the ball against the face of the pendulum block:

1. The lead displaced by the ball in passing through the sheet of lead on the face of the block, is not all carried before the ball into the core of the block; a very considerable part of it is expelled laterally in the direction, as it were, of the surface of a cone whose apex is the centre of the hole made by the ball. The fragments thus expelled are traced very distinctly on the inner faces of the stone piers and on the floor and sides of the shed which covers the pendulum.

2. The hole made by the ball in the sheet of lead is considerably larger than the ball, being with the 32-pounder ball about 6.7 in. in diameter, and with the 24-pounder about 6 in. These are well known effects of the penetration of cannon balls in solid substances.

3. An observer placed in such a position as to see the face of the block unobscured by the smoke of the gun, perceives, at the moment of impact, a circle of *reddish white flame* surrounding the hole made by the ball. Having observed the same effect to be produced in firing through a sheet of lead placed in a frame, in the open air, at 50 feet from the muzzle of a 24-pounder gun, I have supposed that this flame may be produced by the combustion of minute particles of iron and lead ignited by friction. The edges of the hole in the sheet lead have a smooth surface, which may, however, be an entirely mechanical effect of the passage of the ball through the lead.

4. In firing a 32-pounder ball into the pendulum block with a charge of 8 lbs., the sand immediately before the ball was compressed into a solid mass, forming an imperfect sandstone sufficiently firm to bear handling. A specimen is still preserved in that state after a lapse of more than eighteen months. This sand, when tested with an acid, was found perfectly free from any calcareous cement.

JOURNAL.

March 29th, 1843.

The gun pendulum, with the 32-pounder gun mounted, was to-day adjusted with sufficient accuracy to permit of making some preliminary firings for the purpose of testing the stability of the apparatus and the accuracy of direction of the shot.

The 32-pounder pendulum gun is of cast iron, made on the same model as the ordinary sea-coast gun, except in having (as before mentioned) shoulders for the suspension straps cast on it.

The length of bore is - - -	107.6 inches.
Mean diameter of bore - - -	6.43 "
Diameter of the vent - - -	0.175 "

The pendulum block not being yet suspended, a frame was placed in the centre of the pendulum house, having attached to it a sheet of lead on which were traced vertical and horizontal lines intersecting each other in the prolongation of the line which ought to coincide with the axis of the gun. Three blank charges of $\frac{1}{8}$, $\frac{1}{4}$ and $\frac{1}{3}$ the weight of the shot were fired, and then two charges of $\frac{1}{8}$ with balls.

The pendulum frame appeared to have sufficient strength and stiffness, no straining or loosening of the bolts being perceptible; but the gun turned in its collars about 0.5 in. to the left, (measured on the outside of the collars,) in consequence of the straps not being fitted perfectly square to the shoulders against which they rested; some of the boards of the covering shed were started by the concussion.

The first ball passed through the sheet of lead 0.75 in. and the second 0.5 in. to the right of the centre, thus confirming the indications of an error in the direction of the axis of the gun with reference to that of the shaft of the pendulum. The lead was about 0.08 in. thick, or 4 lbs. to the foot, which was too thick for the purpose, the fragments being driven in some instances through the sides of the shed, although these are of $1\frac{1}{4}$-inch yellow pine boards.

March 31st, 1843.

After several ineffectual attempts to correct the direction of the axis of the gun, by twisting the straps of the suspension frame, the object was effected with ease and accuracy by inserting a washer between the collars of the straps at the right end of the shaft, which has the effect of shortening the outer strap and drawing the breech of the gun towards that end.

April 7th to 17th, 1843.

The position of the gun pendulum furnishing a favorable opportunity of comparing the actual ranges of balls projected with different velocities, with the results obtained by computation from the formulæ for the trajectory at low angles, it was thought expedient to combine this object with that of fully testing the strength of the apparatus, before erecting the ballistic pendulum.

In order to determine the co-ordinates of one point in the trajectory, a target of white pine boards, one inch thick, was erected on the wharf which is crossed by the line of fire of the gun.—(See PLATE 1.) The true direction of the axis of the gun being marked on this target, and its height above the wharf being known, the position of the point struck was readily determined; the target was 1,098 feet from the muzzle of the gun. To obtain another point in the trajectory, a base line was established, as shown in the plate, and an observer stationed at the lower extremity of this base, ascertained with a theodolite the angle with the base, which was made by a line drawn to the first graze of the ball on the water; this could be observed by means of the column of spray thrown up by the ball. The angle at the other end of the base, made by the line of fire, was corrected by means of the lateral deviation of the ball measured on the target at the wharf, the direction of the ball being supposed to remain nearly the same until it struck the water. The height of the tide was noted at intervals during the experiments.

The grommet wads used for these experiments were made of three turns of packing yarn, and were consequently heavier than those generally used. It was intended to place them next to the powder, and they were therefore attached to the heavier side of the ball; but when the gun became a little foul, the grommet was caught under the ball, and it was found necessary to facilitate the loading by placing the grommet outside, so that after the fourth round the ball was inserted with the lighter hemisphere next the powder. The straps which held the grommets were in this case cemented to the ball and could not conveniently be removed.

It did not occur to me to make use of these experiments (as was subsequently done) for verifying Lombard's method of determining the initial velocity of a ball by means of two points of the trajectory, one of them being near the gun. The direction of the ball in passing through the house for the pendulum block was therefore observed only to ascertain that it was nearly accurate, and the deviations from the axis were not particularly noted.

The tendency of the gun to turn in its collars was prevented by filling up with strips of sheet iron the openings between the collars and the shoulders on the gun. The suspension frame was fully proved in these trials to possess the requisite strength and stiffness.

Sheet brass had been used for lining the slits in the adjusting weights, by which they were slipped on the screw bolt, but it was found necessary, in consequence of the lead and brass becoming *upset* by the inertia of the weight, to substitute a stouter lining of sheet iron.

The shed over the gun pendulum was somewhat injured by the concussion, and it became necessary to strengthen it by bolting iron straps on the outside, through the timbers of the frame, in several places. Additional windows were also opened in the right and left sides of the shed.

The adjusting weight on the lower screw bolt of the gun frame during these first experiments, was 502 lbs.; and it was found that 500 vibrations of the pendulum were made in 1,114$\frac{1}{4}$ seconds, which gives 194.18 in. for the distance of the centre of oscillation from the axis of suspension.

With the hope of correcting the anomalies observed in the experiments of the 7th, some of them were repeated on the 17th. The results of both days' work are presented in the following table.

In the intervening ten days the suspension frame for the pendulum block had been put together and raised to its place, but without attaching the block to it. The balls were therefore fired through the collars of the suspension straps, where their direction was marked by their passage through sheets of lead; but in consequence of the lead being too thin, (1$\frac{3}{4}$ lbs. to the square foot,) the hole made by the ball was not well defined.

In the experiments on the 17th, a self-registering thermometer was inserted in the bore of the gun, about 5 in. from the bottom, before and after the discharge; but the variations of temperature were found to be altogether inconsiderable, the thermometer standing at about 77° after the first discharge.

The balls were strapped with grommets, and the heavier part placed next to the powder.

No.	DATE.		POWDER.		Weight of the cartridge.	BALL.			Weight of ball and wad.	HEIGHT OF		Vibration of the pendulum.
	Day.	Hour.	Kind.	Weight.		Diameter.	Windage.	Weight.		Cartridge.	Whole charge.	
	1843.			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.	° ′ ″
1	Ap'l 7	10½	*a*	4	4.055	6.268	0.162	32.51	32.73	-	10.88	13 02 36
2			"	4	4.055	6.268	0.162	32.37	32.60	5.06	10.88	13 06 10
3		12	"	5.333	5.388	6.260	0.170	32.27	32.30	6.	12.12	15 23 00
4		1	"	5.333	5.388	6.260	0.170	32.21	32.25	6.	11.88	15 11 40
5			"	6.4	6.454	6.255	0.175	31.97	32.18	6.94	12.63	16 32 15
6			"	6.4	6.454	6.255	0.175	32.05	32.28	7.	12.81	16 47 40
7			"	8	8.054	6.253	0.177	32.18	32.40	8.44	13.50	18 44*
8			"	8	8.054	6.250	0.180	32.07	32.34	8.63	14.20	18 44
9			"	10.666	10.727	6.245	0.185	32.12	32.34	11.06	16.70	21 29 18
10		2½	"	10.666	10.727	6.245	0.185	32.19	32.42	10.94	16.63	21 40 18
11	" 17	11	"	4	4.052	6.265	0.165	32.27	32.50	4.75	10.75	12 33 20
12			"	4	4.051	6.268	0.162	32.38	32.62	4.70	10.50	13 05
13			"	6.4	6.463	6.255	0.175	32.07	32.35	6.85	12.63	16 19 12
14			"	6.4	6.460	6.255	0.175	32.08	32.30	7.	12.75	16 39 40
15		12	"	8	8.063	6.250	0.180	32.33	32.54	8.62	14.06	18 50
16			"	8	8.063	6.255	0.175	31.94	32.18	8.30	14.	18 23 08
Means -			*a*	4	4.053	6.267	0.163	32.38	32.61	4.89	10.75	12 56 47
			"	5.333	5.388	6.260	0.170	32.24	32.28	6.	12.	15 17 20
			"	6.4	6.458	6.255	0.175	32.04	32.28	6.95	12.71	16 34 42
			"	8	8.057	6.253	0.177	32.06	32.31	8.46	13.90	18 37 03
			"	10.666	10.727	6.245	0.185	32.16	32.38	11.	16.67	21 34 48

*The vibration of the pendulum at the 7th round is recorded 17° 44′; but this is no doubt an error of observation, and it is therefore corrected here.

Moment of the pendulum.	Initial velocity of the ball.	POINTS STRUCK BY THE BALL.							No.
		On the target, at 1,098 feet.			First graze on the water.				
		Deviation.		Depression.	Angles at the base.		Range.	Depression.	
		Right.	Left.		At gun.	At S. end.			
	Feet.	Feet.	Feet.	Feet.	° ′ ″	° ′ ″	Feet.	Feet.	
51,104	1225	-	2.17	17.	29 10	-	-	22.31	1*
51,334	1235	-	2.30	13.14	29 09 33	91 42 13	1350	22.15	2
60,216	1404	-	1.	11.23	29 13 38	97 39 13	1437	21.83	3†
59,509	1387	-	1.42	10.56	29 12 19	99 35 13	1467	21.67	4†
64,703	1462	-	0.70	9.12	29 14 35	104 32 13	1555	21.64	5
65,701	1484	-	3.08	11.06	29 07 06	100 26 13	1479	21.60	6
73,222	1579	3.33	-	8.40	29 27 15	107 15 13	1615	21.56	7
73,222	1578	-	1.	8.14	29 13 38	109 00 13	1646	21.52	8
83,874	1684	-	3.75	8.40	29 05	110 02 13	1665	21.48	9
84,582	1698	-	1.20	7.64	29 13	111 23 13	1712	21.44	10
49,205	1179	-	2.38	14.56	29 09 17	85 18 13	1270	20.61	11
51,264	1233	1.93	-	10.96	29 22 52	95 49 13	1412	20.77	12
63,860	1430	0.23	-	6.26	29 17 30	108 38 13	1640	20.93	13
65,195	1470	-	1.04	9.36	29 13 30	103 15 13	1530	21.09	14
73,623	1580	-	0.65	10.66	29 14 44	101 40 13	1503	21.25	15
71,881	1552	1.35	-	8.51	29 21 02	107 38 13	1620	21.41	16
50,727	1218	-	1.23	13.92	29 12 56	-	1311	21.46	‡
59,863	1396	-	1.21	10.90	29 12 59	98 37 13	1452	21.75	
64,865	1462	-	1.15	8.95	29 13 10	104 12 58	1551	21.32	
72,775	1570	1.23	-	8.35	29 20 38	107 57 53	1627	21.49	§
84,228	1691	-	2.48	8.02	29 09	110 42 42	1688	21.46	

* This ball grazed the top of the wharf.

† Balls having straps, without grommets.

‡ Range of No. 1 interpolated at 1212 feet.

§ Rejecting No. 15.

April 21st, 1843.

The pendulum block having been attached to its suspension frame, the requisite adjustments in its position with reference to its own axis of suspension and to that of the gun pendulum, were completed. In order to place the axis of the block perpendicular to that of the shaft of the frame, it was found necessary to introduce a washer between the collars of the straps at one end of the shaft, as in the gun pendulum.

A final adjustment of the centre of oscillation of the gun pendulum was made by placing, on the lower screw bolt, weights amounting to 719 lbs., when by two comparisons with the chronometer, of 500 vibrations of the pendulum, it was found that 1,000 oscillations were made in 2,233 seconds, giving 194.964 in. (say 195 in.) for the distance of the centre of oscillation from the axis of suspension.

April 22nd, 1843.

The first trial of the pendulum block was made to-day. For this purpose the core of the block was filled with coarse sand and gravel, kept in place by a circular board in the mouth of the block. The weight of this core was known, and certain supplementary weights were placed on the lower screw bolt of the frame, so as to bring the centre of oscillation nearly in the axis of the block, being at 194.27 in. from the axis of suspension. The charge of powder was 4 lbs. The object of the experiment being only to test the apparatus, the particulars are not here stated, because the final adjustments of the system have not been made.

Previously to firing with ball, two blank charges of 4 lbs. and 8 lbs. respectively were fired, in order to try the efficacy of the screen of boards placed between the gun and the block, to protect the latter from the blast. The results have been given in the general description of the pendulums.

April 29th to May 27th, 1843.

The adjustments of the pendulums having been completed, the interval between the above dates was chiefly occupied with experiments with increasing charges of powder, in order to thoroughly test the apparatus before commencing a regular series of experiments, and to devise a convenient method of making a suitable core for the pendulum block, which might be easily renewed at each fire.

The particulars of these experiments, so far as they relate to the force of the powder and the velocities of the balls, are presented, for greater convenience, in one tabular view. It is not thought necessary to give all the elements of the calculations for each change that was made in the pendulum block in the course of these preliminary trials, but it may be useful to mention the methods tried for making the cases for the sand forming the core of the block, and to state also some other particulars of the trials.

April 29th. Tried leather cases for the sand, which were made according to the description of those used in the first experiments at Metz. The leather is stretched on iron frames formed of four rings of iron 1 in. square, riveted at one end to a hoop of iron of the same size, and left loose at the other end, so that the leather case may fill the part of the block which it occupies. There are four of these cases which are filled with common building sand, the ends being closed with thin boards.

A hemisphere of lead occupies the bottom of the core; on it were placed two circular pieces of 1-in. pine board, against which the lower sand bag was intended to rest, and another disc of board was placed in the mouth of the block. The sand nearly filled the block, and a small quantity only was lost by the impact of the ball.

The lead on the face of the block, for marking the point struck, was 3½ lbs. to the square foot.

The screen before the gun was made of 1-in. pine boards. The grommet of the first ball, which was made of a single strand of packing yarn, was intercepted by the screen; but that of the second, which was formed of three strands, broke a piece out of one of the boards at the side of the hole made for the passage of the ball, and a part of it struck the face of the pendulum block.

The leather cases were slightly injured and required repairs.

May 1st. Balls weighed and gauged.

May 2nd. The bore of the 32-pounder pendulum gun was to-day measured by means of a sliding calibre gauge, (étoile mobile,) which had been obtained from the Bureau of Artillery in Paris. This instrument was used as being more convenient and more accurate than our own of a similar kind. The measurements of the bore were made at intervals of 5 centimetres, (2 in. nearly,) commencing at 104 in. from the muzzle.

The mean of all these measurements gives 6.43 in. for the diameter of the bore. The particulars are not stated, because the results will be verified and given in detail before the commencement of a regular series of experiments.

May 3d. Another trial was made of the sand cases which had been repaired and strengthened; the bottom case was a good deal damaged by the three rounds fired to-day. The balls penetrated to the lead in the bottom of the core, and deformed it so much that it became necessary to take out the lead, in order to fill up the cavity and to fit it to its place again. When repaired, the lead weighed 626½ lbs., instead of the former weight of 600 lbs.

May 5th. A further trial was made of the same set of sand cases, by firing 6 rounds; this trial showed that some modification was required in the construction of the iron frames, to make them capable of long continued service.

It will be seen, by the tabular view of to-day's experiments, that the penetration of the ball is *less* with high charges than with smaller ones; this unexpected result is explained by the great and sudden compression and solidification, as it were, of the sand in front of the ball, by which the resistance to the ball is increased when its velocity is very great.

The ball fired to-day, with the charge of $10\frac{2}{3}$ lbs., was cracked in a meridional plane passing through the point which struck first; this ball, having been split open, was found to have, under that point and near the surface, an ovoidal cavity or air bubble, 2 in. $\times$ 1.6 in. $\times$ 1 in. in dimensions; this cavity was, as may be supposed, just at the upper end of the principal axis of the ball, which end, in all the balls, was placed outwards, or towards the muzzle of the gun; generally speaking, this front hemisphere of the ball contained the point which first struck the pendulum block, and that point was seldom more than 45° from the end of the principal axis. The balls are sensibly diminished in weight by the friction against the sand, and even when not cracked, they are often so much flattened that they will not again pass through the high gauge of their calibre.

The grommets, although weighing but $1\frac{1}{2}$ oz., struck the screen with so much force as to break and split the 1-in. white pine boards of which it was made, and at the last fire two of the boards were rendered unfit for further use. A screen of oak planks, 2 in. thick, was substituted, and was used in all the experiments afterwards.

The frames of the first set of sand cases were made a little too large for their places; in consequence of this, the outermost case was not more than half an inch within the mouth of the block, and hence some of the sand was forced outwards by the reaction. The loss of weight from this cause could not, however, seriously affect the indications of the pendulum, as it did not exceed 10 lbs., even with the highest charge used.

May 16*th*. The sand cases heretofore used having been modified, by connecting the ribs of the frame together at the smaller end, as well as at the larger, by means of an iron hoop, they were again tried by firing with a charge of $\frac{1}{3}$. In consequence of the unyielding stiffness of this frame, some of the ribs were broken, and others bent; one of the hoops was also broken at a rivet hole, and the experiment was therefore unsuccessful.

The blank charge of $\frac{1}{3}$ was fired to test anew the efficacy of the screen in intercepting the blast.

May 19*th*. Another modification of the sand cases was made and tested to-day; the hoops of one of the frames were cut into three segments, and each pair of these segments connected together by the ribs and by small rods of round iron; the parts of the frame were therefore free to yield to the lateral pressure, being held together in that direction only by the leather covering which was riveted to the hoops. This arrangement, further modified in some particulars, was found to answer the desired object and was adopted in the subsequent experiments, as stated in the description of the pendulums.

May 22nd. Some observations were made on the loss of motion of the pendulums in a given number of oscillations, as follows:

	Extent of first vibration.	Loss in twenty vibrations.				Mean loss in one vibration.
		1st.	2nd.	3d.	4th.	
	° ′ ″	′ ″	′ ″	′ ″	′ ″	″
Gun pendulum.	11 01 34	10 34	10 30	–	–	32
	10 07 30	10 10	10 10	10 00	–	30
	4 32 28	8 28	8 36	8 50	–	26
	3 44 48	8 28	8 40	8 16	–	25
Ballistic pendulum. (Block empty.)	14 11 00	13 50	13 30	13 10	13 00	40
	9 01 00	9 26	9 42	9 32	–	29
	2 52 10	6 00	6 20	6 10	6 20	19

May 27th. The object of to-day's experiments was to test a set of sand cases made on frames like that tried on the 19th; the result was satisfactory with regard to this method of making the cases.

The opportunity was made use of to verify the unlooked for result of the experiment on the 19th, as to the force of the powder then tried.

Note.—In the following tabular statements the hour of the experiment is not designated as A. M. or P. M., because it was always between 9 A. M. and 6 P. M.; therefore no confusion of time can occur.

The *penetration of the ball* is the distance from the face of the pendulum block to the back of the ball.

No.	DATE.		POWDER.		Weight of cartridge.	BALL.			Weight of ball and wad.	HEIGHT OF		POINT Lateral deviation of the ball.	
	Day.	Hour.	Kind.	Weight.		Diameter.	Windage.	Weight.		Cartridge.	Whole charge.	Right.	Left.
	1843.			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.	In.	In.
1	Apr 29	4	*a*	6.4	6.456	6.25	0.180	32.30	32.40	7.	12.75	-	0.25
2	"		"	8.	8.052	.235	.195	.18	.43	8.5	13.88	0.1	-
3	May 3	4	"	4.	4.050	.265	.165	.26	.35	5.1	10.5	-	0.05
4			"	4.	4.052	.268	.162	.36	.45	4.8	10.5	-	0.85
5		6	"	5.333	5.375	.260	.170	.23	.32	5.88	11.3	-	0.65
6	" 5	10 20	"	5.333	5.388	.266	.164	.03	.12	6.12	11.9	-	0.1
7		11 35	"	6.4	6.457	.260	.170	31.98	.07	7.	12.62	0.2	-
8		1 45	"	6.4	6.458	.258	.172	32.11	.20	7.	12.62	-	0.9
9		3	"	8.	8.063	.25	.180	.08	.17	8.38	13.88	-	0.45
10		4	"	8.	8.063	.255	.175	.26	.35	8.38	14.12	-	0.35
11		5 15	"	10.666	10.736	.248	.182	.13	.22	11.1	17.	-	0.5
12	" 16	11	"	10.666	10.745	-	-	-	-	10.62	-	-	-
13		11 20	"	10.666	10.740	.248	.182	.19	.28	10.87	16.5	-	0.05
14	" 19	11	w	8.	-	.265	.165	.13	.22	7.88	13.63	-	0.2
15	" 27	11	"	8.	-	.247	.183	31.75	31.84	8.	13.8	-	0.15
16			"	8.	-	.258	.172	31.77	31.86	8.	13.95	0.6	-

STRUCK.		VIBRATION.			VELOCITY OF THE BALL.			
Distance from the axis.	Penetration of the ball.	Gun pendulum.	Ballistic pendulum.	Moment of the gun pendulum.	By the gun.	By the pendulum.	No.	REMARKS.
In.	In.	° ′ ″	° ′ ″		Feet.	Feet.		
194.25	50.5	*16 16 26	10 49 50	65,371	1468	1450	1	
194.30	49.5	17 50 38	11 18 40	71,633	1526	1513	2	
195.15	53.	12 31 40	9 04	50,399	1218	1204	3	
193.9	54.4	12 48 50	9 12 14	51,544	1247	1219	4	
194.25	55.4	14 33 30	9 59 52	58,522	1358	1337	5	
195.15	52.	14 52 16	10 17	59,771	1402	1381	6	
194.85	44.5	16 13 16	10 54 20	65,165	1481	1460	7	
193.7	44.5	15 59 48	10 38 24	64,280	1451	1427	8	
194.6	46.5	17 53 02	11 24 42	71,788	1548	1525	9	
195.25	47.75	18 11 20	11 41	73,004	1574	1546	10	
194.1	46.5	21 08 24	12 32	84,724	1712	1676	11	
-	-	9 41	0 0 45	38,983	-	-	12	
195.	49.25	21 14 42	12 50	85,138	1720	1705	13	
194.95	48.62	18 16 20	11 45	73,336	1593	1567	14	
194.05	48.8	18 08 20	11 31 18	72,805	1589	1558	15	
194.57	48.1	18 09 20	11 29 40	72,871	1594	1550	16	

*The vibration of the gun pendulum, at the first fire, is recorded 15° 16′ 26″, which was doubtless an error of observation, and it is therefore corrected to 16° 16′ 26″.

July 11th, 1843.

The pendulum experiments having been interrupted by the intervention of other duties, they were resumed to day, by weighing and gauging balls, and re-measuring the bore of the 32-pounder gun.

The points of the calibre gauge were set by a ring gauge of 6.397 in. diameter, and the measurements of the bore, reduced to inches, are as follows:

Measurements of the bore of 32-pounder gun.

Distance from the face.	Vertical diameter.	Distance.	Diameter.	Distance.	Diameter.	Distance.	Diameter.
In.	In.	In.	In.	In.	In.	In.	In.
104.36	6.432	93.53	6.432	78.76	6.433	55.13	6.429
103.38	.434	92.54	.434	76.79	.429	51.20	.429
102.39	.430	91.56	.434	74.82	.429	47.26	.433
101.41	.430	90.58	.435	72.86	.430	43.32	.429
100.42	.432	89.59	.436	70.89	.429	39.38	.429
99.44	.432	88.61	.436	68.92	.429	31.50	.429
98.45	.432	87.63	.438	66.95	.429	23.63	.429
97.47	.434	86.64	.439	64.98	.429	15.75	.429
96.48	.434	84.67	.436	63.01	.433	7.88	.429
95.50	.432	82.70	.432	61.04	.436	0.	.430
94.51	.434	80.73	.432	59.07	.429		

The mean of all these measurements, properly taken, gives 6.43 in. for the mean diameter of the bore, as heretofore used in estimating the windage of the balls; but as the seat of the ball, with charges of $\frac{1}{8}$ to $\frac{1}{3}$, is between 95 and 100 inches from the face of the muzzle, the mean diameter within those limits may, with propriety, be used in estimating the windage, which will be accordingly computed, hereafter, from the diameter 6.433 in.

July 14th, 1843.

On account of the leaden weights, for adjusting the centres of oscillation of the pendulums, becoming bruised and upset against the nuts which confine them to their places, so as to prevent them from sliding readily on the bolts that support them, the front weight of each set, (that which sustains the greatest pressure in the recoil of the pendulum,) has been replaced by one made of a cast iron case filled with lead.

The pendulum block having been filled, both pendulums were carefully adjusted, as follows:

		Weight.	Dist. of centre of gravity from axis.	Dist. of centre of oscillation.
		Lbs.	Inches.	Inches.
Gun pendulum	Frame, with 32-pounder gun	10,500	172.9	195
	Adjusting weights - -	667.5	215	
Ballistic pendulum	Frame, with block empty -	9,358	170.8	194.8
	Hemisphere of lead -	626.5	195	
	Oak board over the lead -	9.5	195	
	Sheet lead on the face -	8	195	
	4 sand bags - -	965	194.34	
	Adjusting weights - -	788.5	219	

For the gun pendulum, therefore, we have:

$$\text{Log.}\ \frac{2\,p'\,g'}{12}\sqrt{\frac{G}{o'}} = 5.6620724;$$

p' being expressed in pounds, and g' in inches, the result will be in pounds and feet.

For the ballistic pendulum, regarding the point of impact as coincident with the centre of oscillation, and assigning a mean value (32.234 lbs. × 194.5 in.) to the factor bi, of the term $pg + bi$, in the numerator of the formula, we have:

$$\text{Log.}\ \frac{2\,(p\,g + b\,i)\sqrt{G\,o}}{12} = 7.9800942$$

No.	DATE.		POWDER.		Weight of cartridge.	BALL.			Weight of ball and wad.	HEIGHT OF		POINT Lateral deviation of the ball.	
	Day.	Hour.	Kind.	Weight.		Diameter.	Windage.	Weight.		Cartridge.	Whole charge	Right.	Left.
	1843.			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.	In.	In.
1	July 15	10 35	A	4.00	4.05	6.268	0.165	32.38	32.48	4.6	10.1	-	0.35
2		11 05	B	"	"	.268	.165	32.21	32.31	4.9	.6	-	0.50
3		11 35	C	"	"	.268	.165	31.87	31.97	4.6	.4	-	0.25
4		12	D	"	"	.269	.164	32.	32.10	4.6	.5	0.	0.
5		1 40	D	"	"	.266	.167	32.15	.25	4.5	.3	-	0.8
6		2 20	C	"	"	.268	.165	31.99	.09	4.5	.3	-	0.4
7		2 50	B	"	"	.268	.165	32.52	.62	4.6	.5	-	0.6
8		4 15	A	"	"	.268	.165	.44	.54	4.5	.2	-	1.
9		4 40	A	"	"	.260	.173	.38	.48	4.6	.4	0.	0.
10		5 05	B	"	"	.265	.168	.23	.33	4.6	.5	-	0.85
11		5 20	C	"	"	.260	.173	.29	.39	4.5	.3	-	0.3
12		5 45	D	"	"	.260	.173	.34	.44	4.5	.3	-	0.5
13	17	9 50	A	5.333	5.388	.260	.173	.31	.41	5.5	11.4	-	0.35
14		10 15	B	"	"	.260	.173	.04	.14	6.	.8	-	0.5
15		10 35	C	"	"	.260	.173	.37	.47	5.7	.4	-	0.7
16		11	D	"	"	.260	.173	31.80	31.90	5.7	.3	-	0.7
17		11 20	D	"	"	.260	.173	32.12	32.22	5.7	.7	-	0.35
18		11 40	C	"	"	.260	.173	.19	.29	5.6	.2	-	0.35
19		1 20	B	"	"	.260	.173	.13	.23	6.	.7	-	0.8
20		1 45	A	"	"	.260	.173	.18	.28	5.5	.5	-	0.5
21		2 15	C	"	"	.260	.173	.37	.47	5.5	.4	-	0.5
22		3 10	D	"	"	.260	.173	.25	.35	5.9	.4	-	0.5
23		3 40	A	"	"	.258	.175	.32	.42	5.6	.3	-	0.25
24		4	B	"	"	.258	.175	.29	.39	6.	.5	-	0.6
25	20	12	A	8.00	8.073	.255	.178	.03	.13	8.1	13.75	0.25	-
26		1 20	A	"	"	.25	.183	.11	.21	8.3	14.2	0.3	-
27		1 40	B	"	"	.255	.178	.16	.26	8.4	14.2	0.3	-
28		2	B	"	"	.25	.183	.15	.25	8.4	14.1	0.25	-
29		2 45	C	"	"	.255	.178	.25	.35	8.	13.6	0.1	-
30		3 05	C	"	"	.25	.183	.10	.20	8.	13.75	0.	0.
31		3 25	D	"	"	.256	.177	.31	.41	8.	13.8	-	0.7
32		3 45	D	"	"	.25	.183	.06	.16	8.	13.4	-	0.2

STRUCK.	VIBRATION.			VELOCITY OF THE BALL.			
Distance from the axis.	Gun pendulum.	Ballistic pendulum.	Moment of the gun pendulum.	By the gun.	By the pendulum.	No.	REMARKS.
In.	° ′ ″	° ′ ″		Feet.	Feet.		
194.	12 51 51	9 21 46	51,450	1243	1241	1	
194.8	12 22	8 57 28	49,469	1194	1189	2	Cartridge turned over.
194.3	12 10	8 44 30	48,672	1184	1176	3	Core 25 lbs. light.
194.2	12 29 40	8 59 16	49,978	1216	1204	4	
194.8	12 23 28	8 57 40	49,566	1202	1192	5	The gun was washed after
194.	12 26 20	8 57 18	49,756	1210	1201	6	four rounds.
194.6	12 25 34	8 54 50	49,705	1190	1173	7	
194.5	13 10	9 25 46	52,655	1274	1256	8	
194.7	12 36 18	9 04 34	50,418	1212	1199	9	
194.75	12 22 50	8 56 16	49,524	1162	1186	10	
194.5	12 22 36	8 53 22	49,508	1190	1179	11	
194.45	12 43 20	9 09 22	50,885	1226	1212	12	
194.55	15 16	10 41	61,007	1425	1415	13	
194.6	14 22 08	9 51 56	57,439	1335	1317	14	
194.3	14 52 16	10 15 30	59,435	1376	1358	15	
194.5	15 01 52	10 24 34	60,071	1417	1401	16	
194.45	14 57 08	10 19 08	59,758	1395	1375	17	
194.05	14 52 18	10 13	59,437	1383	1361	18	
194.3	14 47 50	10 10 10	59,142	1378	1356	19	
194.8	15 26 26	10 41	61,300	1435	1418	20	
194.35	14 52 06	10 17 20	59,424	1376	1362	21	
194.35	14 59 52	10 20 40	59,939	1395	1374	22	
194.75	15 24 26	10 40	61,565	1435	1411	23	
195.	14 36 40	10 00 54	58,402	1351	1324	24	
194.75	18 48 24	12 02 38	75,038	1637	1606	25	Gun washed after two
194.5	19 05 30	12 07 50	76,164	1660	1616	26	rounds.
194.35	18 28 38	11 30	73,735	1597	1531	27	
194.7	18 03 40	11 16 18	72,088	1552	1498	28	
194.5	18 38 26	11 44 52	74,381	1610	1558	29	
194.5	18 36 10	11 37 48	74,231	1610	1550	30	One knife edge of the bal-
194.15	18 50 10	11 56 26	75,159	1628	1588	31	listic pendulum shaft in-
193.55	18 34 04	11 38 26	74,093	1608	1557	32	jured.

In these experiments, on the 15th, 17th, and 20th July, the penetration of the balls was, as before, about 50 in.

A self-registering thermometer was inserted from time to time into the bore of the gun, near the bottom; but the variations which were observed from the temperature of the external air in the shade are not worthy of notice, not exceeding 4°.

The loss of sand through the hole made by the ball, when the pendulum block recoils, is, with the higher charges, about 7 lbs., sufficient to cause a sensible error in the velocity, although not an error of such magnitude as seriously to affect the results, since it cannot amount to more than 1 foot in a velocity of 1600 feet. With lower charges, or with a gun of inferior calibre to the 32-pounder, the error from this cause would, it is presumed, be altogether insignificant, and it could not now be avoided without an alteration of the sand cases, which is not deemed necessary for that purpose.

By the high charges the sand before the ball was driven into the lead in the bottom of the pendulum block, so as to cause a great depression in the centre of it, and a corresponding protrusion at the edges. The sand cases were also much injured, and on these accounts only two charges of each kind of powder were fired with 8 lbs. At the 8th round on the 17th, the lower screw bolt, which supports the adjusting weight of the gun pendulum, was broken immediately under the nut in front of the transom. This accident was caused by the shoulder of the bolt not bearing well against the inner side of the transom, whilst the nut was screwed up hard against the outer side. The iron was also found to be coarse grained and brittle.

As it was observed that the lateral deviations of the balls have been uniformly to the *left* of the centre of the pendulum block, a slight alteration was made in the position of its shaft, and the relative position of the two pendulums was again verified. The effect of this correction is seen in the first experiments on the 20th.

The inaccuracies which occurred in the two last rounds on the 20th, were occasioned by a serious injury to the knife edge on the left (or eastern) end of the shaft of the ballistic pendulum, which was discovered, after the experiments, to be partially crumbled at the edge, owing to the steel having been blistered in hardening it.

In consequence of the great variation in the position of the point of impact, the two last experiments were computed separately from the others; and they would be rejected altogether, but for the conformity which is observed between the indications of the two pendulums, in comparing these with the preceding experiments.

The ballistic pendulum was dismounted and the shaft repaired without difficulty, and it was again adjusted and ready for use on the 27th.

Four sets of sand cases are now used in the service of the ballistic pendulum.

July 28th, 1843.

Experiments in firing shells, with different kinds of powder, were commenced to-day. The shells used were made for the purpose, with a thickness of metal of 1.2 in., having a reinforce of 1.8 in. thick about the interior of the fuze hole, (after the manner of spherical case shot,) intended to give a better support to the fuze in firing with heavy charges from a long gun. The fuze hole, which is 1.2 in. in diameter, is filled with a plug of hard wood weighing about 1 oz. When floated in mercury, the shells always turned with the fuze hole up, (notwithstanding the reinforce,) and the grommets were attached to that part of the shell, so as to turn the fuze hole from the powder.

The weight of the shells was not equalized by putting any thing into them, for fear that the supplementary weight, being loose, might affect the accuracy of the results.

No.	DATE.		POWDER.		Weight of cartridge.	BALL.			Weight of ball and wad.	HEIGHT OF	
	Day.	Hour.	Kind.	Weight.		Diameter.	Windage.	Weight.		Cartridge.	Whole charge
	1843.			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.
1	July 28	5 30	A	5.333	5.38	6.263	0.17	23.852	23.952	5.6	11.2
2		5 45	"	"	"	.26	.173	.94	24.04	5.4	.2
3		6	"	"	"	.26	.173	.92	24.02	5.6	.2
4	August 1	1 50	"	4.000	4.037	.25	.183	.85	23.95	4.4	10.1
5		2 25	"	"	"	.265	.168	.92	24.02	4.5	.3
6		2 45	"	"	"	.25	.183	.95	24.05	4.4	.2
7		3 45	G. 1	"	"	.255	.178	.82	23.92	*4.8	.5
8		4	"	"	"	.268	.165	.91	24.01	4.5	.4
9		4 15	"	"	"	.255	.178	.79	23.89	4.4	.2
10		4 45	"	5.333	5.373	.255	.178	.83	.93	5.6	11.3
11		5	"	"	"	.26	.173	.76	.86	5.6	.2
12		5 20	"	"	"	.25	.183	.79	.89	5.6	.2
13	" 2	10 45	G. 6	"	5.393	.26	.173	.745	.845	5.1	10.8
14		11	"	"	"	.26	.173	.7	.8	5.4	11.1
15		11 15	F. 1	"	5.383	.26	.173	.75	.85	6.4	11.9
16		11 30	"	"	"	.265	.168	.73	.83	6.3	12.
17		11 50	"	"	"	.250	.183	.805	.905	6.5	12.
18		1 30	G. 6	4.000	4.05	.26	.173	.73	.83	4.2	10.
19		1 45	"	"	"	.25	.183	.69	.79	4.2	9.9
20		2 05	"	"	"	.25	.183	.71	.81	4.2	9.8
21		2 30	F. 1	"	4.04	.258	.175	.655	.755	5.	10.6
22		3 10	"	"	"	.260	.173	.71	.81	5.1	.8
23		3 30	"	"	"	.248	.185	.7	.8	5.1	.9

* Cartridge turned over.

POINT STRUCK.			VIBRATION.		Moment of the gun pendulum.	VELOCITY OF THE BALL.		No.
Lateral deviation of the ball.		Distance from the axis.	Gun pendulum.	Ballistic pendulum.		By the gun.	By the pendulum.	
Right.	Left.							
In.	In.	In.	° ′ ″	° ′ ″		Feet.	Feet.	
0.75	-	193.8	13 28	8 56 18	53,850	1621	1609	1*
-	0.5	194.3	13 25	8 54 12	53,650	1607	1593	2*
-	0.8	194.5	13 32	8 59 24	54,115	1624	1608	3*
0.5	-	194.2	11 13 44	7 50	44,933	1407	1408	4†
-	0.3	193.8	11 16 10	7 46 56	45,094	1415	1397	5‡
0.6	-	193.7	11 20	7 50 22	45,349	1416	1406	6†
0.25	-	194.2	11 03	7 38 20	44,219	1384	1375	7‡
-	0.9	194.9	11 07 30	7 46 46	44,518	1396	1389	8†
-	0.9	195.1	11 07 10	7 46 20	44,496	1396	1394	9*
-	0.4	194.65	13 14 22	8 45	52,945	1586	1570	10*
-	0.3	194.	13 11 26	8 42 40	52,750	1586	1573	11*
-	0.1	193.8	13 11 36	8 40	52,761	1580	1564	12*
-	0.9	195.4	13 41 50	9 16 20	54,767	1658	1663	13*
-	0.9	194.7	13 44 44	9 13 40	54,959	1668	1664	14*
-	0.5	193.8	12 41 46	8 18 34	50,781	1515	1502	15*
0.75	-	194.25	12 54 34	8 29 10	51,631	1549	1532	16*
0.1	-	194.4	12 35 26	8 14 40	50,361	1493	1483	17‖
.0	.0	194.1	11 28 50	8 04	45,936	1454	1458	18‡
-	0.8	193.7	11 28 26	8 00 46	45,910	1451	1453	19‖
-	0.2	195.	11 28 24	8 05	45,908	1450	1455	20*
0.4	-	194.7	10 49 10	7 28 10	43,299	1361	1350	21¶
1.	-	124.1	10 46 06	7 22 24	43,095	1351	1334	22¶
1.2	-	195.3	10 42 40	7 22 22	42,867	1338	1338	23†

* Shell broken into many pieces.

† Shell cracked.

‡ Shell broken in three.

‖ Shell broken in two.

¶ Not cracked apparently.

No.	DATE. Day.	Hour.	POWDER. Kind.	Weight.	Weight of cartridge.	BALL. Diameter.	Windage.	Weight.	Weight of ball and wad.	HEIGHT OF Cartridge.	Whole charge.
	1844.			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.
1	August 3	3	A	10.666	10.743	6.248	0.185	32.23	32.33	10.6	16.2
2		3 35	E. 5	5.333	5.383	.260	.173	23.76	23.86	5.3	11.1
3		4	"	"	"	.260	.173	.84	.94	5.3	11.
4		4 20	E. 1	"	"	.248	.185	.60	.70	5.3	11.
5		4 40	"	"	"	.260	.173	.71	.81	5.5	11.2
6		5 05	E. 5	4.000	4.047	.255	.178	.82	.92	4.5	10.2
7		5 25	"	"	"	.250	.183	.86	.96	4.3	10.1
8		5 45	E. 1	"	"	.250	.183	.71	.81	4.8*	10.4
9		6 05	"	"	"	.260	.173	.86	.96	4.4	10.2
10	4	9 45	E	5.333	5.378	.265	.168	.76	.86	5.4	11.3
11		10	"	"	"	.250	.183	.64	.74	5.4	11.1
12		10 30	"	"	"	.248	.185	.81	.91	5.3	11.1
13		10 50	F	"	5.381	.260	.173	.66	.76	6.5	12.
14		11 15	"	"	"	.250	.183	.73	.83	6.5	12.1
15		11 35	"	"	"	.255	.178	.69	.79	6.4	12.
16		12	E	4.000	4.04	.26	.173	.85	.95	4.4	10.1
17		1 30	"	"	"	.25	.183	.76	.86	4.3	10.1
18		2	F	"	4.042	.25	.183	.68	.78	5.2	10.8
19		2 15	"	"	"	.248	.185	.79	.89	5.1	10.6
20		2 30	"	"	"	.25	.183	.73	.83	5.2	10.8

* Cartridge turned over.

POINT STRUCK.			VIBRATION.		Moment of the gun pendulum.	VELOCITY OF THE BALL.		No.
Lateral deviation of the ball.		Distance from axis.	Gun pendulum.	Ballistic pendulum.		By the gun.	By the pendulum.	
Right.	Left.							
In.	In.	In.	° ′ ″	° ′ ″				
0.	0.	194.6	22 07 30	13 07	88,126	1792	1739	1
-	0.3	194.8	13 05 20	8 34 10	52,345	1571	1541	2†
-	0.1	194.75	13 13 08	8 40 24	52,863	1584	1555	3†
-	0.3	194.9	12 30 30	8 07 10	50,033	1492	1469	4†
-	0.2	194.3	12 35 08	8 06 14	50,341	1502	1464	5†
0.2	-	194.85	10 53 20	7 28 54	43,576	1361	1342	6‡
-	0.3	194.05	10 55 06	7 28	43,694	1361	1342	7§
-	0.85	194.7	10 13 10	6 54 30	40,905	1266	1246	8§
0.3	-	194.6	10 23 34	7 01 44	41,596	1288	1260	9§
-	0.2	194.3	12 32 20	8 09 20	50,155	1495	1470	10†
0.45	-	194.55	12 32	8 06 50	50,133	1494	1468	11†
-	0.75	195.35	12 33 50	8 09 20	50,254	1488	1459	12†
-	0.7	194.4	12 50 26	8 23 50	51,356	1541	1519	13†
0.25	-	193.15	12 42 20	8 11 06	50,819	1514	1486	14†
0.75	-	194.2	12 54	8 26 24	51,593	1546	1527	15†
-	0.6	193.85	10 26 20	7 04 40	41,780	1295	1274	16§
-	0.8	195.65	10 24 20	7 05 20	41,647	1291	1269	17§
-	0.35	193.95	10 47 42	7 22	43,202	1352	1335	18§
0.75	-	196.35	10 54 08	7 35 18	43,629	1361	1352	19‡
-	0.35	193.65	10 46 06	7 20	43,095	1346	1328	20§

† Shell broken into many pieces.

‡ Cracked.

§ Not cracked.

The shells which were not broken into pieces, were generally found in the bottom sand bag; those which were broken, in the third bag. There was no uniformity in the position, with reference to the fuze hole, of the part of the shell which first struck the pendulum block; it was sometimes at the point opposite to the fuze hole, sometimes at the fuze hole, and at intermediate points. When the shells were broken in the pendulum block, it was necessary to renew the bottom sand bag only after about three rounds; if not then removed, the sand in it became so closely packed as to occasion considerable difficulty in extracting it.

With the charge of 4 lbs., the diameter of the cartridge is greater than its length or height, which sometimes caused it to turn over, notwithstanding the care taken to insert it, by pushing it with the handle of the rammer; these cases are noted in the column of remarks.

The first round, on the 3d of August, was fired for the purpose of trying the efficacy of substituting, in these high charges, for the bottom sand bag, a case filled with soft bricks. The ball did not penetrate through this case, but the bricks were finely pulverized, and compressed so hard against the sides of the block that they were removed with difficulty, and the dust from them was exceedingly inconvenient.

After the cartridge for the 9th round, on the 3d, had been inserted, it was found that there was no shell at hand, and as the hour was late, the shell used for the 7th round was fired over again, without being gauged; the part of the shell which struck first was the same as before, (opposite to the fuze hole,) and it was afterwards found to be enlarged in the other direction to 6.27 in.; one-half of this increase of diameter has been attributed to each fire.

In computing the initial velocities of the balls, by the ballistic pendulum, in these experiments, a constant value is assigned to the factor $b i$, (in the numerator of the formula,) which is made equal to the mean distance of the points struck, multiplied by the mean weight of the shells, = 194.5 in. × 23.763 lbs.

$$\text{Hence, Log. } \frac{2\,(p\,g + b\,i)\sqrt{G\,o}}{12} = 7.9797518$$

The measures being in inches, the result will be in feet. By calculating the velocity by the correct formula, for a case of extreme variation from this mean value of $b\ i$, (such as the case of the 10th round on the 4th of August,) it is found that the error caused by the transformation of the formula, and by assigning a mean value to $b\ i$, does not exceed $\frac{4}{10}$ths of a foot; in ordinary cases it may therefore be safely disregarded.

Having ascertained that the lateral deviations of the ball from the axis of the pendulum block are unimportant, they will no longer be recorded, except in extraordinary cases.

No.	DATE		POWDER.		Weight of cartridge.	BALL.			Weight of ball and wad.	HEIGHT OF	
	Day.	Hour.	Kind.	Weight.		Diameter.	Windage.	Weight.		Cartridge.	Whole charge
	1843.			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.
1	August 8	9 10	E.	4	4.044	6.265	0.168	31.98	32.08	4.4	10.1
2		9 30	"	"	"	.25	.183	32.55	.65	"	"
3		9 45	F.	"	4.047	.268	.165	.33	.43	5.1	10.7
4		10	"	"	"	.25	.183	.31	.41	"	"
5		10 20	E. 1	"	4.046	.27	.163	.09	.19	4.5	10.3
6		10 35	"	"	"	.252	.181	.30	.40	"	"
7		10 55	F. 1	"	4.047	.25	.183	.31	.41	5.1	10.8
8		11 20	"	"	"	.265	.168	.22	.32	5.2	10.9
9		11 35	G. 1	"	4.045	.26	.173	.32	.42	4.5	10.3
10		11 45	"	"	"	.26	.173	.30	.40	4.4	10.1
11		1 20	E. 2	"	4.046	.26	.173	.27	.37	"	10.2
12		1 35	"	"	"	.255	.178	.32	.42	"	10.1
13		1 55	F. 2	"	4.05	.268	.165	.26	.36	5.2	10.8
14		2 15	"	"	"	.258	.175	.31	.41	"	11.1
15		2 45	G. 6	"	4.044	.26	.173	.31	.41	4.2	9.9
16		3	"	"	"	"	"	.21	.31	4.3	10.
17	August 11	1 20	E. 5	"	4.052	"	"	.16	.26	4.4	10.2
18		1 40	"	"	"	"	"	.61	.71	4.2	10.
19		1 55	A. 1	"	4.043	"	"	.36	.46	4.6	10.2
20		2 15	"	"	"	"	"	.33	.43	4.6	10.2
21	August 12	8 20	B. 1	"	4.049	"	"	.35	.45	4.7	10.4
22		8 40	"	"	"	"	"	.08	.18	"	"
23		8 55	C. 1	"	4.040	"	"	.35	.45	4.5	10.2
24		9 10	"	"	"	"	"	.00	.10	4.4	"
25		9 25	D. 1	"	4.045	"	"	.32	.42	4.6	10.3
26		9 40	"	"	"	"	"	.14	.24	"	"
27		10	A. 2	"	4.048	"	"	.17	.27	"	10.3
28		10 12	"	"	"	"	"	.31	.41	4.7	10.4
29		10 30	B. 2	"	4.049	"	"	.21	.31	"	10.3
30		10 55	"	"	"	"	"	.30	.40	4.8	10.4
31		11 07	C. 2	"	4.040	"	"	.27	.37	4.6	"
32		11 25	"	"	"	"	"	.21	.31	4.5	10.3
33		11 40	D. 2	"	4.038	"	"	.23	.33	4.7	"
34		11 53	"	"	"	"	"	.26	.36	4.5	"

Point struck.	Vibration. Gun pendulum.	Vibration. Ballistic pendulum.	Moment of the gun pendulum.	Velocity of the ball. By the gun.	Velocity of the ball. By the pendulum.	No.	Remarks.
In.	° ′ ″	° ′ ″		Feet.	Feet.		
194.3	11 44 50	8 24	47,000	1133	1126	1	The gun was washed after two rounds.
194.	11 47 50	8 19 40	47,199	1114	1098	2	
194.15	12 13 26	8 43	48,888	1174	1156	3	
194.5	12 01 20	8 33 44	48,096	1147	1135	4	
194.5	11 44	8 16 30	46,944	1129	1104	5	
194.8	11 43 10	8 16	46,889	1115	1094	6	
194.75	12 01 20	8 34	48,096	1147	1134	7	
194.8	12 15	8 47 22	49,004	1180	1166	8	
194.1	12 29 10	9 01	49,944	1201	1196	9*	
194.85	12 39 30	9 13 40	50,631	1220	1221	10	
194.5	11 50	8 27 20	47,343	1131	1122	11†	
194.3	11 54 50	8 28 50	47,664	1136	1125	12†	
194.8	12 06	8 40 20	48,406	1163	1149	13	
195.4	11 44 20	8 24 44	46,966	1118	1110	14	
194.1	12 59	9 26 10	51,925	1256	1253	15	
194.85	12 53	9 22	51,527	1246	1243	16	
194.75	12 17	8 50 20	49,136	1184	1175	17	
194.8	12 32 36	9 05	50,172	1197	1191	18	
194.9	13 02 10	9 25 50	52,135	1260	1245	19	
193.8	12 53 10	9 13 36	51,538	1245	1227	20	
194.65	12 30	9 07 05	50,000	1201	1206	21	
194.65	12 31 10	9 03 40	50,077	1213	1209	22	
194.1	12 21 30	8 52 10	49,435	1186	1176	23	
194.5	12 15 30	8 50 30	49,037	1187	1183	24	
194.5	12 43 26	9 10 50	50,903	1227	1216	25	
194.8	12 41 36	9 07 50	50,774	1230	1214	26	
194.5	12 50 10	9 18	51,339	1245	1238	27	
194.	12 53 30	9 15 16	51,560	1246	1229	28	
194.1	12 26 40	8 58 18	49,778	1200	1195	29	
194.	12 27 50	8 58 14	49,856	1199	1192	30	
194.4	12 20 20	8 48 50	49,358	1187	1170	31	
194.5	12 23 20	8 54	49,557	1194	1183	32	
194.5	12 43 40	9 11 10	50,774	1227	1220	33	
194.25	12 41 30	9 09 10	50,763	1226	1216	34	

* A large piece of the grommet struck the pendulum block.
† This powder contained some portion of fine grains.

In the course of the experiments on the 8th, it was observed that the shaft of the ballistic pendulum shifted a little, in its V's, towards the right hand or west end, in consequence perhaps of the balls striking generally on the left side of the centre of the block. In order to prevent the shoulder of the knife edge from bearing against its seat, the shaft was set back to its place, which was done, without difficulty, by means of a wedge acting on the end of a *shore* placed between the pendulum block and the western pier.

For the calculation of the velocities in these experiments:

$$\text{Log.}\frac{2\,(pg + bi)}{12}\sqrt{Go} = 7.9800953$$

August 24th, 1843.

MEASUREMENTS OF THE BORE OF THE 32-POUNDER GUN.

The measurements are of the vertical diameter, commencing, as on the 11th of July, at the distance of 104.36 in. from the face of the muzzle.

Distance.	Diameter.	Distance.	Diameter.	Distance.	Diameter.	Distance.	Diameter.
In.	In.	In.	In.	In.	In.	In.	In.
104.36	6.432	93.53	6.432	78.76	6.432	55.13	6.427
103.38	.434	92.54	.434	76.79	.429	51.20	.430
102.39	.430	91.56	.432	74.82	.429	47.26	.429
101.41	.432	90.58	.434	72.86	.429	43.32	.429
100.42	.438	89.59	.434	70.89	.429	39.38	.429
99.44	.436	88.61	.432	68.92	.427	31.50	.429
98.45	.436	87.63	.434	66.95	.425	23.63	.429
97.47	.432	86.64	.436	64.98	.425	15.75	.429
96.48	.434	84.67	.436	63.01	.429	7.88	.429
95.50	.432	82.70	.430	61.04	.432	0.	.430
94.51	.432	80.73	.429	59.07	.425		

These measurements agree, as nearly as could be expected, with those on the 11th July, and most of the differences may even arise from variations in the use of the instrument, or from the points not resting precisely on the same spots as before. The *diminutions* of diameter at some points cannot be regarded as evidence of inaccuracy in the measurements, as they may have been caused by bruises from the balloting of the ball. The decided increase of diameter at about 100 in. from the muzzle, or 7.6 in. from the bottom of the bore, indicates a depression of 0.005 in. at that point which is the seat of the ball with a charge of 4 lbs., with which charge 67 rounds have been fired since the former measurement of the bore.

In estimating the windage, the diameter of 6.433 in. will still be used.

No.	DATE.		POWDER.		Weight of cartridge.	BALL.			Weight of ball and wad.	HEIGHT OF	
	Day.	Hour.	Kind.	Weight.		Diameter.	Windage.	Weight.		Cartridge.	Whole charge.
	1843.			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.
1	Aug. 26	9 05	A	4.	4.046	6.26	0.173	28.	28.1	4.5	10.2
2		9 25	A	4.	4.046	6.26	0.173	28.	28.1	4.4	10.1
3		9 40	A	4.	4.046	6.26	0.173	28.	28.1	4.4	10.1
4		10	A	5.333	5.385	6.26	0.173	28.	28.1	5.6	11.3
5		10 10	A	5.333	5.385	6.26	0.173	28.	28.1	5.6	11.4
6		10 30	A	5.333	5.385	6.26	0.173	28.	28.1	5.6	11.3
7		10 55	*a*	8.	8.070	6.252	0.181	32.01	32.11	8.25	14.
8	Sept. 15	1 30	A. 0.	4.	4.087	6.26	0.173	32.25	32.25	5.4	11.
9		2 25	A. 0.	4.	4.087	6.26	0.173	32.25	32.25	5.	10.7
10		2 45	A. 0.	4.	4.044	6.26	0.173	32.25	32.25	5.	10.5
11		3	F. 0.	4.	4.094	6.26	0.173	32.25	32.25	5.3	11.1
12		3 25	F. 0.	4.	4.094	6.26	0.173	32.25	32.25	5.3	11.1
13		3 40	F. 0.	4.	4.051	6.26	0.173	32.25	32.25	5.3	11.1
14		4	A. 0.	5.333	5.4	6.26	0.173	32.25	32.25	6.2	12.1
15		4 15	A. 0.	5.333	5.4	6.26	0.173	32.25	32.25	6.3	12.
16		4 30	F. 0.	5.333	5.428	6.26	0.173	32.25	32.25	6.8	12.5
17		4 50	F. 0.	5.333	5.428	6.26	0.173	32.25	32.25	6.6	12.4
18	Sept. 16	10	A. 1.	4.	4.054	6.18	0.253	31.75	31.85	4.7	10.5
19		10 15	A. 1.	4.	4.054	6.18	0.253	31.75	31.85	4.7	10.4
20		10 30	A. 1.	4.	4.054	6.18	0.253	31.75	31.85	4.7	10.4
21		10 45	A. 1.	4.	4.054	6.30	0.133	33.50	33.60	4.5	10.3
22		11 10	A. 1.	4.	4.054	6.30	0.133	33.50	33.60	4.7	10.3
23		11 25	A. 1.	4.	4.054	6.30	0.133	33.50	33.60	4.6	10.3
24		11 40	A. 1.	4.	4.054	6.405	0.028	35.50	35.50	4.6	10.6
25		11 55	A. 1.	4.	4.054	6.42	0.013	35.50	35.50	4.7	10.6
26		1 15	A. 1.	4.	4.054	6.42	0.013	35.50	35.50	4.7	10.7
27	Sept. 21	1 35	F. 1.	4.	4.045	6.18	0.253	31.75	31.85	5.2	10.8
28		1 50	F. 1.	4.	4.045	6.18	0.253	31.75	31.85	5.1	10.6
29		2 15	F. 1.	4.	4.045	6.30	0.133	33.50	33.60	5.3	11.1
30		2 30	F. 1.	4.	4.045	6.30	0.133	33.50	33.60	5.1	10.8
31		2 45	G. 1.	4.	4.043	6.18	0.253	31.75	31.85	4.8	10.3
32		3	G. 1.	4.	4.043	6.18	0.253	31.75	31.85	4.4	10
33		3 20	G. 1.	4.	4.043	6.30	0.133	33.50	33.60	4.3	10.2
34		3 40	G. 1.	4.	4.043	6.30	0.133	33.50	33.60	4.6	10.2

Point struck.	Vibration. Gun pendulum.	Vibration. Ballistic pendulum.	Moment of the gun pendulum.	Velocity of the ball. By the gun.	Velocity of the ball. By the pendulum.	No.	Remarks.
In.	° ′ ″	° ′ ″		Feet.	Feet.		
194.	11 58 20	8 29 34	47,897	1309	1302	1	Struck opposite to fuze hole; not cracked.
193.4	11 55 20	8 21 50	47,697	1303	1289	2	
193.75	12 01 50	8 29 10	48,129	1316	1302	3	Struck like No. 1; cracked; deviation 1.2 in. to left.
194.45	14 25 20	9 46 20	57,651	1517	1494	4	Struck at fuze hole; broken in two.
194.55	14 22 30	9 46 28	57,463	1512	1493	5	Perp. to fuze hole; cracked.
194.4	14 25	9 47	57,629	1517	1496	6	At fuze hole; broken into many pieces.
194.7	18 18 40	11 39	73,077	1585	1555	7	
194.	12 31 40	9 00 40	50,110	1211	1200	8*	Two tin bands on cartridge.
194.5	12 41 40	9 07 30	50,774	1229	1211	9	
195.6	12 54 42	9 23 30	51,640	1254	1240	10	
194.7	12 31 48	9 00 40	50,119	1211	1195	11	Do. Do.
194.6	12 27 30	8 56 40	49,834	1203	1187	12*	
195.	12 34	9 03 20	50,265	1216	1199	13	
193.9	15 12 36	10 29	60,782	1421	1396	14*	
194.2	15 18 10	10 32	61,150	1431	1400	15	
194.4	14 32 40	9 59	58,137	1349	1326	16	
193.7	14 45 26	10 06 50	58,983	1372	1348	17	
194.7	12 15	8 38 10	49,004	1166	1163	18	Gun washed after 3 rounds.
194.7	12 20 36	8 40 08	49,376	1176	1168	19	
194.5	12 18 20	8 39 40	49,225	1172	1168	20	
194.9	13 25 30	9 52	53,684	1276	1258	21	
194.15	13 27 46	9 54	53,834	1281	1267	22	
193.9	13 28 46	9 50	53,900	1282	1261	23	
193.1	14 26 26	10 54	57,724	1356	1324	24	
194.1	14 26 40	11 00 20	57,739	1363	1330	25	
194.55	14 19 42	10 54 30	57,277	1351	1315	26	
193.9	11 45 08	8 17 24	47,020	1112	1122	27	Gun washed after 2 rounds.
194.55	11 52 40	8 22 40	47,531	1126	1129	28	
195.05	12 33	9 11	50,199	1182	1171	29	
194.4	12 42 20	9 17 10	50,819	1199	1187	30	
195.9	11 59 30	8 31 50	47,841	1129	1142	31	Cartridge turned over.
194.	12 04 30	8 30 24	48,306	1147	1150	32	
195.	13 05	9 44 10	52,323	1239	1241	33	
194.6	13 10 06	9 47 14	52,626	1247	1250	34	

* Ball turned over in the gun.

For the experiments on the 26th August, the shells were filled to a uniform weight (intermediate between that of the empty shell and the solid shot) with bits of lead and iron filings, in order to obtain additional data for comparing the velocities of balls of different densities, fired with the same charge of powder.

The pieces of lead, and even the iron filings, were found to be compressed into a solid mass by the concussions.

The 7th round was fired for the purpose of trying a case filled with *hard* bricks, in place of the bottom sand bag; this was found to be of better service than the soft bricks before tried, and it was more easily extracted, on account of the bricks being less pulverized.

For the experiments on the 15th September, the balls were brought to a uniform weight by pouring lead (when the ball was too light) into a hole drilled at the upper extremity of the principal axis; this hole was then stopped with an iron plug turned to fit it, driven in hard. No grommet or wad was used, but the ball was supported in the axis of the bore by means of four little *wings* of sheet iron, about ½ in. long, attached to the ball in the direction of its principal axis; these wings were too short to prevent the ball from turning over in some instances, as noted in the remarks.

The tin bands mentioned in the column of remarks were straps of tin, 0.2 in. wide, with four drops of solder on them, intended to support the cartridge also in the axis of the gun, by keeping it clear of the bottom. The weight of these bands is included in that of the cartridge; they had probably no influence on the force of the charge.

In the firing, the iron plugs were driven down to the bottoms of the holes in the balls, forcing out the lead in the holes, although the plugs and the holes were both made tapering.

For the experiments on the 16th and 21st of September, with balls of different windages, the balls were *turned* by means of an accurate and simple circular rest adapted to a lathe, and by means of the holes bored for the arbor they were adjusted in weight, like those used on the 15th. Balls of large size, for turning, were obtained from the Columbia foundry, near Georgetown, D. C., and they proved to be remarkably sound and free from air bubbles; they are of greater specific gravity than the hammered balls made for these experiments at West Point foundry.

Grommets were attached, in the usual way, to all except the largest balls, these being made to fill the bore as nearly as it was thought safe for firing. It is remarkable that all these balls struck the pendulum block with the plugs foremost; the plugs were forced, as before, to the bottoms of the holes in which they were inserted, expelling the greater part of the lead from the holes.

After the experiments of the 21st, an attempt was made to fire again one of the balls of 6.42 in. diam. which was used on the 16th, and which had been dressed over with the file and passed through the same gauge as before; but the ball stuck in the bore at about 77 in. from the muzzle, and could be extracted only by screwing a rod into it. The experiment was thought too hazardous to repeat.

November 1*st*, 1843.

In order to repeat, with more care and with different powder, the experiments on ranges, &c., the pendulum block was dismounted, and a frame to receive a sheet of lead was attached to the front pair of suspension straps, to mark the point struck by the ball at that distance from the gun; the other arrangements for observing the ranges were the same as those on the 7th and 17th of April.

Experiments on ranges,

No.	Hour.	POWDER. Kind.	POWDER. Weight.	Weight of cartridge.	BALL. Diameter.	BALL. Windage.	BALL. Weight.	Weight of ball and wad.	HEIGHT OF Cartridge.	HEIGHT OF Whole charge.	Vibration of the pendulum.
			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.	° ′ ″
1	11 20	A	4	4.044	6.26	0.173	32.32	32.42	4.6	10.3	12 28 50
2	11 30	A	4	4.044	6.26	0.173	32.27	32.37	4.5	10.3	12 34 06
3	11 45	A	4	4.044	6.26	0.173	32.22	32.32	4.5	10.3	12 40 40
4	11 55	A	5.333	5.383	6.26	0.173	32.31	32.41	5.6	11.3	15 11 50
5	12	A	5.333	5.383	6.26	0.173	32.33	32.43	5.7	11.5	15 09
6	12 10	A	5.333	5.383	6.26	0.173	32.20	32.30	5.9	11.6	15 05 30
7	1 20	A	8	8.065	6.26	0.173	32.33	32.43	8.	14.2	19 08 20
8	1 30	A	8	8.065	6.26	0.173	32.29	32.39	8.2	14.1	19 12
9	1 40	A	8	8.065	6.26	0.173	32.19	32.29	7.8	13.6	18 46 26
10	1 50	A	10.666	10.745	6.26	0.173	32.22	32.32	10.7	16.4	22 49
11	2	A	10.666	10.745	6.26	0.173	32.46	32.56	10.3	15.9	22 21 50
12	2 10	A	10.666	10.745	6.26	0.173	32.19	32.29	10.1	15.7	22 22 10
Means		A	4	4.044	6.26	0.173	32.27	32.37	4.5	10.3	12 34 32
Means		A	5.333	5.383	6.26	0.173	32.28	32.38	5.7	11.5	15 08 47
Means		A	8	8.065	6.26	0.173	32.27	32.37	8.	14.	19 02 15
Means		A	10.666	10.745	6.26	0.173	32.29	32.39	10.4	16.	22 31

November 1*st*, 1843.

Moment of the pendulum.	Initial velocity of the ball.	POINTS STRUCK BY THE BALL.								No.
		Deviation from the line of fire.						On the water.		
		At 47.35 ft. from the gun.			At 1098 ft. from the gun.					
		Right.	Left.	Above.	Right.	Left.	Below.	Range.	Depression.	
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	
49,922	1200	-	0.042	0.033	-	1.97	16.76	-	23.95	1*
50,272	1212	0.	0.	0.017	-	0.1	12.58	1412	23.81	2†
50,708	1226	-	0.008	0.017	1.7	-	15.66	1315	23.70	3
60,731	1414	0.008	-	0.054	-	2.45	9.41	1598	23.60	4
60,543	1408	-	0.013	0.075	-	2.7	13.36	1387	23.53	5
60,312	1407	-	0.017	0.042	0.	0.	13.46	1384	23.43	6
76,351	1660	-	0.013	0.038	-	2.45	9.06	1597	22.54	7†
76,593	1668	-	0.058	0.050	-	1.92	7.76	1659	22.48	8
74,908	1627	-	0.008	0.008	0.06	-	10.31	1567	22.36	9
90,845	1868	-	0.033	0.033	-	2.2	7.31	1752	22.23	10
89,065	1811	0.	0.	0.046	-	2.37	6.06	1778	22.13	11
89,087	1823	0.046	-	0.033	2.1	-	6.82	1723	22.05	12
50,301	1213	-	0.017	0.022	-	0.12	15.	1310	23.76	‡
60,529	1410	-	0.007	0.057	-	1.72	12.08	1456	23.53	
75,951	1652	-	0.027	0.032	-	1.44	9.04	1608	22.46	
89,666	1834	-	0.004	0.038	-	0.82	6.73	1751	22.14	

* Ball grazed the wharf.

† Grommet came off.

‡ First range estimated at 1200 feet.

November 2nd, 1843.

EXPERIMENTS WITH THE 32-POUNDER GUN PENDULUM, WITH BLANK CARTRIDGES.

Hour.	POWDER.		CARTRIDGE.		PENDULUM.	
	Kind.	Weight.	Weight.	Height.	Vibration.	Moment.
		Lbs.	Lbs.	In.	° ′ ″	
11 55	A.	4.	4.05	4.2	3 25 10	13,703
	A.	4.	4.05	4.2	3 23 40	13,603
	A.	5.333	5.385	5.2	4 50	19,366
	A.	5.333	5.385	5.4	4 50 30	19,399
	A.	8.	8.064	7.5	7 29 10	29,983
12 15	A.	8.	8.064	7.6	7 29	29,971
12 40	A.	10.666	10.740	9.6	9 57 26	39,858
	A.	10.666	10.740	9.7	10 02 30	40,195
	E. 2	8.	8.062	7.4	7 04 40	28,349
	E. 2	8.	8.062	7.4	7 06 30	28,471
	F. 2	8.	8.065	9.5	7 03 30	28,271
	F. 2	8.	8.065	8.8	7 06	28,438
	G. 6	8.	8.058	7.	7 38 30	30,604
1 05	G. 6	8.	8.058	7.	7 46 10	31,115
Means	A.	4.	4.05	4.2	3 24 25	13,653
	A.	5.333	5.385	5.3	4 50 15	19,388
	A.	8.	8.064	7.6	7 29 05	29,977
	A.	10.666	10.740	9.7	9 59 58	40,027
	E. 2	8.	8.062	7.4	7 05 35	28,410
	F. 2	8.	8.065	9.2	7 04 45	28,355
	G. 6	8.	8.058	7.	7 42 20	30,860

EXPERIMENTS WITH THE 24-POUNDER GUN.

February 1st, 1844.

On account of the prompt destruction of the sand cases for the core of the pendulum block, by firing the 32-pounder balls with high charges, it was determined to lay aside the 32-pounder gun for the present, and to continue the experiments with a 24-pounder, with which higher proportional charges might be conveniently used. In order to give this gun such a weight as to reduce its recoil within moderate limits, with the highest charges which it may be desirable to use, and at the same time to make the piece of undoubted strength to resist a repetition of such charges, the exterior form and dimensions of the 32-pounder gun were preserved; and as the piece was intended for use exclusively with the pendulum, it was not furnished with trunnions.

This 24-pounder gun, which is of iron, like the 32-pounder, was cast at West Point foundry; the metal has the appearance and all the characteristics of the best quality of gun iron. The length of the bore is the same as that of the siege and garrison 24-pounder, 9 feet; diameter of the vent 0.175 in.; weight 7,935 lbs.

Before replacing the pendulum block some experiments on ranges were to be made with the 24-pounder gun, in the same manner as with the 32-pounder; and for this purpose the necessary arrangements were made to-day. It was found that, on account of the more accurate fitting of the 24-pounder gun in the collars of the suspension straps, its axis deviated less than that of the 32-pounder from a plane perpendicular to the axis of the shaft, and a thinner washer was therefore substituted for the one before introduced between the straps on the right hand end of the shaft.

February 2nd, 1844.

The experiments on ranges were made to-day. The river being covered with strong ice, the points struck by the ball were marked by observers stationed on the ice, and the ranges were afterwards measured; they struck at too low an angle to break the ice, in which they left a distinct mark. The loss of two observations was probably caused by the balls striking in the channel opened by the steamboat.

The cartridge bags used in the experiments with the 24-pounder gun, are made, like those for the 32-pounder, of twilled woollen stuff; they are made with circular bottoms, and sewed on a cylinder 5.35 in. in diameter.

Experiments with the 24-pounder

No.	Hour.	POWDER.		Weight of cartridge.	BALL.			Weight of ball and wad.	WEIGHT OF		Vibration of the pendulum.
		Kind.	Weight.		Diameter.	Windage.	Weight.		Cartridge.	Whole charge.	
			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.	° ′ ″
1	1 30	A.	4	4.042	5.68	0.135	23.87	23.954	5.2	10.5	11 04
2		A.	4	4.042	5.68	0.135	24.01	24.094	5.2	10 5	11 13
3		A.	4	1.042	5.68	0.135	24.21	24.294	5.1	10.3	11 25
4		A.	6	6.050	5.68	0.135	24.17	24.254	7.3	12.6	14 13 50
5		A.	6	6.050	5.68	0.135	24.04	24.129	7.5	12.6	14 22 20
6		A.	6	6.050	5.68	0.135	24.01	24.089	7.4	12.6	14 21 10
7		A.	8	8.053	5.68	0.135	24.10	24.184	9.3	14.5	16 46 50
8		A.	8	8.053	5.68	0.135	24.03	24.109	9.2	14.3	16 28 20
9	3 30	A.	8	8.053	5.68	0.135	23.97	24.054	9.4	14.3	16 28 24
Means.		A.	4	4.042	5.68	0.135	24.030	24.114	5.2	10.4	11 14
		A.	6	6.050	5.68	0.135	24.070	24.154	7.4	12.6	14 19 07
		A.	8	8.053	5.68	0.135	24.032	24.116	9.3	14.4	16 31 31

The balls were fixed with grommets and leather straps as before, and the grommets were placed at the upper or lighter part of the ball floated in mercury, that part being turned towards the muzzle of the gun; mean weight of the 12 grommets and straps used to-day, 0.084 lbs.

The adjusting weights on the gun pendulum were the same as for the 32-pounder gun; the additional weight of 246 lbs., placed symmetrically about the axis of the gun, does not appear to have sensibly affected the height of the centre of oscillation of the system; the exact determination of that centre was left for a more favorable season.

gun pendulum, February 2nd, 1844.

Moment of the pendulum.	Initial velocity of the ball.	POINTS STRUCK BY THE BALL. Deviations from the line of fire. At 47.35 ft. from the gun.				At 1098 feet from the gun.			On the river.		No.
		Right.	Left.	Above.	Below.	Right.	Left.	Below.	Range.	Depression.	
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet	Feet.	
45,372	1437	0.046	-	-	0.013	3.5	-	10.56	1557	23.56	1
45,985	1451	0.063	-	-	0.029	2.	-	15.56	1336	.47	2
46,802	1475	0.075	-	-	0.008	2.	-	9.06	1685	.40	3
58,283	1712	-	0.029	0.	0.	0.3	-	7.71	1790	.30	4
58,861	1742	-	0.075	0.050	-	-	0.5	8.01	Lost	.24	5
58,782	1740	-	0.033	-	0.042	1.2	-	8.36	1845	.17	6
68,658	1902	0.008	-	-	0.008	-	1.	5.61	2060	.10	7
67,406	1864	-	0.033	0.013	-	0.3	-	8.21	Lost	.03	8
67,410	1868	-	0.054	0.008	-	-	1.8	6.66	1964	22.96	9
46,053	1454	0.061	-	-	0.017	2.5	-	11.73	1526	23.47	
58,642	1731	-	0.046	0.003	-	0.33	-	8.03	1826	23.24	
67,825	1878	-	0.026	0.004	-	-	0.83	6.83	1950	23.03	

March 11*th*, 1844.

The pendulum block having been remounted, the requisite adjustments of the two pendulums were verified.

In the gun pendulum, as left on the 2nd of February, the centre of oscillation was found to be still in the axis of the gun, or at 195 in. from the knife edges.

The weight of the gun being 246 lbs. greater than that of the 32-pounder, and this weight being distributed symmetrically about the axis, we have:

$$p' g' = 1,958,963 + 246 \times 195 = 2,006,933;$$

$$\text{Hence, Log. } \frac{2 p' g'}{12} \sqrt{\frac{G}{o'}} = 5.6725937.$$

The first hemisphere of lead in the pendulum block having been much bruised and deformed, it was replaced by another weighing 481 lbs.; with this change, and a slight alteration in the core, the height of the centre of oscillation of the pendulum was again determined; but as the pendulum was used in this state only for the three rounds fired on the 12th, the elements of the calculation are not set down.

March 13*th*, 1844.

The ballistic pendulum block was charged, and the centre of oscillation of the system adjusted, as follows:

	Weight.	Centre of gravity.
	Lbs.	In.
Hemisphere of lead - - - - -	481	195
2 circular pieces of board - - - -	$11\frac{1}{2}$	195
Sheet of lead on the face - - - -	7	195
4 sand bags - - - - - -	940	194.34
Adjusting weights - - - - -	917	219
Pendulum frame, with block empty - - -	9,358	170.8

Consequently, the moment of the pendulum, $p\,g = 2,079,250$.

In this condition, the pendulum was found to make 1000 oscillations in 2234 seconds, therefore $o = 195.14$.

In the experiments with solid shot, the mean value of b is 24.16 lbs., and that of i will be found nearly 195.03 in. Hence, in the formula for the velocity of the ball, we have:

$$\text{Log.}\ \frac{2\,(p\,g + b\,i)}{12} \sqrt{G\,o} = 7.9791267.$$

The bore of the 24-pounder gun was carefully measured today, the points of the calibre gauge being set to 5.815 in., the diameter at the muzzle.

Measurements of the bore of the 24-pounder pendulum gun.

Distance from the muzzle.	DIAMETER.		Distance.	DIAMETER.		Distance.	DIAMETER.	
	Vertical.	Horizontal.		Vertical.	Horizontal.		Vertical.	Horizontal.
In.	In.	In.	In.	In.	In.	In.	In.	In.
106.33	5.815	5.816	91.56	5.815	5,815	66.95	5.822	5.815
105.34	"	5.823	90.58	"	"	64.98	5.825	"
104.36	"	5.815	89.59	"	"	63.01	5.815	"
103.38	"	"	88.61	"	"	61.04	"	5.823
102.39	"	"	87.63	"	"	59.07	"	5.823
101.41	"	"	86.64	"	"	55.13	5.819	5.815
100.42	"	"	84.67	"	"	51.20	5.815	5.819
99.44	"	"	82.70	"	"	47.26	"	5.819
98.45	"	"	80.73	"	"	43.32	5.822	5.815
97.47	"	"	78.76	5.823	"	39.38	5.815	"
96.48	"	"	76.79	5.815	"	31.50	"	"
95.50	"	"	74.82	"	5.823	23.63	"	"
94.51	"	"	72.86	5.823	5.815	15.75	5.811	"
93.53	"	"	70.89	5.815	"	9.85	5.810	"
92.54	"	"	68.92	"	5.823	0.	5.815	"

No.	DATE.		POWDER.		Weight of cartridge.	BALL.			Weight of ball and wad.	HEIGHT OF		POINT	
												Lateral deviation of the ball.	
	Day.	Hour.	Kind.	Weight.		Diameter.	Windage.	Weight.		Cartridge.	Whole charge.*	Right.	Left.
	1844.			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.	In.	In.
1	Mar. 12	5	A	3	3.037	5.68	0.135	23.75	23.83	4.2	9.5	-	0.65
2		5 15	"	"	"	"	"	24.00	24.08	4.3	9.4	-	0.15
3		5 30	"	"	"	"	"	.43	.51	4.1	9.3	-	0.90
4	" 14	1 40	"	4	4.043	"	"	.16	.24	5.	10.2	0.30	-
5		2	"	"	"	"	"	.01	.09	5.2	"	-	0.60
6		2 15	"	"	"	"	"	.30	.38	5.1	"	1.4	-
7		2 30	"	6	6.053	"	"	.15	.23	7.6	12.8	0.1	-
8		2 45	"	"	"	"	"	.20	.28	7.2	12.3	-	0.1
9		3 45	"	"	"	"	"	.10	.18	7.3	12.5	-	0.5
10		4	"	8	8.06	"	"	.20	.28	9.2	14.1	0.15	-
11		4 15	"	"	"	"	"	.18	.26	9.5	14.6	-	0.2
12		4 30	"	"	"	"	"	.12	.20	9.7	14.9	-	0.2

STRUCK.	VIBRATION.		Moment of the gun pendulum.	VELOCITY OF THE BALL.		No.	REMARKS.
Distance from the axis.	Gun pendulum.	Ballistic pendulum.		By the gun.	By the pendulum.		
In.	° ′ ″	° ′ ″		Feet.	Feet.		
195.25	9 10 30	6 58	37,634	1239	1230	1	All the balls were cracked, except Nos. 2 and 3.
195.35	9 19	7 06	38,214	1249	1240	2	
195.10	9 31 10	7 16	38,919	1254	1248	3	
194.5	11 15 30	8 07 20	46,155	1450	1436	4	
195.25	11 14 50	8 10 10	46,109	1456	1448	5	The lead in the bottom of the block was deeply indented by the higher charges.
194.75	11 11 20	8 05 10	45,871	1432	1420	6	
195.4	14 15 20	9 32 40	58,385	1717	1680	7	
194.8	14 14 30	9 35 20	58,329	1711	1690	8	
195.1	14 16 20	9 33 50	58,453	1722	1690	9	
195.15	16 01	10 08	65,554	1790	1782	10	
195.1	16 46 20	10 36	68,624	1895	1866	11	
195.2	16 48	10 29 50	68,737	1903	1852	12	

No.	DATE.		POWDER.		Weight of cartridge.	BALL.			Weight of ball and wad.	HEIGHT OF	
	Day.	Hour	Kind.	Weight.		Diameter.	Windage.	Weight.		Cartridge.	Whole charge
	1844			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.
1	March 20	2 15	F. 1&2	6	6.052	5.46	0.355	21.7	21.78	8.4	13.2
2			"	"	"	"	"	"	"	8.5	13.2
3			"	"	"	"	"	"	"	8.	13.
4			"	"	"	5.57	0.245	23.4	23.48	8.3	13.
5			"	"	"	"	"	"	"	"	13.3
6			"	"	"	"	"	"	"	"	13.2
7			"	"	"	5.70	0.115	25.	25.08	"	13.2
8		4	"	"	"	"	"	"	"	"	13.4
9	" 22	9 30	A. 1&2	"	6.046	5.46	0.355	21.7	21.78	7.3	12.2
10			"	"	"	"	"	"	"	7.2	12.2
11			"	"	"	"	"	"	"	7.3	12.2
12			F. 1&2	"	6.052	5.57	0.245	23.4	23.48	8.5	13.4
13			A. 1&2	"	6.046	"	"	22.93	23.01	7.4	12.6
14			"	"	"	"	"	23.4	23.48	7.2	12.2
15			"	"	"	"	"	"	"	7.2	12.2
16			"	"	"	5.70	0.115	25.	25.08	7.1	12.2
17			"	"	"	"	"	"	"	7.2	12.3
18			"	"	"	"	"	"	"	7.4	12.5
19		11 50	"	"	"	"	"	"	"	7.4	12.5
20		2 30	B.	3	3.035	5.68	0.135	23.88	23.96	4.1	9.1
21			"	"	"	"	"	24.45	24.53	4.1	9.3
22			C.	"	"	"	"	.04	.12	4.	9.1
23			"	"	"	"	"	23.96	.04	4.1	9.2
24			D.	"	"	"	"	24.12	.20	4.1	9.4
25			"	"	"	"	"	.14	.22	4.	9.2
26			B.	6	6.045	"	"	.02	.10	7.6	12.7
27			"	"	"	"	"	.23	.31	7.4	12.4
28			C.	"	6.048	"	"	23.95	.03	7.2	12.3
29			"	"	"	"	"	24.24	.32	7.4	12.4
30			D.	"	6 052	"	"	23.98	.06	7.4	12.5
31		5 15	"	"	"	"	"	24.36	.44	7.1	12.2

Point struck.	VIBRATION. Gun pendulum.	VIBRATION. Ballistic pendulum.	Moment of the gun pendulum.	VELOCITY OF THE BALL. By the gun.	VELOCITY OF THE BALL. By the pendulum.	No.	REMARKS.
In.	° ′ ″	° ′ ″		Feet.	Feet.		
195.1	11 41	7 01 20	47,891	1381	1378	1	Gun cleaned with a brush of stiff bristles, and washed after three rounds.
195.7	11 57 30	7 09 20	49,014	1421	1400	2	
193.8	11 35	6 59 50	47,483	1366	1385	3	
195.85	12 36	8 03	51,634	1469	1450	4	
194.8	12 49 40	8 05 20	52,564	1501	1473	5	
194.6	12 13 50	7 48	50,126	1416	1423	6	
195.4	12 10	8 55 20	53,946	1522	1518	7	
195.4	13 09	8 50	53,878	1520	1503	8	
194.15	12 44	7 45 20	52,178	1536	1530	9	
194.95	12 43 20	7 46	52,133	1534	1525	10	
195.	12 47 40	7 46 30	52,427	1545	1527	11	
195.	12 28 30	7 55 30	51,124	1451	1443	12	
195.15	13 38 40	8 43 30	55,895	1649	1620	13	
195.05	13 41	8 48	56,053	1623	1602	14	
194.8	13 38 40	8 46	55,895	1618	1602	15	
194.75	13 49 40	9 27 52	57,166	1633	1615	16	
195.3	14 27 10	9 51 38	59,189	1703	1678	17	
195.2	14 44	10 04 52	60,332	1742	1711	18	Grommet struck the pendulum block.
195.4	14 42 40	10 02 30	60,241	1739	1707	19	
195.35	9 10	6 51 50	37,600	1232	1223	20	Gun washed after two rounds.
195.35	9 12 30	6 55 30	37,771	1211	1205	21	
195.3	9 20	7 02	38,282	1249	1245	22	
195.15	9 10	6 50 30	37,600	1228	1216	23	
194.3	9 20 50	6 56	38,339	1248	1230	24	
195.1	9 22	7 02 52	38,419	1250	1244	25	
195.2	13 42	9 04 32	56,121	1645	1609	26	
195.15	13 44 30	9 08 44	56,291	1638	1607	27	
195.4	13 50 40	9 08 20	56,710	1670	1622	28	
195.	14 01 20	9 22	57,435	1678	1647	29	Ball cracked.
194.6	14 04 40	9 23 20	57,661	1702	1672	30	
195.35	13 58	9 19 30	57,208	1662	1628	31	

The powder designated by No. 1 & 2, is a mixture of the two sizes of grain denoted by Nos. 1 and 2 respectively; the difference between these sizes of grain appears, by the experiments of August 12th, 1843, to be inappreciable, so far as regards the force of the charge in the gun, and they were therefore mixed together, (or not sifted out separately,) for the purpose of economizing the powder.

The balls for the experiments on windage were accurately turned and adjusted to the weights set down for them; most of them were turned from the large 32-pounder balls obtained from Columbia foundry, which, as before observed, are of remarkably sound iron, and of greater density than those cast at West Point foundry; this explains, in part, the marked difference in the weight of the turned balls of 5.7 in. diam., and the common shot of 5.68 in.; it was observed, too, that the former were not cracked by being fired against the pendulum block with a velocity of 1700 ft., whilst the latter were very often cracked with a velocity of little more than 1400 feet.

In consequence of a slight accidental derangement of the arc of the ballistic pendulum, which it is not necessary to particularize, some doubt was thrown on the result of the 6th round on the 20th, although the indications of the two pendulums correspond very nearly; a fourth round of the same powder and ball was therefore tried on the 22nd.

For the 1st and 2nd rounds on the 20th, the sand bags for the pendulum block were filled with very fine, but pure, sand; and for the 3d round, with coarse sand of a similar kind; but no difference worthy of note was remarked in the penetration of the shot. Habitually the same sand is used over repeatedly for filling the bags, adding to it, however, a portion of fresh sand.

A striking difference is remarked in the appearance of the residuum left in the bore by the combustion of the several kinds of gunpowder; that of powder A is black, but marked with streaks and spots of a blood red color; that of powder F is of a bright yellow color, softer and more easily removed than the other; the residuums of the powders B, C, and D, are of a dark grey, or slate color, and very hard; the quantity of dirt left by the powders C and D, is greater than that from the other kinds.

An additional quantity of 5 barrels of powder A was received from Frankford Arsenal, on the 14th inst.; it is from the same lot as the first 5 barrels received, and was originally inspected and received on the same day, 19th July, 1837.

No.	DATE. Day.	Hour.	POWDER. Kind.	Weight.	Weight of cartridge.	BALL. Diameter.	Windage.	Weight.	Weight of ball and wad.	HEIGHT OF Cartridge.	Whole charge
	1844.			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.
1	Mar. 26	10	A. 1	6	6.055	5.68	0.135	24.19	24.27	7.3	12.4
2			"	"	"	"	"	23.92	.00	7.2	12.5
3			B. 1	"	6.053	"	"	24.18	.26	8.1	13.2
4			"	"	"	"	"	.10	.18	7.6	12.8
5			C. 1	"	6.050	"	"	23.79	23.87	7.5	12.7
6			"	"	"	"	"	24.27	24.35	7.2	12.4
7			D. 1	"	6.056	"	"	.05	.13	7.5	12.6
8		12	"	"	"	"	"	.15	.23	7.6	12.6
9		1 20	E. 1	"	6.050	"	"	23.89	23.97	7.	12.2
10			"	"	"	"	"	24.29	24.37	7.2	12.4
11			F. 1	"	"	5.69	0.125	.20	.28	8.7	13.7
12			"	"	"	5.67	0.145	.33	.41	8.9	13.9
13			G. 1	"	6.051	5.68	0.135	.12	.20	7.2	12.4
14			"	"	"	"	"	23.89	23.97	7.4	12.6
15			A. 1&2	"	6.046	5.57	0.245	.34	.34	7.3	12.6
16		3	"	"	"	"	"	.35	.35	7.4	12.7
17	" 27	1 40	"	4	4.042	5.46	0.355	24.	24.08	5.1	10.1
18			"	"	"	"	"	"	"	"	"
19			"	"	"	"	"	"	"	"	"
20			"	"	"	5.57	0.245	"	"	"	10.2
21			"	"	"	"	"	"	"	"	"
22			"	"	"	"	"	"	"	"	"
23			"	"	"	5.70	0.115	"	"	"	10.4
24			"	"	"	"	"	"	"	"	"
25		3 40	"	"	"	"	"	"	"	"	10.3

Point struck.	Vibration. Gun pendulum.	Vibration. Ballistic pendulum.	Moment of the gun pendulum.	Velocity of the ball. By the gun.	Velocity of the ball. By the pendulum.	No.	Remarks.
In.	° ′ ″	° ′ ″		Feet.	Feet.		
195.	14 24 20	9 41 50	58,997	1735	1707	1	Gun washed after 2 rounds.
195.30	14 03 20	9 26	57,571	1702	1678	2	
195.6	13 59 30	9 21 30	57,310	1677	1644	3	
195.65	13 49 20	9 13 10	56,619	1657	1625	4	Many of the balls cracked.
196.	13 45	9 07 02	56,325	1666	1625	5	
195.8	14 05	9 27	57,684	1684	1652	6	
194.8	14 15 20	9 27	58,408	1724	1676	7	
195.1	14 20 30	9 34 30	58,736	1729	1689	8	Grommet struck the pendulum block.
194.95	13 13 40	8 35 10	54,196	1584	1531	9	
195.4	13 15 30	8 39 20	54,320	1566	1515	10	
195.3	13 11 30	8 43 18	54,048	1561	1533	11	
195.4	13 22 20	8 44	54,785	1579	1526	12	
195.75	13 49 40	9 15 40	56,642	1657	1630	13	
195.1	13 55	9 19 40	57,004	1684	1663	14	
195.5	13 32 10	8 42 20	55,453	1611	1585	15	Turned balls, without grommets or wads.
195.05	13 39 30	8 46 40	55,951	1628	1601	16	
194.5	10 03 20	6 40 52	41,237	1188	1189	17	Turned shells, 0.9 in. thick, loaded with lead.
194.8	10 10	6 40 20	41,692	1203	1186	18	
195.3	10 09 30	6 41 08	41,658	1202	1186	19	
195.35	10 44 24	7 27 36	44,036	1332	1322	20*	Turned shells, 0.95 in. thick, with lead.
194.1	10 42	7 22	43,873	1326	1317	21*	
195.1	10 46 20	7 27 30	44,168	1336	1324	22†	
194.95	11 17	8 05 20	46,257	1472	1437	23†	Not turned, 1 in. thick; loaded with lead.
195.9	11 19 24	8 10 50	46,420	1478	1446	24†	
195.55	11 18 30	8 13 30	46,359	1476	1456	25*	1.4 in thick.

* Cracked. † Broken in two.

No.	DATE.		POWDER.		Weight of cartridge.	BALL.			Weight of ball and wad.	HEIGHT OF	
	Day.	Hour.	Kind.	Weight.		Diameter.	Windage.	Weight.		Cartridge.	Whole charge.
	1844.			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.
1	Mar. 28	11 10	A.	4	4.042	5.68	0.135	27.6	27.68	5.1	10.2
2			"	"	"	"	"	"	"	5.	10.1
3			"	"	"	"	"	"	"	5.2	10.2
4		12	"	"	"	"	"	25.8	25.88	5.1	"
5		1 15	"	"	"	"	"	"	"	"	"
6			"	"	"	"	"	"	"	"	"
7			"	"	"	"	"	21.	21.08	"	"
8			"	"	"	"	"	"	"	"	"
9		2 30	"	"	"	"	"	"	"	"	10.3
10		3	"	"	"	"	"	9.21	9.29	5.	10.2
11			"	"	"	"	"	17.6	17.68	5.1	"
12			"	"	"	"	"	"	"	"	"
13			"	"	"	"	"	"	"	"	"
14			"	"	"	"	"	4.4	4.48	5.	"
15			"	"	"	"	"	"	"	5.2	10.4
16			A. 1&2	"	"	5.808	0.007	25.06	25.06	5.1	10.6
17		5	"	"	"	"	"	"	"	"	10.5

In these experiments on balls of different weights, marble and wooden balls were tried, because it was thought that shells made thin enough to reduce their weight to 9 or 10 lbs. would be broken in the gun with a charge of 4 lbs. The first lignum vitæ ball passed through the hole in the screen, but was so much broken at the instant of striking the block as to tear the sheet of lead to pieces; the whole of the ball appeared, however, to have entered the block. The second of these balls, and another fired on a subsequent day, were broken in the gun, and fragments of them went through the 2-in. oak plank of the screen.

The two large balls, for the 16th and 17th rounds, were turned, and their weights reduced as much as practicable by

Point struck.	Vibration. Gun pendulum.	Vibration. Ballistic pendulum.	Moment of the gun pendulum.	Velocity of the ball. By the gun.	Velocity of the ball. By the pendulum.	No.	Remarks.
In.	° ′ ″	° ′ ″		Feet.	Feet.		
195.	11 42 30	8 34 52	47,994	1340	1325	1*	Shells 1 in. thick, filled with lead.
195.2	11 43 10	8 34 40	48,039	1342	1324	2*	
195.3	11 44 40	8 35 38	48,141	1345	1325	3	
194.65	11 30 30	8 16 34	47,176	1399	1369	4	1.4 in. thick; with lead.
195.25	11 25 50	8 14 50	46,859	1388	1361	5	
195.55	11 22	8 13 46	46,598	1379	1356	6§	
195.1	10 38	7 25 54	43,600	1543	1507	7§	1.4 in. thick; empty.
195.5	10 35 40	7 27	43,442	1536	1508	8§	
195.	10 42 18	7 36	43,893	1555	1542	9†	
196.15	7 51	4 41 10	32,209	2195	2154	10	Marble ball; dev. 1.25 in. to right.
195.75	9 51	6 51	40,397	1654	1651	11	Shells 1 in. thick; empty. Broken in pieces.
195.35	9 54 30	6 47 40	40,635	1666	1645	12	
195.1	9 54	6 46 28	40,601	1664	1642	13	
193.	6 02 50	2 49 20	24,820	2742	2759	14	Lignumvitæ ball.
–	6 06	–	25,036	2778	–	15	Ditto; broke in gun.
194.8	12 01 30	9 02 06	49,286	1581	1538	16	
195.35	11 59	9 01 24	49,116	1574	1532	17	

* Broken in two. † Cracked. § Not cracked.

boring holes in them, and enlarging these holes at the centre of the balls; they were inserted in the gun with the axis of the hole in the axis of the gun, by screwing a small rod into the plug with which the hole in the shot was stopped.

There was some peculiarity, which cannot be explained, about the 9th round of to-day's experiments. It is almost certain that there was no error in the charge; yet its force appears to have been, in a marked degree, superior to that of the other two charges with similar balls, and several persons at a distance from the gun asked the cause of the remarkable sharpness of the report. Two other rounds were fired, with the same weight of powder and ball, on the 4th April. See the next table.

No.	DATE. Day.	Hour.	POWDER. Kind.	Weight.	Weight of cartridge.	BALL. Diameter.	Windage.	Weight.	Weight of ball and wad.	HEIGHT OF Cartridge.	Whole charge.
	1844.			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.
1	April 4	11.40	A. 1	6	6.055	5.68	0.135	18.	18.08	7.3	12.5
2		11.50	"	"	"	"	"	"	"	7.3	12.5
3		1.20	B. 1	"	6.056	"	"	"	"	7.5	12.6
4			"	"	"	"	"	"	"	7.7	12.8
5			C. 1	"	6.057	"	"	"	"	7.5	12.6
6			"	"	"	"	"	"	"	7.4	12.5
7			D. 1	"	6.050	"	"	"	"	7.2	12.4
8			"	"	"	"	"	"	"	7.3	"
9			E. 1	"	6.053	"	"	"	"	7.1	"
10			"	"	"	"	"	"	"	7.2	"
11			F. 1	"	6.054	"	"	"	"	8.6	13.7
12			"	"	"	"	"	"	"	8.4	13.3
13			G. 1	"	6.049	"	"	"	"	6.9	12.
14			"	"	"	"	"	"	"	7.	12.1
15			G. 6	"	6.045	"	"	"	"	6.4	11.7
16			"	"	"	"	"	"	"	6.3	11.4
17			A.	4	4.042	5.66	0.155	21.	21.08	5.	10.
18			E. 5	6	6.045	5.68	0.135	18.	18.08	6.6	11.9
19			"	"	"	"	"	"	"	6.7	"
20			A.	4	4.042	5.66	0.155	21.	21.08	5.	10.
21			A. 1&2	6	6.050	5.69	0.125	24.16	24.24	6.9	12.1
22		5.45	E. 1	"	"	5.67	0.145	23.98	24.06	7.2	12.3
23	April 17	1.40	A.	3	3.037	5.68	0.14	23.89	24.85	4.1	15.
24			"	"	"	"	"	24.20	25.40	4.1	14.8
25			A. m.	"	3.08	"	"	23.88	23.96	5.3	9.8
26			"	6	6.12	"	"	24.12	24.20	10.4	15.1
27			"	6	"	"	"	24.	24.08	10.2	15.2
28			"	3	3.08	"	"	24.15	24.23	5.3	9.9
29			A.	"	3.037	"	"	23.96	26.08	4.1	15.
30			"	"	3.03	"	"	24.16	24.24	4.6	9.6
31			"	"	"	"	"	24.06	24.14	4.5	9.5
32			"	"	"	"	"	23.98	24.06	4.5	9.6
33			"	4	4.038	"	"	4.42	4.50	5.1	10.4
34			"	"	"	"	"	9.28	9.36	5.1	10.5
35			"	"	"	"	"	9.27	9.35	5.1	10.3
36			"	6	6.043	"	"	24.21	24.29	8.3	13.3
37			"	"	"	"	"	24.16	24.24	8.3	13.2
38		5.40	"	"	"	"	"	24.09	24.17	8.3	13.4

Point struck.	VIBRATION. Gun pendulum.	Ballistic pendulum.	Moment of the gun pendulum.	VELOCITY OF THE BALL. By the gun.	By the pendulum.	No.	REMARKS.
In.	° ′ ″	° ′ ″		Feet.	Feet.		
195.8	12 39 30	8 06 42	51,872	1923	1912	1	The balls were shells 1 in. thick, filled with sand and saw-dust, and plugged with wood; all broken into small pieces.
195.3	12 58 50	8 16 38	53,187	1983	1955	2	
195.5	12 18 40	7 44 50	50,455	1859	1829	3	
195.55	12 26	7 47 20	50,954	1882	1838	4	
195.5	12 36	7 57 36	51,634	1911	1879	5	
195.15	12 22 48	7 46 48	50,736	1872	1840	6	Grommet struck the pendulum block.
194.25	12 36 40	7 57	51,679	1915	1889	7	
195.5	12 32 40	7 55 40	51,407	1903	1871	8	
194.8	11 47 30	7 07 20	48,328	1762	1687	9	
195.1	11 51	7 14	48,572	1773	1711	10	
196.3	11 48	7 21 28	48,368	1764	1730	11	Deviated 1.1 in. to the right. (11, 12)
196.	11 42 22	7 12 20	47,984	1747	1697	12	
194.5	12 13	7 42 26	50,070	1842	1829	13	
195.35	12 26 50	7 54 40	51,010	1884	1869	14	
195.15	13 01	8 27 00	53,304	1989	1998	15	
196.	12 54 36	8 20 50	52,899	1971	1965	16	Sheet lead on the block torn to pieces.
195.05	10 35	7 24 50	43,396	1527	1504	17	Shell 1.4 in. thick; not cracked.
194.5	12 24 26	7 43	50,847	1877	1831	18	
194.55	12 26 20	7 48 40	50,976	1883	1853	19	
194.85	10 32 34	7 24 50	43,230	1521	1505	20	Shell 1.4 in. thick; cracked.
194.75	13 24 40	8 53 50	54,943	1600	1571	21	2 kinds of powder mixed together in equal parts. (21, 22)
193.9	13 46 50	9 02 20	56,437	1653	1615	22	
196.45	9 13 44	6 42 20	37,855	1197	1189	23	Hay wad; ball 3.2 in. to left.
195.4	9 31 24	6 49	39,060	1216	1200	24	Do. do. 1.15 in. to right.
195.	7 43	5 29 32	31,662	1006	982	25	Balls strapped with grommets; cartridge bags double. (25–28)
195.65	10 54 20	6 52	44,713	1233	1211	26	
196.8	10 57	6 58	44,895	1245	1227	27	
195.3	7 45 20	5 32 40	31,822	1002	978	28	
195.2	9 31	6 31 10	39,032	1185	1160	29	Greased junk wad; ball struck 4.85 in. to left.
194.8	9 11	6 48 10	37,668	1219	1203	30	Cartridges 5 in. diameter. (30–32)
195.1	9 11 30	6 51	37,702	1225	1214	31	
196.1	9 06 50	6 46	37,384	1217	1198	32	
-	5 59 20	-	24,580	2696	-	33	Lignum vitæ ball; broke in gun.
194.65	7 44 20	4 41 38	31,753	2140	2160	34	Marble balls. (34, 35)
194.4	7 42 30	4 39 10	31,628	2131	2146	35	
195.7	14 01 44	9 12 24	57,462	1678	1616	36	Ball cracked.
195.	14 10 44	9 24 20	58,073	1703	1661	37	Cartridges 5 in. diameter. (37, 38)
195.2	14 06	9 20	57,752	1696	1651	38	

Remarks on the experiments of April 17th, 22nd, and 23d.

April 17th. The lead in the bottom of the pendulum block having again become much deformed, there was substituted for it to-day a block composed of 4 parts of lead and 1 of tin, in order to make it harder and more capable of resisting the compression caused by the balls. The weight of this block is $501\frac{1}{2}$ lbs., and an oak board weighing 8 lbs. is placed over it; the sheet lead on the face of the pendulum weighs $7\frac{1}{2}$ lbs.; the four sand bags weigh $230 + 238 + 230 + 238 = 936$ lbs. The moment of the pendulum is therefore:

$$p\,g = 9358 \times 170.8 + 516 \times 195 + 936 \times 194.34 + 917 \times 219 = 2{,}081{,}691;$$

and the centre of oscillation being still at 195.14 in. from the axis, we have:

$$\text{Log.}\ \frac{2(pg + bi)}{12} \sqrt{Go} = 7.9796345.$$

In the experiments to-day it was intended to compare the effects of using various kinds of wads. The hay wads fitted tight in the bore of the gun; the junk wad was not very tight, and it was well covered with tallow to diminish its friction, the intention being to try also some wads that were not greased; but in firing with two of the hay wads and one junk wad, the deviations of the ball at the face of the pendulum block were so great that the experiments were discontinued, for fear of striking the iron part of the block; the ball fired with the junk wad narrowly missed the edge of the face plate, and nearly destroyed the outer sand bag.

In firing the wooden and marble balls the outer sand bag was omitted, and its place supplied by iron rings of the same weight.

The bags for the cartridges of 5 in. diam. were made, in other respects, like those before used.

As the bore of the gun was not supposed to be sensibly enlarged, it was not again measured until the 18th June, when there was found to be an enlargement, at the seat of the shot, of about 0.01 in.; one-half of this enlargement has been attributed to the effect of the firing previously to the present date, and the windage is accordingly estimated by the diameter of 5.82 in.

April 22nd. The percussion primers used in to-day's experiments were wafers, which were fired by means of a lock arranged for the purpose by Mr. Hidden; the lock has a strong spring, but it is set to go off at a slight touch; so that, by pulling the trigger, no motion is communicated to the pendulum; the object was perfectly accomplished and the lock never failed to fire the charge.

The cartridges were filled on the 18th, since which time the weather has been wet.

April 23d. The anomaly in the height of the cartridge for the 7th round to-day, can be explained only by supposing that a bag for a cartridge of 5 in. diam. was inadvertently used.

The cartridge bags for the 37th and 38th rounds were made on a former of very nearly the diameter of the bore, and after they were filled, the bags were closed by folding down and sewing the stuff, so that the powder may be regarded as occupying the least possible height in the bore of the gun.

For the 39th round, the core of the pendulum block was formed of a wooden case, or barrel, filled with sand; the penetration of the ball was the same as before; the staves of the barrel were pressed so closely against the sides of the block as to make it difficult to remove them. This barrel of sand weighed 722 lbs., and the centre of oscillation of the pendulum, with this core in the block, appeared to be at 194.8 in. from the axis.

No.	DATE. Day.	Hour	POWDER. Kind.	Weight.	Weight of cartridge.	BALL. Diameter.	Windage.	Weight.	Weight of ball and wad.	HEIGHT OF Cartridge.	Whole charge
	1844.			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.
1	April 22	10	F. 1	3	3.034	5.68	0.14	24.14	24.22	4.6	9.8
2			"	"	"	"	"	24.17	24.25	4.8	9.8
3			"	"	"	"	"	23.81	23.89	4.8	9.8
4			"	"	"	"	"	24.24	24.32	4.8	9.8
5			"	"	"	"	"	24.12	24.20	4.7	9.7
6			"	"	"	"	"	23.91	23.99	4.9	9.9
7			G. 6	6	6.04	"	"	24.27	24.35	6.9	11.9
8		12	"	"	"	"	"	.24	.32	7.	12.1
9		1	"	"	"	"	"	.24	.32	6.8	12.
10			"	"	"	"	"	.26	.34	6.7	11.8
11			"	"	6.045	"	"	.19	.27	7.4	12.6
12			"	"	"	"	"	.28	.36	7.4	12.6
13			H.	3	3.033	"	"	.10	.18	4.3	9.5
14			"	"	"	"	"	.32	.40	4.3	9.5
15			"	"	"	"	"	.02	.10	4.4	9.6
16			"	6	6.043	"	"	.13	.21	7.7	12.8
17			"	"	"	"	"	.33	.41	7.7	12.9
18		3 10	"	"	"	"	"	.05	.13	7.8	13.
19	April 23	11	F. 2	"	6.057	"	"	23.91	.00	8.6	13.8
20			"	"	"	"	"	24.31	.39	8.6	13.8
21			E. 5	"	6.043	"	"	.03	.11	6.9	12.1
22			"	"	"	"	"	.23	.31	6.8	12.
23		12	A. 3	"	6.05	"	"	.08	.16	7.7	12.8
24		1 15	"	"	"	"	"	.21	.29	7.6	12.8
25			B. 3	"	"	"	"	.19	.27	8.3	13.4
26			"	"	"	"	"	.23	.31	7.5	12.7
27			C. 3	"	"	"	"	.02	.10	7.5	12.6
28			"	"	"	"	"	.27	.35	7.8	13.
29			D. 3	"	6,045	"	"	.01	.09	7.6	12.8
30			"	"	"	"	"	.34	.42	7.7	12.9
31			E. 3	"	"	"	"	.01	.09	7.5	12.7
32			"	"	"	"	"	.31	.39	7.	12.
33			F. 0	"	6.054	"	"	.15	.23	8.9	14.
34			"	"	"	"	"	.04	.12	9.	14.
35			A. 0	"	6.05	"	"	.00	.08	8.6	13.6
36			"	"	"	"	"	.25	.33	8.4	13.5
37			A.	"	"	"	"	.07	.15	6.8	12.
38		4 30	"	"	"	"	"	.00	.08	6.9	12.
39		5	E. 2	"	6.035	"	"	.14	.22	7.2	12.35

Point struck.	Vibration. Gun pendulum.	Vibration. Ballistic pendulum.	Moment of the gun pendulum.	Velocity of the ball. By the gun.	Velocity of the ball. By the pendulum.	No.	Remarks.
In.	° ′ ″	° ′ ″		Feet.	Feet.		
195.4	9 04 20	6 47 30	37,214	1203	1198	1	Fired with tubes. (1–3)
195.2	8 58	6 39	36,781	1186	1173	2	
195.7	9 01 50	6 44 24	37,043	1212	1204	3	
195.15	8 58 24	6 38	36,809	1183	1167	4	Fired with a percussion lock. (4–8)
194.8	9 08 30	6 49 40	37,498	1214	1209	5	
195.4	9 02 20	6 43 40	37,077	1208	1198	6	
194.85	14 31 40	9 53	59,494	1745	1738	7	
195.3	14 32	9 53 40	59,517	1748	1738	8	
194.9	14 27 40	9 47	59,223	1738	1722	9	Tubes. (9–10)
195.15	14 35	10 01 10	59,721	1754	1760	10	
194.	14 18 40	9 35 26	58,612	1719	1700	11	Cartridges 5 in. diameter. (11–12)
195.7	14 27 20	9 50	59,200	1735	1721	12	
195.45	9 09 40	6 51 20	37,577	1218	1211	13	
195.	9 14 40	6 56 30	37,919	1221	1218	14	
194.7	9 09	6 48 50	37,532	1220	1213	15	
195.05	13 39	9	55,917	1629	1591	16	
196.	13 47 30	9 10 20	56,495	1637	1600	17	
195.9	13 46 40	9 08 40	56,438	1652	1615	18	
195.5	12 59 30	8 32 34	53,232	1546	1520	19	
195.4	12 59	8 30	53,198	1523	1489	20	
194.45	13 55	9 12 04	57,004	1673	1638	21	
194.8	13 59 10	9 20 30	57,287	1671	1646	22	
194.25	13 57 50	9 16	57,197	1677	1648	23	
196.3	13 53 40	9 15	56,914	1659	1619	24	
195.5	13 45 50	9 07 40	56,382	1641	1606	25	
194.55	13 48 30	9 07 40	56 563	1645	1611	26	
194.5	13 51 20	9 06 38	56,755	1665	1616	27	
194.25	13 52	9 07 20	56,801	1651	1606	28	
195.45	13 46 30	9 09 50	56,427	1654	1625	29	
194.75	13 53	9 13	56,868	1649	1617	30	
195.1	13 33	8 50 40	55,510	1621	1571	31	
194.45	13 48	9 06	56,529	1639	1601	32	
195.2	12 27 40	8 13 20	51,067	1457	1451	33	
194.9	12 48 10	8 31 38	52,462	1512	1514	34	
194.85	14 05	9 17 40	57,684	1699	1653	35	
194.7	14 18 30	9 30	58,601	1715	1674	36	
194.45	13 09 30	8 49	53,912	1561	1567	37	Cartridges of the diameter of the bore. (37–38)
195.05	13 15 40	8 50 10	54,332	1580	1570	38	
195.2	13 22 30	8 56	54,796	1589	1544	39	

No.	DATE.		POWDER.		Weight of cartridge.	BALL.			Weight of ball and wad.	HEIGHT OF	
	Day.	Hour.	Kind.	Weight.		Diameter.	Windage.	Weight.		Cartridge.	Whole charge.
	1844.			Lbs	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.
1	April 25	2	A 1&2	4	4.04	5.808	0.012	25.06	25.06	5.2	10.2
2			A	3	3.034	5.68	0.14	24.10	24.18	4.	9.1
3			"	"	"	"	"	.03	.11	"	"
4			"	"	"	"	"	.20	.28	"	"
5			"	6	6.043	"	"	.28	.36	7.5	12.6
6			"	"	"	"	"	.23	.31	7.2	12.4
7		3 30	"	"	"	"	"	.17	.25	"	"
8		4 30	"	"	6.045	"	"	.12	.20	7.5	12.6
9			"	10	10.055	"	"	.33	.41	11.1	16.2
10			"	"	"	"	"	23.98	.06	11.8	16.7
11		5 30	"	"	10.060	"	"	24.33	.41	12.3	17.4

One object of to-day's experiments was to ascertain if the effect of closing the vent of the gun is appreciable by its influence on the velocity of the ball.

The arrangement of the apparatus for closing the vent was suggested by that proposed for Mr. Colson's eprouvette, in the 4th No. of the "Mémorial de l'Artillerie."

The apparatus is represented in PLATE III; it consists of a block of wrought iron, hollowed out on the under part to fit the gun, and having a small hole through it to correspond with the vent of the gun when the block is in place; this block is bored longitudinally, to receive a hollow conical plug of cast steel which is ground to fit tight in its place when pushed down to the bottom of the bore in the block; the plug has also a transverse hole, or vent, through it, which corresponds with that in the block when the plug is drawn out about 0.4 in. from the

Point struck.	Vibration. Gun pendulum.	Vibration. Ballistic pendulum.	Moment of the gun pendulum.	Velocity of the ball. By the gun.	Velocity of the ball. By the pendulum.	No.	Remarks.
In.	° ′ ″	° ′ ″		Feet.	Feet.		
194.85	12 01 35	9 29 10	49,520	1587	1582	1	Vent closed.
193.8	9 21	6 54 50	38,526	1254	1232	2	Do.
195.3	9 24 20	7 03 50	38,755	1266	1253	3	Do.
195.9	9 23 10	7 04	38,675	1254	1240	4	Do.
195.	14 07 20	9 30 10	58,100	1697	1669	5*	
194.6	14 19	9 41 24	58,903	1727	1709	6	Do.
195.2	14 11 50	9 31 08	58,414	1714	1678	7	Do.
195.2	13 52 30	9 17 30	57,095	1671	1642	8	Do.
195.35	17 12 30	10 19 30	70,396	1774	1807	9	
195.5	18 38 50	11 02	76,232	1989	1957	10	
195.	18 55 10	11 12 20	77,335	2001	1964	11	Ball cracked.

*Vent stopper did not act perfectly.

bottom of its lodgement in the block, so that, in that position, there is a direct communication open with the bore of the gun. The hollow plug is charged with a small quantity of fine, quick (sporting) powder, over which a paper wad is rammed; it is then placed in the position above described, and the charge is fired by means of a small piece of quick match inserted in the upper part of the vent in the iron block; the charge in the gun is ignited with certainty, although there is no priming in the proper vent of the piece; but before the explosion of the charge the conical plug has recoiled to the bottom of its lodgement, and effectually closed the vent, as is proved by the distinct impression made on the under side of the plug by the gas which tends to escape in that direction.

After the discharge, the plug is again driven out, through a hole made for the purpose in the bottom of the iron block; the plug should be fitted so as to bear against the bottom at nearly the same time that it becomes wedged in its seat, otherwise too great a force is required to drive it out; on the other hand, if the plug touches the bottom before it binds on the sides, it will fly out again, and not produce the desired effect; the latter case occurred at the 5th round in to-day's experiments.

The gun being without a lock piece, or other projection at the vent, the vent stopper was secured to it by a broad band of ½-in. iron, which was put on hot and keyed underneath; but unfortunately, with the view of making it fit more closely to the gun, the workmen put a piece of sheet lead between the block and the gun; this lead was expelled with great force at the first discharge, and the tightness of the joint was consequently impaired, as the vent stopper was jarred from its place and had to be refitted at each fire; there was evidently some escape of gas between it and the surface of the gun, but it is believed the loss was quite inconsiderable.

The weight of the vent stopper and band was 41 lbs. For the first round to-day the core of the pendulum block was formed (like that for the last round on the 23d) of a barrel filled with sand. For the other experiments the leather cases were used as before; the impression made by the balls fired with the charge of 10 lbs. seemed to be but little greater than that with 6 lbs.

Up to this time the vent of the gun had not been particularly examined, as no alteration of the exterior orifice appeared to have occurred, and as it was not supposed that the vent could be much enlarged by the comparatively small number of discharges which had been made; but after the experiments to-day, it was observed that the exterior orifice of the vent was sensibly enlarged, and its form no longer round. A careful examination was therefore made, when it was found that the exterior opening of the vent was about 0.25 in., and that it was enlarged gradually to the bottom, where the impression of the opening, taken with wax, was of the form and dimensions represented in *Fig. A*, PLATE III. By the necessity which this enlargement of the vent produced, of bouching the gun, an opportunity was soon presented of perfecting the adjustment of the vent stopper, which was accordingly done in the manner represented in the drawing, and described under date of July 16th.

It may be well to remark that no sensible vibration of the gun pendulum is produced by firing the charge in the vent stopper alone.

May 28th, 1844.

In consequence of the great deviations in the direction of the balls, occasioned by the use of wads, in the experiments on the 17th April, I was induced to try further experiments on this subject.

For this purpose I used a 24-pounder gun, which was mounted on a garrison (barbette) carriage, near the ballistic pendulum; the chassis was blocked up underneath, and a block of wood was substituted for the elevating apparatus, to support the breech of the gun, so that the bore might be accurately levelled at each fire, and directed uniformly alike.

At 50 feet from the muzzle of the gun was erected a frame for a target, of poplar boards $\frac{3}{8}$ of an inch thick and 2 feet square, the centre of which was in the prolongation of the axis of the bore when level; these boards were renewed at each fire.

A second target was placed on the wharf, (see PLATE 1,) at 1004 feet from the muzzle of the gun, and the direction of the line of fire marked on it.

The axis of this gun is 6.75 in. above that of the pendulum gun, and consequently 17.62 ft. above the surface of the wharf.

The diameter of the bore of the gun is 5.833 in.

Length of bore is 108 in.

The balls were all of 5.69 in. diameter.

The cartridge bags were like those used for the pendulum experiments.

The points struck by the balls at the first target were observed with the view of comparing the results with the theo-

Experiments on the use of wads, with a

No.	POWDER. Kind.	POWDER. Weight.	BALL. Windage.	BALL. Weight.	WAD. Kind.	WAD. Weight.	Weight of ball and wad.	DEVIATION At Above.	DEVIATION At Below.
		Lbs.	In.	Lbs.		Lbs.	Lbs.	In.	In.
1	W	6	0.143	24.39	Junk; placed on the ball.	2.24	26.63	-	3.25
2	"	"	"	.28		2.22	.50	-	0.5
3	"	"	"	.18		2.03	.21	0.5	-
4	"	"	"	.12	Hay; do.	1.07	25.19	1.5	-
5	"	"	"	.16		0.98	.14	1.25	-
6	"	"	"	.08		1.30	.38	-	0.75
7	"	"	"	.16	Sabot next the powder; grommet over the ball.	0.85	25.01	1.	-
8	"	"	"	.17		.85	.02	1.	-
9	"	"	"	.15		.85	.00	0.5	-
10	"	"	"	.54	A grommet on the powder, and another over the ball.	0.16	24.70	1.25	-
11	"	"	"	.02		.16	.18	0.75	-
12	"	"	"	.16		.16	.32	1.	-
13	"	"	"	.12	Grommet strapped over the ball.	0.08	24.20	1.	-
14	"	"	"	.10		.08	.18	1.25	-
15	"	"	"	.16		.08	.24	0.	0.
16	"	"	"	.07	Junk wad on powder and another on ball.	4.39	28.46	0.25	-
17	"	"	"	.09		4.36	.45	0.	0.
18	"	"	"	23.98	Junk wad on powder; hay wad on ball.	3.45	27.43	-	4.5

retical computation, by means of the equation of the trajectory and Lombard's method of determining the initial velocity of a ball.

The results of these experiments are exhibited in the following tabular view:

24-pounder gun, May 28th and 29th, 1844.

OF BALL FROM LINE OF AXIS OF GUN.					No.	REMARKS.
50 feet.		At 1004 feet.				
Right.	Left.	Below.	Right.	Left.		
In.	In.	Feet.	Feet.	Feet.		
3.38	-	16.27	4.1	-	1	These wads were somewhat smaller than the bore of the gun.
1.38	-	8.02	-	1.55	2	
1.	-	6.32	0.	0.	3	
1.25	-	2.37	-	1.3	4	Wads full size of the bore, and rammed in with some difficulty.
2.	-	5.72	4.8	-	5	
4.	-	10.37	4.7	-	6	
1.25	-	3.17	0.2	-	7	The grommets were held on the ball by leather straps nailed to the sabots.
1.25	-	4.62	3.5	-	8	
1.	-	5.72	0.2	-	9	
0.	0.	3.32	-	0.4	10	Grommets inserted separately, by using a rammer with a large head, (32-pounder).
0.5	-	5.52	1.4	-	11	
0.5	-	5.07	-	0.55	12	
1.5	-	4.62	0.	-	13	Balls prepared like those for the pendulum experiments.
1.	-	4.37	1.8	-	14	
0.	0.	6.92	-	0.2	15	
-	1.	7.52	-	4.75	16	The wads on the powder were greased with tallow.
-	1.5	8.52	-	4.6	17	
0.	0.	16.42	-	0.55	18	

No.	DATE. Day.	DATE. Hour.	POWDER. Kind.	POWDER. Weight.	Weight of cartridge.	BALL. Diameter.	BALL. Windage.	BALL. Weight.	Weight of ball and wad.	HEIGHT OF Cartridge.	HEIGHT OF Whole charge.
	1844.			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.
1	June 15	9	K. 1. r.	6	6.048	5.68	0.145	24.35	24.43	7.5	12.6
2			"	"	"	"	"	.01	.09	.5	.6
3			"	"	"	"	"	.26	.34	.5	.6
4			"	"	"	"	"	.22	.30	.5	.6
5			K. 1. g.	"	6.053	"	"	23.96	.04	.4	.5
6			"	"	"	"	"	24.07	.15	.2	.4
7			"	"	"	"	"	23.92	.00	.4	.5
8			"	"	"	"	"	24.20	.28	.2	.3
9			L. 1	"	6.05	"	"	.10	.18	.1	.3
10			"	"	"	"	"	.23	.31	.1	.3
11			"	"	"	"	"	.28	.36	.1	.2
12			"	"	"	"	"	23.97	.05	.2	.3
13			M. 1	"	6.053	"	"	24.25	.33	.5	.6
14		12	"	"	"	"	"	.01	.09	.5	.5
15		1 15	"	"	"	"	"	23.99	.07	.2	.3
16			"	"	"	"	"	24.18	.26	.3	.4
17			N.	"	6.05	"	"	.17	.25	.5	.5
18			"	"	"	"	"	.25	.33	.5	.5
19			"	"	"	"	"	.25	.33	.1	.3
20		2 30	"	"	"	"	"	.10	.18	.4	.4

Point struck.	VIBRATION.		Moment of the gun pendulum.	VELOCITY OF THE BALL.		No.	REMARKS.
	Gun pendulum.	Ballistic pendulum.		By the gun.	By the pendulum.		
In.	° ′ ″	° ′ ″		Feet.	Feet.		
195.	13 48 30	9 13 38	56,563	1635	1616	1	Gun washed after four rounds.
195.	35 50	9 03	55,714	1626	1608	2	
194.9	27 05	8 59 30	55,109	1590	1582	3	
195.4	37 30	9 09 12	55,815	1617	1609	4	
195.3	48 20	9 15	56,552	1659	1644	5	
195.8	25 26	8 58 24	54,995	1597	1584	6	
195.45	27 44	8 56 10	55,151	1611	1586	7	
194.8	26	9 01 20	55,034	1591	1592	8	Powders K, L, and M, leave a yellow residuum in the gun; powder N, a black residuum.
194.9	52 30	9 11 06	56,812	1659	1627	9	
195.95	46 28	9 14 14	56,402	1637	1618	10	
195.15	32 26	9 15 40	55,458	1601	1626	11	
194.9	39 30	9 02 34	55,815	1632	1610	12	
195.4	54 30	9 17 40	56,970	1655	1632	13	
194.7	56	9 14 40	57,072	1674	1645	14	
195.	36 20	9 04	55,736	1628	1612	15	
194.9	54 42	9 19 20	56,984	1660	1645	16	
195.35	26	9 02 20	55,034	1593	1592	17	
195.9	24 40	9 01	54,943	1585	1579	18	
194.65	24	8 59 20	54,898	1583	1584	19	
195.	42	9 07 20	56,121	1635	1615	20	

No.	DATE. Day.	Hour	POWDER. Kind.	Weight.	Weight of cartridge.	BALL. Diameter.	Windage.	Weight.	Weight of ball and wad.	HEIGHT OF Cartridge.	Whole charge
	1844.			Lbs.	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.
1	June 17	1 20	R. 15′	6	6.053	5.68	0.145	24.32	24.40	8.9	13.9
2			"	"	"	"	"	.20	.28	8.8	13.9
3			"	"	"	"	"	.32	.40	8.8	13.8
4			R. 30′	"	6.047	"	"	.17	.25	8.1	13.
5			"	"	"	"	"	.19	.27	8.2	13.2
6			"	"	"	"	"	.26	.34	8.5	13.5
7			R. 60′	"	"	"	"	.17	.25	8.2	13.2
8			"	"	"	"	"	.20	.28	7.9	13.
9			"	"	"	"	"	.21	.29	8.1	13.2
10			R. 90′	"	"	"	"	.04	.12	7.8	13.
11			"	"	"	"	"	23.90	23.98	8.2	13.4
12			"	"	"	"	"	.87	23.95	8.	13.1
13			S.	"	6.040	"	"	24.17	24.25	8.	13.1
14			"	"	"	"	"	.33	.41	7.7	12.8
15			"	"	"	"	"	.34	.42	7.9	13.
16			T.	"	"	"	"	.06	.14	7.8	13.
17			"	"	"	"	"	23.99	.07	7.9	13.
18		5	"	"	"	"	"	24.00	.08	7.4	12.6
19	June 18	10 45	A.	"	6.06	"	"	.10	.18	7.3	12.5
20			"	"	"	"	"	.20	.28	7.3	12.4
21			"	4	4.042	5.635	0.19	30.8	30.88	5.2	10.3
22			"	"	"	"	"	"	"	5.2	10.3
23			"	"	"	"	"	"	"	5.3	10.5
24		12	A. 1&2	6	6.06	5.68	0.145	24.20	24.28	7.3	12.3
25		1 15	A.	12	12.085	"	"	.26	.34	15.3	20.1
26		1 30	"	"	"	"	"	.10	.18	14.1	19.1

Point struck.	Vibration. Gun pendulum.	Vibration. Ballistic pendulum.	Moment of the gun pendulum.	Velocity of the ball. By the gun.	Velocity of the ball. By the pendulum.	No.	Remarks.
In.	° ′ ″	° ′ ″		Feet.	Feet.		
195.25	12 54 30	8 34 10	52,892	1509	1501	1	Gun washed after 3 rounds.
195.35	12 45 40	8 22 20	52,292	1495	1473	2	
195.10	13 18 10	8 44 50	54,501	1565	1534	3	
196.2	12 44	8 28 30	52,178	1492	1487	4	
195.	12 53 20	8 33	52,813	1514	1508	5	
194.7	13 08 06	8 39 30	53,840	1546	1525	6	
195.	12 51	8 25	52,654	1509	1482	7	
195.	13 15 20	8 48 10	54,309	1565	1552	8	
194.65	13 11 10	8 43	54,026	1555	1539	9	
194.3	13 39 30	9 03	55,952	1633	1612	10	
194.9	13 40 20	9 00 10	56,008	1643	1602	11	
195.15	13 56	9 14 20	57,072	1683	1650	12	
195.1	13 57 20	9 21	57,163	1665	1649	13	
195.15	13 34 30	9 03 30	55,612	1604	1587	14	
195.	14	9 20	57,344	1663	1636	15	
195.	11 36 40	7 27	47,596	1337	1321	16	Smoke very dense, and the gun very foul.
195.6	11 26 50	7 19	46,926	1281	1297	17	
195.85	11 43	7 33	48,027	1356	1337	18	
193.9	13 59 30	9 22	57,310	1676	1667	19	
195.05	13 33 50	9 03	55,566	1609	1595	20	
194.	12 06	8 45 40	49,593	1233	1220	21	Shells 0.5 in. thick, filled with lead.
194.55	12 05	8 46 50	49,525	1231	1220	22	
195.	12 08	8 54 20	49,729	1237	1234	23*	
195.6	14 07 46	9 27 10	57,872	1690	1661	24	
195.	20 41 50	11 31 40	84,526	2065	2026	25	Balls cracked.
194.9	19 41 30	11 59 40	80,461	1946	1946	26	

*This shell made an *oval* hole in the lead on the face of the pendulum block, in consequence probably of the shell undergoing a change of form in the gun.

June 18*th*, 1844.

After the experiments to-day, the vent of the gun was again examined; the exterior orifice is perceptibly, though slightly, more enlarged; the form and size of the interior opening are represented by *Fig. B*, PLATE III.

The bore of the gun was again measured, in the same manner as on the 13th of March, with the following results:

Measurements of the bore of the 24-pounder gun.

Distance from muzzle.	DIAMETER.		Distance.	DIAMETER.		Distance.	DIAMETER.	
	Vertical.	Horizontal.		Vertical.	Horizontal.		Vertical.	Horizontal.
Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
106.33	5.83	5.847	91.56	5.827	5.823	66.95	5.827	5.815
105.34	.83	.839	90.58	.827	.821	64.98	.827	.815
104.36	.827	.831	89.59	.818	.821	63.01	.819	.823
103.38	.835	.831	88.61	.819	.819	61.04	.815	.823
102.39	.839	.839	87.63	.819	.819	59.07	.819	.815
101.41	.847	.835	86.64	.819	.819	55.13	.819	.815
100.42	.847	.835	84.67	.819	.819	51.20	.815	.823
99.44	.827	.827	82.70	.819	.819	47.26	.819	.815
98.45	.827	.825	80.73	.817	.817	43.32	.821	.815
97.47	.831	.823	78.76	.823	.818	39.38	.815	.819
96.48	.825	.823	76.79	.817	.819	31.50	.819	.815
95.50	.825	.823	74.82	.815	.819	23.63	.819	.819
94.51	.823	.823	72.86	.827	.817	15.75	.819	.817
93.53	.823	.823	70.89	.815	.821	9.85	.821	.817
92.54	.825	.823	68.92	.815	.823	0.	.819	.823

A comparison of these measurements with the former shows an enlargement of the bore to a mean diameter of about 5.825 in., at the seat of the shot with a charge of 6 lbs.; this diameter has therefore been used in estimating the windage of the balls, in the experiments made since the 15th inst.

July 16th, 1844.

Since the experiments of the 18th of June, the 24-pounder gun has been bouched with a copper vent piece, having a vent 0.175 in. in diameter; this vent piece was left projecting above the gun for the purpose of attaching to it the vent stopper used in the experiments of April 25th.

The vent stopper was screwed on the top of the vent piece, in the manner represented in PLATE III. This arrangement furnished the means of repeating, in a more satisfactory manner, the experiments on the effect of closing the escape from the vent.

In these experiments, the impression of the blast on the under side of the vent stopper showed that the vent was perfectly closed at the 1st, 2d, 3d and 6th rounds; a distinct impression, but not equally strong, was made at the 4th and 5th rounds; but as the conical plug was, in those two instances, thrown out of its seat, by striking against the bottom of it, some doubt may exist as to the vent having been closed at the time of the explosion of the charge in the gun.

The vent being now in the same condition as at the beginning of the experiments with this gun, (on the 12th of March,) three charges of powder A were fired in order to determine what effect on the velocity of the ball might be traced to the sensible alteration which has taken place in the diameter of the bore about the seat of the charge.

The trial of powder W, on the 17th of July, was with the view of ascertaining the initial velocity of the balls fired with that powder, in the experiments with wads, on the 28th and 29th of May.

No.	DATE.		POWDER.		Weight of cartridge.	BALL.			Weight of ball and wad.	HEIGHT OF	
	Day.	Hour.	Kind.	Weight.		Diameter.	Windage.	Weight.		Cartridge.	Whole charge
	1844.			Lbs	Lbs.	In.	In.	Lbs.	Lbs.	In.	In.
1	July 16	10 15	K. 1. g	6	6.031	5.68	0.145	23.93	24.01	7.7	13.
2			"	"	"	"	"	24.35	.43	.7	12.7
3			"	"	"	"	"	.23	.31	.7	.8
4			N.	"	6.033	"	"	23.80	23.88	.2	.2
5			"	"	"	"	"	24.34	24.42	.4	.6
6		12	"	"	"	"	"	.19	.27	.6	.6
7		1 15	K. 1. g	"	6.031	"	"	.18	.26	.4	.7
8			"	"	"	"	"	.27	.35	.7	.9
9		2	"	"	"	"	"	.35	.43	.5	.6
10		3 30	N.	"	6.033	"	"	.36	.44	.9	13.
11			"	"	"	"	"	23.99	.07	.7	12.7
12			"	"	"	"	"	24.15	.23	.1	.3
13			A.	"	6.043	"	"	.17	.25	.7	.5
14			"	"	"	"	"	.01	.09	.4	.5
15		4 45	"	"	"	"	"	.05	.13	.4	.4
16	July 17	9	*a.*	"	6.04	"	"	.05	.13	.7	.8
17			"	"	"	"	"	23.95	.03	.5	.5
18			"	"	"	"	"	24.17	.25	.6	.6
19			W.	"	"	"	"	23.70	23.78	.0	.0
20			"	"	"	"	"	24.22	24.30	.0	.1
21		10 30	"	"	"	"	"	.17	.25	.0	.1
22	Dec. 9	10 30	X.	"	6.042	"	"	.16	.26	.4	.7
23			"	"	"	"	"	.27	.37	.6	.6
34			"	"	"	"	"	23.96	.06	.5	.7
25			X. p	"	"	"	"	24.06	.16	.3	.4
26			"	"	"	"	"	.15	.25	.4	.6
27		11 50	"	"	"	"	"	.12	.22	.6	.7

Point struck.	Vibration. Gun pendulum.	Vibration. Ballistic pendulum.	Moment of the gun pendulum.	Velocity of the ball. By the gun.	Velocity of the ball. By the pendulum.	No.	Remarks.
In.	° ′ ″	° ′ ″		Feet.	Feet.		
195.5	13 52 10	9 16 50	56,812	1670	1650	1	Vent closed. (Nos. 1–6)
196.4	52 30	9 19 10	56,835	1645	1621	2*	
195.3	55 10	9 15 50	57,016	1659	1628	3	
195.	19 10	8 50 20	54,569	1598	1584	4	
195.2	44 30	9 06 24	56,291	1627	1594	5	
195.5	28 20	8 55	55,192	1598	1568	6*	
194.7	52 44	9 11 30	56,850	1656	1624	7*	
194.2	50 42	9 08	56,712	1646	1612	8	
194.8	50 30	9 10 14	56,699	1641	1608	9	
195.55	40 50	9 09 20	56,042	1617	1599	10†	
194.8	49 14	9 10 10	56,613	1659	1629	11	
194.65	13 20	8 48 10	54,173	1564	1558	12	
195.35	14 09 00	9 23 10	57,955	1695	1654	13	
195.	09 28	9 24	57,987	1706	1670	14	
195.3	12 20	9 28 40	58,182	1711	1678	15	
196.1	13 11	8 47 50	54,014	1564	1552	16	
194.7	16	8 49	54,354	1582	1573	17	
195.4	25 30	8 59 40	55,000	1592	1584	18	
194.9	30 20	8 50	55,328	1631	1591	19	
195.	38 50	9 02	55,906	1620	1591	20	
194.9	40	9	55,985	1626	1589	21	
196.5	10	8 49 06	53,946	1554	1545	22‡	
194.6	47 40	9 10 30	56,506	1637	1616	23‡	
195.	24	8 52 16	54,898	1599	1579	24‡	
195.	48 30	9 08 40	56,563	1652	1621	25‡	
194.9	33 50	9 04 20	55,567	1611	1603	26‡	
195.9	14 02	9 21 40	57,480	1680	1648	27‡	

* Ball broke; has a large cavity in it.

† Grommet struck the pendulum block.

‡ These balls were strapped without being floated in mercury.

July 22nd, 1844.

The measurement of the bore of the 24-pounder pendulum gun was verified with an instrument made at Washington Arsenal, after the model of the French instrument heretofore used for that purpose.

The moveable points of the instrument were set by a ring gauge of 5.82 in. diameter. The vernier is graduated to read *hundredths of an inch*, and these divisions are readily subdivided by the eye. The results of this measurement are as follows:

Dist. from muzzle.	Vertical diameter.	Distance.	Diameter.	Distance.	Diameter.	Distance.	Diameter.
In.	In.	In.	In.	In.	In.	In.	In.
106	5.828	95	5.823	82	5.818	61	5.815
105	.828	94	.823	80	.816	59	.814
104	.827	93	.821	78	.818	55	.820
103	.832	92	.824	76	.814	51	.814
102	.840	91	.822	74	.813	47	.813
101	.849	90	.818	72	.821	43	.818
100	.835	89	.818	70	.816	39	.815
99	.827	88	.818	69	.815	31	.816
98	.830	87	.818	67	.817	23	.815
97	.830	86	.818	65	.828	15	.815
96	.825	84	.818	63	.816	10	.819

August 9th, 1844.

EXPERIMENTS WITH THE 24-POUNDER GUN PENDULUM, WITH BLANK CARTRIDGES.

No.	Time.	POWDER. Kind.	POWDER. Weight.	Weight of cartridge.	Height of charge.	GUN PENDULUM. Vibration.	GUN PENDULUM. Moment.	REMARKS.
			Lbs.	Lbs.	In.	° ′ ″		
1	11 20	B.	6	6.044	7.4	5 19 10	21,835	
2		"	"	"	.4	20 30	21,926	
3		C.	"	"	.2	22 08	22,038	
4		"	"	"	.3	21 30	21,994	
5		D.	"	6.040	.3	11 40	21,322	Gun washed.
6		"	"	"	.2	09 40	21,185	
7		E.	"	6.042	.0	08 40	21,117	
8		"	"	"	.0	09	21,140	
9		F. 1	"	6.040	8.6	14 50	21,539	Do.
10	12	"	"	"	.6	06	20,935	
11	1 15	G. 1	"	6.043	7.2	23 10	22,108	Do.
12		"	"	"	.2	20 06	21,899	
13		A. 2	"	6.044	.5	35 30	22,951	
14		"	"	"	.4	36 20	23,009	
15		G. 6	"	6.040	6.6	34 30	22,883	Do.
16		"	"	"	.6	39 50	23,247	
17		E. 5	"	"	.6	22 30	22,063	
18		"	"	"	.5	25 50	22,291	
19		K. 1, g.	"	"	.4	30 10	22,587	Do.
20		"	"	"	.6	28 10	22,450	
21		N.	"	"	.4	28	22,439	
22	2 10	"	"	"	.3	27 30	22,404	
Means.		B.	6	6.044	7.4	5 19 50	21,881	
		C.	"	.044	7.25	21 49	22,016	
		D.	"	.040	7.25	10 40	21,254	
		E.	"	.042	7.	08 50	21,129	
		F. 1	"	.040	8 6	10 25	21,237	
		G. 1	"	.043	7.2	21 38	22,004	
		A. 2	"	.044	7.45	35 55	22,980	
		G. 6	"	.040	6.6	37 10	23,065	
		E. 5	"	.040	6.55	24 10	22,177	
		K. 1, g.	"	.040	7.5	29 10	22,519	
		N.	"	.040	7.35	27 45	22,422	

III. EXPERIMENTS WITH THE MUSKET PENDULUM AND ITS BALLISTIC PENDULUM.

DESCRIPTION OF THE PENDULUMS. (PLATE IV.)

These pendulums, like the large ones, are constructed on the model of those used at the powder works in France, for the drawings of which I am likewise indebted to the kindness of Messrs. Dupont, of Delaware. The arrangement of the apparatus being represented in the accompanying drawings, a brief description only will be requisite.

The musket pendulum.

The frame for supporting the musket barrel consists of two parallel bars of iron, connected together by a transom at each end; each of these bars has an ear containing a trunnion hole to receive the trunnions of the musket barrel, which are fitted into a solid cylinder of iron that is substituted for the breech screw of the musket; the barrel is held in its place and adjusted, by means of four set screws passing horizontally through the bars of the frame, one pair near each end of it; a fifth set screw, passing vertically through the front transom, serves to adjust the musket barrel in a horizontal position when the frame is horizontal.

This frame is suspended by means of four iron rods; at the lower end of each rod is a shackle which is bolted to the transoms of the barrel frame, and a similar shackle serves to connect the rods above with the shaft of the pendulum; the screws cut in the ends of each rod, to unite it with the shackles, are right and left hand screws, respectively, so that by turning the rod, the distance of the frame from the shaft is increased or diminished at pleasure, and, in this manner, the height of the axis of the barrel is readily adjusted; when once adjusted, the rods are held fast by nuts screwed up against the shackles, to prevent the rods from turning.

The shaft of the pendulum is a flat bar of steel, at each end of which is a knife edge well hardened and tempered.

The parts of this pendulum are so arranged that, when it is at rest, the frame is nearly horizontal; the slight adjustment requisite for making it exactly horizontal is effected by means of leaden weights, supported by a small bolt screwed into the rear transom of the frame; a thumb-screw nut serves to keep these weights in place, by pressing them up against the transom.

The knife edges of the shaft rest in V's of hardened steel, which are set in cast iron hangers connected by a plate, and this plate is secured by four bolts to another plate, also of cast iron, which is firmly bolted and braced to a brick wall.

The arc of vibration is measured on a brass limb, which is clamped to an iron plate, on which it can slide in a circular direction, so that the zero of the limb may be properly adjusted; the iron plate is supported by a frame of wrought iron secured to the wall, and furnished with four set screws which serve to adjust the arc to the proper distance from the knife edges; a slider moves in a groove in the brass limb, and is retained at any part of the limb by the pressure of a slight spring. In the vibration of the pendulum, the slider is moved by an index attached to a bar which is fastened, at a suitable height, to two of the rods of the pendulum frame.

The radius of the graduated arc is 57.3 in.; each degree of the brass limb is divided into six parts, and the vernier on the slider subdivides these parts into minutes.

The ballistic pendulum.

This pendulum is composed of a hollow, conical block of bronze, suspended by two iron straps to a shaft formed of a flat bar of steel, with knife edges like those of the musket pendulum; a brace between the straps serves to stiffen them, and into one end of this brace is screwed the index which moves the slider on the brass limb for measuring the vibration of the pendulum.

An iron clamp, of a simple construction, presses a circular wooden plate against the face of the pendulum, and the point struck by the ball is marked by the perforation of this wooden plate.

In the pendulum represented in the French drawings, the core of the pendulum block consists chiefly of a block of lead against which the ball is fired, and which is renewed at each shot.

The inconvenience which I anticipated from the fragments of the lead and the ball, and the trouble attending the renewal of the leaden core, induced me to try other methods of forming the core, as will be seen in the Journal of the experiments. The result of these trials was the adoption of a core composed of:

1st. A block of hard wood turned to fit the bottom part of the pendulum block.

2nd. A conical block of lead, faced with a plate of iron, occupying nearly the centre of the core.

3d. A block of hard wood, turned and cut to such a length as just to fill the pendulum block, and to bear against the face plate. In my experiments these blocks were made of well seasoned hickory, and they were accurately adjusted to the proper weight by boring holes in them, which were, when necessary, filled with plugs of lead; the wood being exceedingly well seasoned, (more than 20 years old,) was nearly uniform in weight, and required little alteration after being turned; in order to avoid the alterations that might have been produced by changes in the hygrometric state of the air, the weight of the blocks was generally adjusted on the day on which they were used; this weight is such as to keep the axis of the block horizontal when the pendulum is at rest.

As there was but very little variation in the position of the point struck by the ball, it was not requisite to renew the wooden face plate at each fire; the same plate was therefore used for many rounds, the balls always striking in a hole 1 in. in diameter, in the centre of the plate.

The arrangements for suspending the ballistic pendulum, and for measuring the vibration, are the same as those for the musket pendulum. The distance between the axes of the two pendulums is 10 ft.; the muzzle of the musket is 6 feet from the face of the pendulum block.

A screen of boards, having a hole 2 in. in diam. for the passage of the ball, is placed two feet in front of the ballistic pendulum, to intercept the wads and the blast of the charge.

The musket pendulum frame is very stiff, having perhaps an unnecessary degree of strength; but the suspension straps of the ballistic pendulum are subject to a good deal of lateral vibration, as stated in the Journal.

The pendulums are attached to the south side of a brick wall, and covered by a wooden shed, occupying the position indicated on the plan—PLATE I.

Service of the pendulums.

After numerous experiments on the manner of loading the musket barrel, it was determined to adopt nearly the same method that is pursued in ordinary service.

The charges are weighed, with an accurate balance, and put into small tin canisters; to load the piece, the charge is poured into a small copper or tin charger attached to the end of a ramrod; the musket barrel is inverted over it, the vent being previously stopped with a brass wire; the barrel and charger are then again reversed together, and the charge of powder is shaken out into the bottom of the barrel.

The ball is wrapped, as for a common cartridge, in a rectangle of ball cartridge paper, 3 in. × 4.5; the paper is choked tight over the ball, and also slightly choked below, to prevent the ball from falling out. Instead of merely inserting the ball, with the paper, over the powder, the paper is first formed into a wad, in a manner nearly uniform, by putting the cartridge case, with the paper down, into a piece of musket barrel, and pressing on the ball with a wooden rammer, which crumples the paper neatly into a sort of sabot. In loading, the paper is inserted next to the powder; the ball is followed up with the rammer which is of steel, and weighs $1\frac{1}{2}$ lbs.; this rammer is then raised 6 in. and let fall on the charge once; the height of the charge was always measured by a graduation on the rammer, in order to guard against error in loading.

The common cast balls being generally rough and unequal in size and weight, I had balls prepared for these experiments by compression, by means of dies adapted to an ordinary punching machine for punching iron plates; by this simple arrangement, balls were made very nearly exact, in size, form and weight. Those used in most of the experiments were of the present regulation size, 0.64 in diameter, and they were gauged with rings of the diameters of 0.642 in. and 0.6385 in.; the average weight of 1151 of these balls was 397.523 grs.; many of them were weighed separately, and found to be between 396.5 grs. and 398.5 grs.

After each discharge, the musket barrel is taken from its frame and wiped carefully with dry rags; it is washed generally after five rounds.

The set screws on one side of the frame being undisturbed, the direction of the barrel requires no other adjustment, after being once set, than to be pressed up gently, but firmly, by means of the screws on the other side of the frame.

The charge is fired with a piece of quick match in the vent.

The wooden block into which the ball is fired is 4.5 in. long; with a charge of even 100 grains, the musket ball generally penetrates through this block (of hickory wood) and is flattened against the iron plate with which the lead block is faced; the lead and the wooden core are usually wedged slightly against the sides of the block, and have to be driven out through a hole left in the bottom of the pendulum block for that purpose.

ELEMENTS FOR COMPUTING THE VELOCITY OF THE BALL.

The formulæ for this purpose are the same as those before given for the large pendulums.

The constant elements of the calculations, in the usual condition of the pendulums, are as follows:

1. *For the ballistic pendulum.*

Weight of the bronze block and frame - - - -	46.86 lbs.
Weight of the wooden block in the bottom of core - - -	0.84
Weight of lead block, faced with iron,	5.03
Weight of wooden core to receive the ball - - - -	1.19
Weight of face clamp and wooden disc - - - -	1.08

Total weight of pendulum - $p = 55$ lbs.

Dist. of centre of gravity from knife edges, $g = 61.4$ in.

Time of 1000 oscillations - 1379 seconds.

Dist. of centre of oscillation from knife edges, $o = 74.354$

Force of gravity, - - - $G = 385.86$

Dist. of the axis of the block, or usual point of impact, from the knife edges - $i = 79.$ in.
Weight of the ball of 0.64 in. diameter, $b = 0.05679$ lbs.
Do do 0.65 do $= 0.05861$

$$\text{Log.}\ \frac{2\sqrt{(pg+bi)\,(pgo+bi^2)\,G}}{12\,b\,i}\ \begin{cases}\text{for ball 0.64 in.} & = 4.3279424\\ \text{for ball 0.65 in.} & = 4.3142795\end{cases}$$

The variations in the point of impact being very small, its distance has been regarded as constant, in the denominator as well as in the numerator of the formula; but, in case of any considerable variation, the correction is easily made in the above logarithms, by adding or subtracting, as the case may be, the difference between the logarithm of 79, and that of the true value of i.

2. *For the musket pendulum.*

Weight of the suspension frame -	78.26 lbs.
Weight of musket barrel and breech	9.12
Weight of adjusting weights -	1.56

Total weight of pendulum - - - $p' = 88.94$ lbs.
Dist. of centre of gravity from knife edges $g' = 43.85$ in.
Time of 1000 oscillations - - 1297 sec.
Dist. of centre of oscillation from knife edges, $o' = 65.77$
Force of gravity - - - - $G = 385.86$
Dist. of axis of barrel from knife edges $i' = 79.$

$$\text{Log.}\frac{2\,p'\,g'\sqrt{G\,o'}}{12\,i'} = 3.1175821$$

Mean weight of the rectangle of cartridge paper, (3 in. × 4.5 in.,) in which the ball is wrapped, 10.5 grs.
Diameter of the bore of the musket barrel - 0.69 in.

As I have before remarked, in the discussion of the formula for the velocity of the ball by the recoil of the cannon pendulum, I do not find the same coincidence with the results given by the ballistic pendulum, in applying that formula to the musket pendulum. No value that can be assigned to the quantity N in the formula, (see page 32,) will produce results of equal accuracy when applied to different kinds of gunpowder, and in all cases, it appears that the value of N is much smaller for the musket than for the cannon pendulum. This would appear to be the natural consequence of variations in the force or intensity of the flame produced by the combustion of various kinds of powder; that powder which acts with the greatest force on the ball whilst it is near the bottom of the musket barrel, having been more thoroughly consumed at the first moment of ignition, will probably have a smaller proportional expansive force remaining, after the ball has left the barrel, than the powder which, burning with less energy at first, continues to develope its force as the ball passes through the barrel; and this difference of effect becomes greater in proportion as the length of the barrel is increased, and the absolute quantity of powder in the charge diminished.

It may be said, also, that similar considerations should influence the estimate of the velocity attributed to the gaseous fluid resulting from the combustion of the powder; in our formula it is supposed that the mean velocity of this fluid behind the ball, or the velocity of its centre of gravity, is *half* that of the ball; but it is quite probable that when a small charge of very strong powder is burnt in a long barrel, (long in proportion to its calibre,) this estimate of the mean velocity of the flame is too high. This correction is also suggested by Hutton, who thinks that we should perhaps be nearer the truth in estimating the velocity of the mass of the flame at *one-third* that of the ball.

There is still another cause of error in the application of this formula to the musket pendulum, resulting partly from the method which I have adopted for loading the musket barrel. It will be remembered that, in the first term of the denominator of the formula, it is supposed that the elastic fluid acts on the ball as it would on a surface equal to that of a great circle of the ball; but the paper wad, which is placed between the powder and the ball, must tend to increase the surface on which the fluid acts, and the same effect is also produced by the cartridge paper which is wrapped around the ball; these circumstances make it impossible to appreciate exactly the measure which should be assumed for the diameter d, which, in the formula for the pendulum, represents the diameter of the ball itself, but should here be something greater, since the windage is partly destroyed; moreover, it is almost impossible to measure the true windage of each ball, and a slight error in this respect becomes appreciable in the value of the term $\frac{D^2}{d^2}$.

The method of loading, which is here referred to, was adopted, because it corresponds very nearly with that habitually practised in the service of the musket, and because it gives, with the same charge, a greater velocity to the ball than could be obtained by placing the ball next to the powder, with the wad on top; that this method by no means annihilates the windage, is shown by the marked increase of velocity produced by using a larger, though a heavier, ball.

But, whatever may be the cause, I have not found the formula for the velocity of the ball by the recoil of the musket pendulum, to represent correctly the results of my experiments, and I have therefore contented myself with recording *the moment of the musket pendulum*, calculated by the mean recoil in each series of fires with similar powder and ball; this furnishes an easy method of comparing the velocities and the recoils produced by the same charge of different kinds of powder, *May 10th*, 1844.

The first experiments were made with the ballistic pendulum, before the musket pendulum was suspended. It was intended first to compare the effects of the flint and percussion locks in firing the charge. For this purpose a musket was altered to the percussion system, by substituting a hammer for the cock, and by screwing a cone into the top of the barrel; the hole cut for the cone being plugged with a solid screw of the same form as that of the cone, and the original vent remaining open, the musket was first fired with a flint lock.

In the first arrangement of the ballistic pendulum the lead in the core of the block weighed $9\frac{1}{2}$ lbs., and instead of the wooden block afterwards adopted to receive the ball, a paper case filled with sand was used. The whole weight of the pendulum was 59.5 lbs.

The dies for compressing the balls had not been perfected; the balls first made were therefore not quite spherical, and they were too large, their mean diameter being about 0.6415 in., and their mean weight 400 grs.

The musket was loaded by introducing the charge of powder in the manner before described; on this was placed a circular wad made of a single thickness of cannon cartridge paper, and a similar wad was inserted over the ball; the object of these wads being merely to keep the powder and ball in place.

The diameter of the bore of the musket used is 0.69 in.

DATE.	No.	POWDER. Kind.	POWDER. Weight.	BALL. Diameter.	BALL. Windage.	BALL. Weight.	HEIGHT OF Powder.	HEIGHT OF Whole charge	Point struck.	Vibration of pendulum.	Velocity of ball.
1844.			Grs.	In.	In.	Grs.	In.	In.	In.	° ′	Feet.
May 8th,	1	G. 6	175	0.6415	0.0485	401	1.7	2.25	78.9	9 55	2034
	2	"	"	"	"	"	1.75	2.3	79.	9 58	2032
	Mean	"	175	"	"	"	1.73	2.28	78.95	9 57	2033
May 10th,	1	"	150	"	"	"	1.5	2.1	79.2	8 07	1652
	2	"	"	"	"	"	"	"	79.	8 48	1793
1 15 P.M.	3	"	"	"	"	"	"	"	79.2	7 58	1621
	4	"	"	"	"	"	"	"	78.	9 02	1868
	5	"	"	"	"	"	"	"	78.8	8 59	1837
	Mean	"	150	"	"	"	1.5	2.1	78.83	8 36	1754
	1	"	120	"	"	"	1.2	1.8	79.	6 47	1384
	2	"	"	"	"	"	"	"	79.	7 38	1559
	3	"	"	"	"	"	"	"	79.	6 47	1384
	4	"	"	"	"	"	"	"	79.	6 14	1272
	5	"	"	"	"	"	"	"	79.2	7 32	1533
	Mean	"	120	"	"	"	1.2	1.8	79.04	7	1426
	1	"	100	"	"	"	1.	1.6	79.2	6 02	1228
	2	"	"	"	"	"	"	"	79.	5 45	1174
	3	"	"	"	"	"	"	"	79.	6 08	1252
	4	"	"	"	"	"	"	"	79.	6 49	1391
3 45 P. M.	5	"	"	"	"	"	"	"	79.3	6 15	1270
	Mean	"	100	"	"	"	1.	1.6	79.1	6 12	1263
May 11th,	1	A. 4	150	0.641	0.049	399	1.8	2.4	79.	6 59	1432
11 A. M.	2	"	"	"	"	"	"	"	79.2	7 13	1477
	3	"	"	"	"	"	"	"	79.	6 45	1381
	4	"	"	"	"	"	"	"	"	6 55	1415
11 45	5	"	"	"	"	"	"	"	"	6 55	1415
	Mean	"	150	"	"	"	1.8	2.4	79.04	6 57	1424
1 P. M.	1	"	120	"	"	"	1.4	2.	79.	6	1228
	2	"	"	"	"	"	"	"	"	6 04	1241
	3	"	"	"	"	"	"	"	"	6	1228
	4	"	"	"	"	"	"	"	"	6 09	1258
	5	"	"	"	"	"	"	"	"	6 12	1269
	Mean	"	120	"	"	"	1.4	2.	79.	6 05	1245
	1	"	100	"	"	"	1.2	1.8	79.	5 13	1070
	2	"	"	"	"	"	"	"	79.2	5 18	1085
	3	"	"	"	"	"	"	"	79.	5 14	1074
	4	"	"	"	"	"	"	"	79.3	5 24	1104
2 15	5	"	"	"	"	"	"	"	79.	5 25	1111
	Mean	"	100	"	"	"	1.2	1.8	79.1	5 19	1089

By comparing the results of these first experiments with those obtained by means of the same instrument in France, as marked on the packages of gunpowder received from that country, (see page 10,) it is evident that the velocities of the ball are much too low for the charges used, and not knowing that the French instructions for the use of the pendulums were in possession of Messrs. Dupont, from whom the drawings were obtained, I proceeded to make experiments, for the purpose of ascertaining the cause of these discrepancies.

Before trying the musket pendulum, and changing the manner of loading the musket, I made experiments on various modes of forming the core of the ballistic pendulum block, in order to determine the most advantageous arrangement for that purpose, and to ascertain if any marked variation in the effect of the blow could be traced to the formation of the core, or to changes in the weight of the pendulum.

May 13th, 1844.

Three different arrangements for the core of the pendulum block were tried to-day:

1st. A paper case filled with sand, as in the preceding experiments, with a leaden block behind it.

2nd. A block of wood in place of the sand case.

3d. A core formed of a conical block of lead, faced with a plate of iron.

With each of these cores the weight of the pendulum was made to remain the same as before.

The firing was with a new flint lock musket, except the two rounds noted "with percussion lock," for which the altered musket was used.

The balls in all these preliminary experiments were of the same kind as those used on the 11th inst., being of the diam. of 0.641 in.; weight 399 grs.

The wads were also the same as in the previous experiments. The charge of 77 grains was used for the sporting powder, because it is marked as the proof charge, on the package of French sporting powder, which gives to the musket ball, with that charge, a velocity of 1306 feet.

DATE.	No.	POWDER. Kind.	POWDER. Weight.	HEIGHT OF Powder.	HEIGHT OF Whole charge.	Kind of core.	Point struck.	Vibration of pendulum.	Velocity of ball.
1844.			Grs.	In.	In.		In.	° '	Feet.
May 13	1	G. 6	77	0.7	1.3	Sand	79.1	5	1025
	2	"	"	"	"	"	78.9	4 53	1003
	3	"	"	"	"	"	79.3	5	1022
	4	"	"	0.8	"	"	79.	4 49	988
	1	"	"	0.7	"	"	79.	4 44	971*
	2	"	"	"	"	"	79.2	5	1024*
	1	"	"	"	"	Wood	78.8	4 51	998
	2	"	"	"	"	"	79.	4 49	988
	1	"	"	"	"	Lead	79.	4 54	1005
	2	"	"	"	"	"	79.1	4 49	987
	1	A. 4	140	1.6	2.15	Sand	79.	6 51	1405
	2	"	"	"	"	"	79.3	6 40	1362
	3	"	"	"	"	"	79.	6 58	1429
	1	"	"	"	"	Wood	78.9	6 38	1362
	2	"	"	"	"	"	79.	6 40	1368
	3	"	"	"	"	"	79.	6 52	1409
	1	French sporting.	77	0.8	1.3	Sand	79.	5 01	1029
	2		"	"	"	"	79.2	5 04	1038
	3		"	"	"	"	79.	4 58	1019
	1		"	"	"	Wood	78.75	4 46	981
	1	French musket.	140	1.75	2.25	Sand	78.9	6 27	1325
	2		"	"	"	"	79.	6 34	1347
	3		"	"	"	"	78.9	6 20	1301
	4		"	"	"	"	78.8	6 34	1351
	5		"	"	"	"	79.	6 23	1310

* With percussion lock.

May 14*th*, 1844.

In order to ascertain whether the lateral vibration of the pendulum frame, occasioned by its want of stiffness, produced any sensible error in the result of the experiments, the frame was well stiffened with light wooden braces, which increased its weight about 2 lbs. The centre of gravity and centre of oscillation having been again determined, three rounds were fired with the charge of 77 grs. of powder, *G.* 6, when it was found that the mean velocity of the ball was 971 ft., not very different from the result of previous trials; the braces were therefore removed, and the pendulum was used in its first condition.

May 16*th*, 1844.

The condition of the pendulum was again changed by attaching a supplemental weight to the lower side of the block, so as to bring the centre of oscillation to coincide with the point of impact of the ball; the weight of the pendulum was then 82.58, lbs. and its centre of gravity was 65.45 in. from the knife edges. Five rounds were fired from a percussion musket, with the pendulum in its original condition, and five more with the supplemental weight attached to it.

Weight of pendulum.	No.	POWDER. Kind.	POWDER. Weight.	Point struck.	Vibration.	Velocity.	REMARKS.
Lbs.			Grs.	In.	° ′	Feet.	
59.5	1	G. 6	175	78.8	10 05	2059	1st ball 401 grs; the rest 399 grs.
	2	"	77	79.	4 58	1019	
	3	"	"	78.6	5 26	1120	No wad on the powder.
	4	"	"	78.2	5 41	1178	
	5	"	"	78.2	4 42	974	
82.58	1	G. 6	77	79.	3 09	961	
	2	"	"	78.9	3 15	993	
	3	"	175	78.	6 14	1930	
	4	A. 4	140	79.3	4 25	1342	
	5	"	"	79.2	4 12	1278	

May 17th, 1844.

The next experiments were made with a reduced weight in the core of the block :

1st. A wooden core with an iron plate on the front end, and a sand case over it—Weight of pendulum 51.54 lbs.

2d. With a block of lead lighter than the one heretofore used, and a sand case over it—Weight 55.3 lbs.

Weight of pendulum.	POWDER. Kind.	POWDER. Weight.	Point struck.	Vibration of pendulum.	Velocity of ball.	REMARKS.
Lbs.		Grs.	In.	° ′	Feet.	
51.54	G. 6	77	79.	6 04	1030	
	A. 4	140	"	8 25	1430	
	"	"	"	8 22	1419	
	Hall's	77	79.3	6 11	1051	Sporting powder.
55.3	G. 6	77	79.1	5 23	1004	A small part of the charge thought to have been lost in loading.
	"	"	79.	5 31	1029	
	"	175	78.4	11 26	2131	
	A. 4	140	79.	7 53	1470	
	"	"	79.5	7 30	1400	

As the weight of 82 lbs., which is required in order to bring the centre of oscillation of the pendulum to coincide with the usual point of impact of the ball, appears to be disproportionate to the momentum of the ball, it was determined to adopt, for the present, the last mentioned method of forming the core of the pendulum block, viz: that which makes the weight of the pendulum 55.3 lbs.

May 20th, 1844.

The musket pendulum was to-day suspended and adjusted, preparatory to making experiments on the proper mode of loading the musket barrel.

The first trials were made with the same mode of loading as has been heretofore used, the wads being cut out of thin paper.

No.	POWDER.		Point struck.	VIBRATION.		Velocity of ball by the ballistic pendulum.	REMARKS.
	Kind.	Weight.		Musket pendulum.	Ballistic pendulum.		
		Grs.	In.	° ′	° ′	Feet.	
1	G. 6	77	79.	7 33	5 48	1082	
2	"	"	79.2	7 33	5 44	1066	
3	"	154	79.	14 35	10 20	1925	
4	"	175	79.	15 57	10 53	2027	
5	A. 4	140	78.8	11 45	7 55	1478	
6	"	"	78.5	11 42	7 40	1489	
7	"	"	78.8	11 45	7 54	1476	

May 22nd.

The next experiments were made with balls wrapped in cartridge paper, as for ball cartridge, and the paper then cut off close to the ball.

No.	POWDER.		Point struck.	VIBRATION.		Velocity by the ballistic pendulum.	REMARKS.
	Kind.	Weight.		Musket pendulum.	Ballistic pendulum.		
		Grs.	In.	° ′	° ′	Feet.	
1	A. 4	140	79.	12 01	8 19	1550	
2	"	"	79.2	11 49	7 58	1481	
3	"	"	79.	12 02	8 15	1538	
4	G. 6	77	79.	7 47	6 06	1137	

May 24th, 1844.

The increased velocity obtained by simply wrapping the ball in cartridge paper, led to further trials on different kinds of wadding. Three kinds were tried to day:

1. Circular *felt wads*, cut from the body of a hat, weight 3 grs.
2. Circular *pasteboard wads*, about $\frac{1}{10}$th in. thick, " 8 grs.
3. Rectangles of *cartridge paper*, 3 in. × 4.5 in. " 9 grs.

In using the wadding of cartridge paper, (except in two instances specially noted,) the balls were wrapped in the cartridge papers, which were then crumpled into a wad inserted next to the powder.

No.	Powder. Kind.	Powder. Weight.	Kind of wad.	Height of charge.	Vibration. Musket pendulum.	Vibration. Ballistic pendulum.	Velocity by the ballistic pendulum.
		Grs.		In.	° ′	° ′	Feet.
1	G. 6	77	Cartridge paper wad inserted separately on powder.	1.6	7 48	6 00	1119*
2	"	"	Cartridge paper -	1.65	8 42	7 01	1308
3	"	"		1.5	8 54	7 23	1377
4	"	"	2 felt wads on powder and 1 on ball.	1.62	9 19	7 57	1482
5	"	"	1 felt wad on powder and 1 on ball.	1.4	8 46	7 13	1346
6	A. 4	140	Cartridge papers -	2.5	12 16	8 18	1547
7	"	"		2.45	12 28	8 31	1586
8	"	"		"	12 14	8 22	1560
9	"	"		2.3	12 31	8 37	1606
10	"	"	Cartridge papers, inserted separately.	2.4	12 20	8 44	1628
11	"	"	1 felt wad on powder and 1 on ball.	2.3	11 56	8 08	1516
12	"	"		"	11 44	7 50	1460
13	"	"	2 felt wads on powder and 1 on ball.	2.4	11 57	8 04	1504
14	"	"		"	12 09	8 06	1510
15	"	"		"	12 16	8 20	1553
16	"	"		"	12 06	8 13	1532
17	"	"	1 pasteboard wad on powder and 1 on ball.	2.35	12 10	8 31	1587
18	"	"		2.4	12 25	8 32	1591
19	"	"		"	12 30	8 41	1619

* Wad turned edgewise.

From these experiments it appears that the discrepancies between the former results and those of the French experiments, are occasioned by differences in the mode of wadding the charge, and that the most advantageous wads are those made of thick pasteboard, or of the paper of the cartridges commonly used in service.

May 27th, 1844.

The conclusions drawn from the foregoing experiments are confirmed by information received on the 25th inst. from Mr. A. Dupont, who has a copy of the French instructions for the proof of gunpowder by the ballistic pendulum. It appears that, in proving *sporting* powder, the charge is 5 grammes, (77.17 grs.,) and that a pasteboard wad is put on the powder and another on the ball. For *war* powder, the charge is 10 grammes, (154.33 grs.) and the ball is wrapped in cartridge paper, which forms the wad, as in my experiments of the 24th inst.; but the ball is placed next to the powder and the wad on top.

Having, in the mean time, procured some circular wads of a very neat kind, such as are used by sportsmen, I made to-day some further trials to compare the effects of different kinds of wads.

The sportsmen's wads referred to are "Baldwin's elastic indented wadding," made in Birmingham, England; they are cut from a soft, spongy kind of pasteboard, a little more than $\frac{1}{10}$th of an inch thick. Those tried to-day were No. 14, which are a little too large for the musket. The mean weight of 253 of these wads is 5.127 grs.

The cartridge papers were 4.5 in. × 3.5 in., weighing 12.82 grs.; they were still inserted with the ball uppermost. The pasteboard and felt wads were of the same kind as on the 24th.

Heretofore the charge has been rammed with a hickory ramrod, in the usual manner. To produce greater uniformity in this respect, I now adopted the method described in the French instructions; letting fall on the charge, from the height of 6 in., a ramrod weighing 1.5 lb.

The ball was fired into a case filled with sand, as in the former experiments.

No.	POWDER.		Kind of wad.	Height of charge.	Point struck.	VIBRATION.		Velocity by the ballistic pendulum.
	Kind.	Weight.				Musket pendulum.	Ballistic pendulum.	
		Grs.		In.	In.	° ′	° ′	Feet.
1	French sporting	77.17	2 elastic wads; 1 on powder & 1 on ball.	1.55	78.8	7 47	5 53	1096
2		"		"	79.	8 03	6 16	1169
3	"	"	2 pasteboard wads -	1.47	78.7	8 14	6 26	1200
4	"	"	2 felt wads - - -	1.4	79.	7 35	5 50	1088
5	G. 6	"	2 elastic wads - -	1.5	78.8	7 50	5 54	1100
6	"	"	Do. do. - -	"	79.	7 45	5 47	1079
7	"	"	2 pasteboard wads -	1.42	"	8 04	6 24	1193
8	"	"	2 felt wads - - -	1.4	"	7 39	5 56	1106
9	"	"	2 do. on powder and 1 on ball.	1.4	"	8 07	6 23	1190
10	"	"	1 elastic wad; ball wrapped in paper.	1.5	"	8 06	6 22	1187
11	"	"	Cartridge paper - -	"	"	8 22	6 52	1280
12	"	"	Do. do. - -	"	"	8 36	7 08	1330
13	"	"	Do. do. - -	"	"	8 02	6 13	1159
14	"	"	Do. do. - -	"	78.8	8 07	6 20	1181
15	French musket.	154.33	2 elastic wads - -	2.52	79.3	12 54	8 44	1628
16		"	Do. do. - -	2.6	78.8	12 43	8 20	1553
17		"	Cartridge paper - -	2.45	79.	13 09	9 04	1690
18		"	Do. do. - -	2.6	"	12 59	8 53	1655
19	A. 4	"	Do. do. - -	2.5	"	13 01	8 53	1655
20	"	"	Do. do. - -	"	"	13 42	9 38	1795
21	"	"	2 elastic wads - -	"	"	13	8 40	1615
22	"	"	Do. do. - -	"	"	13 29	9 13	1718

May 29*th*, 1844.

In order to try a ballistic pendulum much lighter than the one heretofore used, the bronze block was removed, and a sheet iron case substituted for it; beneath this case, which was to contain the sand core, adjusting weights were attached to the suspension frame, so as to bring the centre of oscillation to coincide nearly with the point of impact of the ball.

The whole weight of the pendulum was 47.27 lbs.

Distance of centre of gravity from knife edges, 62.33 in.

Distance of centre of oscillation from knife edges, 79.06 in.

The pendulum was tried with the following results:

No.	POWDER. Kind.	POWDER. Weight.	VIBRATION. Musket pendulum.	VIBRATION. Ballistic pendulum.	Velocity by the ballistic pendulum.	REMARKS.
		Grs.	° ′	° ′	Feet.	
1	French musket.	154.33	12 55	9 58	1663	Ball 0.64 in. diameter, weighing 397.5 grs.; cartridge paper wads 3 in. × 4.5 in., weighing 11 grs.
2	"	"	12 41	9 27	1577	
3	"	"	12 39	9 37	1605	
4	A. 4	"	13 36	10 32	1757	

At the fourth round, some of the rivets which held the sheet iron case gave way, and the apparatus could be no longer used without repair; but as the indications of the two pendulums corresponded with each other, and with the results of former trials, it was concluded that the inertia of the pendulum, in its previous state, is not too great for the force of the ball; further trials with the lighter pendulum were therefore considered unnecessary, and the apparatus was restored to its original form.

May 31*st* and *June* 1*st*, 1844.

Wishing to avoid the inconvenience of renewing the leaden cores which are used to receive the impact of the ball, in the French arrangement of the pendulum, and the further inconvenience resulting from the fragments of lead which must be driven off against the sides of the pendulum block and against the face plate, I made some comparative trials of these leaden cores and of the wooden and sand cores before employed. In order to increase the resistance of the cores of oak wood, they were turned across the grain; other cores of cypress wood, very light and dry, were also tried.

The dies for making the balls by compression having been well adjusted, a large number of balls have been prepared, of the diam. of 0.64 in.; mean weight 397.5 grs. These balls will be used in the future experiments, when not otherwise mentioned.

DATE.	No.	POWDER.		Kind of wad.	Kind of core.	VIBRATION.		Velocity by the ballistic pendulum.
		Kind.	Weight.			Musket pendulum.	Ballistic pendulum.	
1844.			Grs.			° ′	° ′	Feet.
May 31	1	A. 4	154.33	Cartridge papers.	Oak	13 25	9 22	1746
	2	"	"		"	13 19	9 17	1730
	3	"	"		"	13 45	9 43	1811
	4	G. 6	77.17		"	9 02	7 33	1408*
	5	"	"		"	9 06	7 36	1417*
	6	"	"	2 elastic wads.	"	7 52	5 40	1057†
	7	"	"		"	7 45	5 36	1044†
	8	A. 4	154.33		"	13 19	8 51	1650†
	9	"	"		"	12 59	8 37	1606†
June 1	10	"	"	Cartridge papers.	Cypress	13 31	9 39	1774
	11	G. 6	77.17		"	8 30	7	1288
	12	"	"		Lead	8 51	7 11	1333
	13	A. 4	154.33		"	13 44	9 56	1842
	14	"	"		"	13 46	9 33	1772
	15	"	"		Sand	13 10	9	1713
	16	"	"		"	13 22	9 11	1748

* Wads struck the pendulum.

† Baldwin's patent elastic wads, No. 15.

The following is a tabular view of the mean results of the experiments in which cartridge paper wads were used:

Date.	Number of rounds.	POWDER. Kind.	POWDER. Charge.	Kind of core.	VIBRATION. Musket pendulum.	VIBRATION. Ballistic pendulum	Velocity by the ballistic pendulum.	Moment of musket pendulum.
1844.			Grs.		° ′	° ′	Feet.	
May 27	2	A. 4	154.33	Sand	13 22	9 15	1725	
June 1	2	"	"	"	13 16	9 06	1731	
May 31	3	"	"	Oak	13 30	9 27	1762	
June 1	1	"	"	Cypress	13 31	9 39	1774	
"	2	"	"	Lead	13 45	9 45	1807	
Mean	10	A. 4	154.33	–	13 29	9 25	1758	153.8
May 24	2	G. 6	77.17	Sand	8 48	7 12	1343	
" 27	2	"	"	"	8 29	7	1305	
" 27	2	"	"	"	8 05	6 17	1170	
" 31	2	"	"	Oak	9 04	7 35	1413	
June 1	1	"	"	Cypress	8 30	7	1288	
"	1	"	"	Lead	8 51	7 11	1333	
Mean	10	G. 6	77.17	–	8 38	7 03	1309	98.67
May 27	2	French musket	154.33	Sand	13 04	8 59	1673	149.92

From this table, it appears that the indications of the ballistic pendulum are not sensibly affected by the kind of core used for the pendulum block, since the velocities of the ball, by that pendulum, follow very nearly the same order with the corresponding recoils of the musket pendulum; thus showing that the cause of variation is in the force with which the ball is propelled.

The cypress core affords too little resistance to the ball, which passes through it with such force as to indent the iron plate behind it.

The oak core, turned across the grain of the wood, causes a deviation in the course of the ball after it enters the pendulum block. As the wooden cores are the neatest and most convenient for use, it was determined to adopt that arrangement in the future experiments, and the pendulums were finally adjusted in the manner pointed out in the general description of them; the cores being turned out of seasoned hickory, and placed with the end of the grain towards the musket.

June 3d, 1844.

Preparatory to determining the proper charge for the proof of gunpowder with the musket pendulum, the following trials were made with a musket altered to percussion:

1st. Firing 25 rounds, (at the rate of 2 rounds in a minute,) with a charge of 130 grains of powder, A. 4. The barrel became exceedingly heated, and the recoil was too great to be borne without serious inconvenience.

2nd. 11 rounds with 120 grs. of powder taken from old musket cartridges, which have been made probably since 1816. Recoil not too great.

3d. 5 rounds with the cartridges from which the powder just mentioned was taken; they contain about 160 grs. Recoil much too great.

4th. 10 rounds with 120 grs. of powder, A. 4. The recoil with this charge is inconveniently great, being probably increased by the foul condition of the barrel. At 400 yards, the balls pass through a pine board 1 in. thick, and are flattened against a brick wall. The cartridge for the flint musket containing 130 grs., the charge of 120 grs. may be regarded as the present musket charge, exclusive of priming.

These 51 rounds were fired without cleaning the barrel, and only one percussion cap exploded without firing the charge, although when the breech screw was taken out there was found in the bottom of the barrel a hard cake of dirt, which, as subsequent trials showed, was produced almost entirely by the powder from old cartridges.

As it is obvious that the charge of the percussion musket cannot exceed 120 grs., and will probably have to be less than that, and as the effect of 120 grs. of our usual quality of musket powder appears to be sufficiently great for service, it was determined to adopt that charge for the experiments to be made in comparing different kinds of powder by means of the musket pendulum.

June 5th, 1844.

The comparative trials of the flint and percussion muskets were now resumed. For this purpose the musket pendulum was dismounted, and the altered musket used on the 10th and 11th of May was again placed between wooden clamps, in a bench vice, by which it was held steadily in a proper direction for firing horizontally at the centre of the pendulum block. After firing ten rounds with the percussion lock, the vent in the cone of this musket was slightly enlarged, to the size of a common vent for a flint lock, and the piece was fired by means of a strand of quick match.

The percussion caps were English, and such as are used for the military service; the charge of powder was 120 grains; the musket was washed at every fifth round.

Experiments with musket ballistic pendulum, June 5th, 1844.

No.	Mode of firing.	Kind of powder.	Point struck.	Vibration of pendulum.	Velocity of the ball.	REMARKS.
			In.	° ′	Feet.	
1	Percussion	A. 4	78.8	7 55	1469	Core of oak 4.5 in. long; the balls pass through it, and are flattened against the iron plate behind it.
2	lock.	"	79.	7 45	1438	
3	"	"	79.	8 07	1506	
4	"	"	79.1	8 15	1531	
5	"	"	79.	7 57	1475	
Mean	Percussion	A. 4	78.98	8	1484	
1	"	G. 6	79.	9 46	1812	Balls generally broken into small fragments.
2	"	"	78.7	10 08	1886	
3	"	"	78.3	10 11	1896	
4	"	"	78.4	10 22	1937	One cap missed fire.
5	"	"	78.5	10 13	1907	
Mean	Percussion	G. 6	78.58	10 08	1888	
1	Match	G. 6	78.9	9 53	1844	Core of hickory wood, weighing 1.4 lb., causes a slight change in the coefficient for the velocity of the ball.
2	"	"	78.3	9 51	1852	
3	"	"	79.	10 10	1895	
4	"	"	78.8	10	1868	
5	"	"	78.25	9 54	1863	
Mean	Match	G. 6	78.65	9 58	1864	
1	"	A. 4	79.	7 43	1439	Ditto.
2	"	"	79.2	7 55	1472	
3	"	"	79.	7 48	1455	
4	"	"	79.	8 13	1532	
5	"	"	79.2	7 48	1451	
Mean	Match	A. 4	79.08	7 53	1470	

From these experiments it would appear that the increase of force, from the use of the percussion cap, is not so great as to authorize any reduction of the charge on that account alone.

Charge of powder 120 grs.; diameter of ball 0.64 in.; weight 397.5 grs.; wad of cartridge paper 3 in. × 4.5 in., weighing 10.8 grs.; point struck 79 in. when not otherwise specified.

DATE.	No.	Kind of powder.	Height of charge.	VIBRATION. Musket pendulum.	VIBRATION. Ballistic pendulum.	Moment of musket pendulum.	Velocity of ball by ballistic pendulum.	REMARKS.
1844.			In.	° ′	° ′		Feet.	
June 5th,	1	A. 4	2.	10 53	8 01	–	1488	Core 1.19 lb.
	2	"	"	10 43	7 43	–	1432	
	3	"	"	10 57	8 10	–	1515	
	4	"	"	11	8 21	–	1549	
	5	"	"	11	8 09	–	1512	
	Mean	A. 4	2.	10 55	8 05	124.64	1499	
	1	G. 6	–	–	–	–	–	Part of charge lost
	2	"	1.8	12 43	9 53	–	1841	Core 1.4 lb.
	3	"	"	12 43	9 54	–	1845	
	4	"	"	12 39	9 54	–	1845	
	5	"	"	12 51	10 09	–	1892	
	Mean	G. 6	1.8	12 44	9 57	145.37	1856	
June 6th, 1 30 P.M.	1	A.	2.03	9 24	6 30	–	1212	Ditto.
	2	"	"	9 41	6 48	–	1267	
	3	"	"	9 41	6 45	–	1259	
	4	"	"	9 39	6 47	–	1265	
	5	"	"	9 46	6 58	–	1299	
	Mean	A.	2.03	9 38	6 46	110.11	1260	
	1	B.	1.98	9 57	7 02	–	1312	Ditto.
	2	"	"	10 37	7 50	–	1461	
	3	"	"	10 15	7 19	–	1365	
	4	"	2.	9 54	6 56	–	1293	
	5	"	"	10 44	7 46	–	1448	
	Mean	B.	1.99	10 17	7 23	117.58	1376	
	1	C.	2.	10 26	7 34	–	1411	
	2	"	1.94	10 50	8 04	–	1497	Core 1.19 lb.
	3	"	2.02	10 20	7 22	–	1367	
	4	"	2.	10 12	7 23	–	1370	
	5	"	2.	10 03	7 08	–	1324	
	Mean	C.	1.99	10 22	7 30	118.47	1394	

DATE.	No.	Kind of powder.	Height of charge.	VIBRATION. Musket pendulum.	VIBRATION. Ballistic pendulum.	Moment of musket pendulum.	Velocity of ball by ballistic pendulum.	REMARKS.
1844.			In.	° ′	° ′		Feet.	
June 6th,	1	D.	1.9	9 40	6 46	–	1256	
	2	"	1.98	9 13	6 18	–	1169	
	3	"	2.	9 48	6 59	–	1296	
	4	"	"	9 15	6 20	–	1176	
	5	"	"	9 37	6 43	–	1247	
	Mean	D.	1.98	9 31	6 38	108.56	1229	
	1	F.	2.1	10 50	7 57	–	1475	
	2	"	"	10 25	7 29	–	1389	
	3	"	"	10 41	7 48	–	1447	
	4	"	"	11 05	8 16	–	1534	
4 30 P. M.	5	"	"	10 50	7 56	–	1472	
	Mean	F.	2.1	10 46	7 53	123.03	1463	
June 7th, 10 A. M.	1	A. 1	2.05	9 12	6 18	–	1169	
	2	"	"	9 34	6 41	–	1240	
	3	"	"	9 55	6 59	–	1296	
	4	"	"	9 46	6 52	–	1274	
	5	"	"	9 59	7	–	1299	
	Mean	A. 1	2.05	9 41	6 46	110.55	1256	
	1	B. 1	2.02	9 41	6 47	–	1259	
	2	"	2.1	9 55	7	–	1299	
	3	"	2.05	9 30	6 34	–	1219	
	4	"	2.07	9 55	6 59	–	1296	
Noon,	5	"	"	9 46	6 51	–	1271	
	Mean	B. 1	2.06	9 45	6 50	111.35	1269	
1 45 P. M.	1	C. 1	2.05	9 55	7 09	–	1327	
	2	"	"	9 44	6 56	–	1287	
	3	"	"	9 46	6 51	–	1271	
	4	"	"	9 46	6 53	–	1277	
	5	"	"	9 32	6 39	–	1234	
	Mean	C. 1	2.05	9 45	6 54	111.19	1279	

DATE.	No.	Kind of powder.	Height of charge.	VIBRATION. Musket pendulum.	VIBRATION. Ballistic pendulum.	Moment of musket pendulum.	Velocity of ball by ballistic pendulum.	REMARKS.
1844.			In.	° ′	° ′		Feet.	
June 7th,	1	D. 1	2.06	9 03	6 13	–	1154	
	2	"	"	9 16	6 23	–	1185	
	3	"	2.04	9 22	6 26	–	1194	
	4	"	"	9 24	6 33	–	1214	
	5	"	"	9 20	6 25	–	1190	
	Mean	D. 1	2.05	9 17	6 24	106.09	1187	
	1	E. 1	2.	8 32	5 42	–	1058	Core not split.
	2	"	"	8 42	5 50	–	1084	Same core used
	3	"	"	8 52	6 05	–	1129	again, with correction.
	4	"	"	8 44	5 55	–	1098	
	5	"	"	8 58	6 03	–	1123	
	Mean	E. 1	2.	8 46	5 55	100.15	1098	
	1	F. 1	2.05	9 50	6 53	–	1276	
	2	"	2.11	10 34	7 35	–	1406	
	3	"	2.04	10 38	7 45	–	1438	
	4	"	2.09	10 39	7 41	–	1426	
	5	"	2.13	10 51	7 56	–	1471	
	Mean	F. 1	2.08	10 30	7 34	120.03	1404	1435 ft., omitting No. 1.
	1	G. 1	2.01	9 32	6 40	–	1237	
	2	"	2.	9 57	7 02	–	1305	
	3	"	2.	9 42	6 44	–	1250	
	4	"	2.02	10	6 57	–	1289	
	5	"	2.02	9 50	6 51	–	1271	
	Mean	G. 1	2.01	9 48	6 51	108.23	1270	
	1	E. 5	1.90	10 08	7 06	–	1318	
	2	"	1.88	10 33	7 31	–	1395	
	3	"	1.88	10 19	7 29	–	1389	
	4	"	1.92	10 18	7 20	–	1361	
5 P. M.	5	"	1.85	10 04	6 58	–	1293	
	Mean	E. 5	1.89	10 16	7 17	117.37	1351	

DATE.	No.	Kind of powder.	Height of charge.	VIBRATION. Musket pendulum.	VIBRATION. Ballistic pendulum.	Moment of musket pendulum.	Velocity of ball by ballistic pendulum.	REMARKS.
1844.			In.	° ′	° ′		Feet.	
June 10th	1	F. 2	2.	10 55	7 42	–	1429	This powder
10 45 A.M.	2	"	2.06	43	46	–	1441	was the finer
	3	"	2.13	29	30	–	1392	grain sifted
	4	"	2.11	35	33	–	1401	from F. 2.
	5	"	2.10	58	54	–	1466	
	Mean	F. 2	2.08	10 44	7 41	122.6	1426	
	1	A. 3	2.	9 58	7 00	–	1299	
	2	"	2.02	10 19	16	–	1349	
	3	"	2.05	13	06	–	1318	
	4	"	"	19	20	–	1361	
11 45 A.M.	5	"	2.02	20	17	–	1352	
	Mean	A. 3	2.02	10 14	7 12	116.86	1336	
1 20 P. M.	1	B. 3	2.	10 30	7 33	–	1401	
	2	"	"	48	50	–	1454	
	3	"	"	47	48	–	1446	
	4	"	"	34	32	–	1398	
	5	"	"	11 05	8 10	–	1515	Barrel very foul; ball entered hard.
	Mean	B. 3	2.	10 45	7 47	122.77	1443	
	1	C. 3	1.98	10 29	7 30	–	1392	
	2	"	2.	11 21	8 24	–	1559	
	3	"	"	10 44	7 48	–	1447	
	4	"	"	11 03	8 08	–	1507	
	5	"	"	10 34	7 36	–	1410	
	Mean	C. 3	2.	10 50	7 53	123.77	1463	
	1	D. 3	2.02	10 36	7 42	–	1429	
	2	"	2.	20	19	–	1358	
	3	"	"	33	29	–	1389	
	4	"	"	36	30	–	1392	
	5	"	"	02	6 59	–	1296	
	Mean	D. 3	2.	10 25	7 24	119.06	1373	

DATE.	No.	Kind of powder.	Height of charge.	VIBRATION. Musket pendulum.	VIBRATION. Ballistic pendulum.	Moment of musket pendulum.	Velocity of ball by ballistic pendulum.	REMARKS.
1844. June 10th			In.	° ′	° ′		Feet.	
	1	E. 3	1.91	9 15	6 17	-	1166	
	2	"	1.95	12	14	-	1157	
	3	"	1.98	17	20	-	1176	
	4	"	1.99	31	35	-	1222	
	5	"	1.98	32	33	-	1216	
	Mean	E. 3	1.96	9 21	6 24	106.94	1187	
	1	F. 0	2.10	10 10	7 20	-	1361	
	2	"	2.08	27	31	-	1395	
	3	"	2.10	09	17	-	1352	
	4	"	2.12	24	28	-	1385	Barrel foul.
	Mean	F. 0	2.10	10 17	7 24	117.56	1373	
	1	A. 0	2.10	10 13	7 21	-	1363	
	2	"	2.13	17	15	-	1340	Point struck
	3	"	2.15	25	25	-	1376	79.3 in.
	4	"	2.18	10	05	-	1314	
	Mean	A. 0	2.14	10 16	7 16	116.34	1348	
	1	H.	2.10	9 42	6 41	-	1240	
	2	"	2.05	10 05	7 10	-	1330	
	3	"	2.01	19	18	-	1355	
	4	"	2.06	16	20	-	1361	Barrel easily
5 P. M.	5	"	2.05	04	02	-	1305	cleaned.
	Mean	H.	2.05	10 05	7 06	115.20	1318	
June 11th 10 A. M.	1	K. 1. r.	2.05	9 40	6 44	-	1250	
	2	"	2.10	40	44	-	1250	
	3	"	2.09	46	45	-	1253	
	4	"	2.08	10 04	7 04	-	1311	
	5	"	2.10	9 49	6 47	-	1259	
	Mean	K. 1. r.	2.08	9 48	6 49	111.89	1265	

DATE.	No.	Kind of powder.	Height of charge.	VIBRATION. Musket pendulum.	VIBRATION. Ballistic pendulum.	Moment of musket pendulum.	Velocity of ball by ballistic pendulum.	REMARKS.
1844.			In.	° ′	° ′		Feet.	
June 11th.	1	K. 1. g.	2.02	9 09	6 13	–	1154	
	2	"	2.05	43	33	–	1216	
	3	"	2.02	25	30	–	1207	
	4	"	2.02	42	32	–	1213	
Noon.	5	"	2.05	41	42	–	1244	
	Mean	K. 1. g.	2.03	9 32	6 30	108.92	1207	
1 30 P. M.	1	L. 1	2.08	9 20	6 27	–	1197	
	2	"	2.02	24	29	–	1203	
	3	"	2.02	39	39	–	1234	
	4	"	2.09	41	44	–	1250	
	5	"	2.03	44	47	–	1259	
	Mean	L. 1	2.05	9 34	6 37	109.22	1229	
	1	M. 1	2.11	9 28	6 31	–	1210	
	2	"	2.08	9 50	6 51	–	1271	
	3	"	2.06	10 25	7 25	–	1376	
	4	"	2.10	10 04	7	–	1299	Barrel foul.
	5	"	2.02	9 58	6 53	–	1277	
	Mean	M. 1	2.07	9 57	6 56	113.65	1287	
	1	N.	2.05	10 33	7 35	–	1407	
	2	"	2.08	48	48	–	1447	
	3	"	2.06	42	41	–	1426	
	4	"	2.10	31	27	–	1382	
	5	"	2.09	54	53	–	1463	
	Mean	N.	2.08	10 42	7 41	122.12	1425	
	1	R. 15′	2.10	10 16	7 20	–	1361	
	2	"	2.20	26	30	–	1392	
	3	"	2.13	16	15	–	1345	
	4	"	2.15	33	35	–	1407	
	5	"	2.12	23	24	–	1373	
	Mean	R. 15′	2.14	10 23	7 25	118.63	1376	

DATE.	No.	Kind of powder.	Height of charge.	VIBRATION. Musket pendulum.	VIBRATION. Ballistic pendulum.	Moment of musket pendulum.	Velocity of ball by ballistic pendulum.	REMARKS.
1844.			In.	° ′	° ′		Feet.	
June 11th,	1	R. 30′	2.13	11 03	8 06	–	1503	
	2	"	2.20	10 55	7 56	–	1472	
	3	"	2.18	51	49	–	1450	
	4	"	2.10	52	48	–	1447	
	5	"	2.20	59	59	–	1481	
	Mean	R. 30′	2.16	10 56	7 56	124.88	1471	
	1	R. 60′	2.12	10 29	7 26	–	1379	
	2	"	2.20	59	57	–	1475	
	3	"	2.13	45	42	–	1429	
	4	"	2.17	46	42	–	1429	
	5	"	2.15	53	51	–	1457	
	Mean	R. 60′	2.15	10 46	7 44	123.14	1434	
	1	R. 90′	2.12	10 06	7 08	–	1324	
	2	"	2.10	06	04	–	1311	
	3	"	2.13	32	35	–	1407	
	4	"	2.16	40	42	–	1429	Barrel foul.
5 P. M.	5	"	2.17	48	53	–	1463	
	Mean	R. 90′	2.14	10 26	7 28	119.25	1387	
June 12th,	1	English cannon.	2.03	10	7 02	–	1305	
10 30 A.M.	2		2.03	9 56	13	–	1339	
	3		2.05	9 57	10	–	1330	
	4		2.06	10 35	40	–	1423	
	5		2.06	10 19	29	–	1389	Barrel easily cleaned.
	Mean	"	2.05	10 09	7 19	116.02	1357	
	1	English musket.	2.08	11 15	8 21	–	1549	
	2		2.08	29	38	–	1602	
	3		2.04	20	18	–	1538	
	4		2.09	28	29	–	1574	
	5		2.08	18	19	–	1543	
	Mean	"	2.07	11 22	8 25	129.82	1561	

DATE.	No.	Kind of powder.	Height of charge.	VIBRATION. Musket pendulum.	VIBRATION. Ballistic pendulum.	Moment of musket pendulum.	Velocity of ball by ballistic pendulum.	REMARKS.
1844.			In.	° ′	° ′		Feet.	
June 12th	1	English rifle.	2.16	11 21	8 26	–	1565	
	2		2.18	12 06	9 06	–	1688	
	3		2.10	11 30	8 34	–	1588	
	4		2.20	11 25	8 19	–	1543	
11 45 A.M.	5		2.15	11 45	8 53	–	1648	Ball fitting tight.
	Mean	"	2.16	11 37	8 40	132.73	1606	
1 P. M.	1	French cannon.	2.09	10 48	8 18	–	1540	
	2		2.13	11 04	8 16	–	1534	
	3		2.02	11 10	8 32	–	1583	
	4		2.10	11 05	8 20	–	1546	
	5		2.10	11 05	8 20	–	1546	
	Mean	"	2.09	11 02	8 21	126.27	1550	
	1	French musket.	2.10	10 45	8 13	–	1523	
	2		2.15	57	8 03	–	1493	
	3		2.11	43	7 57	–	1475	
	4		2.15	34	39	–	1420	
	5		2.12	49	59	–	1481	
	Mean	"	2.13	10 46	7 58	122.94	1478	
	1	French sporting.	1.99	12 05	9 29	–	1759	
	2		1.99	04	28	–	1756	
	3		2.	04	18	–	1725	
	4		"	12	25	–	1747	
	5		"	11 59	06	–	1688	
	Mean	"	2.	12 05	9 21	138.	1735	
	1	English sporting, J. Hall & Son's.	2.	12 55	9 55	–	1839	
	2		2.02	13 04	10 16	–	1905	
	3		2.	11 44	8 41	–	1611	
	4		2.01	12 28	9 36	–	1781	
	5		2.02	12 39	9 52	–	1830	
	6		2.	12 14	9 21	–	1734	
	Mean	"	2.01	12 40	9 48	144.61	1818	Rejecting No. 3.

DATE.	No.	Kind of powder.	Height of charge.	VIBRATION. Musket pendulum.	VIBRATION. Ballistic pendulum.	Moment of musket pendulum.	Velocity of ball by ballistic pendulum.	REMARKS.
1844.			In.	° ′	° ′		Feet.	
June 12th	1	C. 5	2.	11 04	8 11	-	1518	
	2	"	2.01	10 54	06	-	1503	
	3	"	2.	11 07	24	-	1559	
	4	"	2.	11 01	13	-	1525	
	5	"	2.02	10 59	06	-	1503	
	Mean	C. 5	2.01	11 01	8 12	125.83	1522	
	1	C. 6	2.	11 20	8 27	-	1568	
	2	"	"	25	8 35	-	1591	
	3	"	"	58	9 15	-	1716	
	4	"	1.98	41	8 56	-	1657	
	5	"	1.99	12 03	9 12	-	1707	
	Mean	C. 6	1.99	11 41	8 53	133.49	1648	
	1	From old musket cartridges.	2.18	9 56	7 11	-	1332	
	2		2.21	10 05	7 15	-	1345	
	3		2.21	9 56	7 05	-	1314	
	4		2.20	10 09	7 16	-	1349	
	5		2.18	9 53	7 06	-	1318	
	Mean	"	2.20	10	7 11	114.24	1332	
	1	Swedish musket.	1.97	10 15	7 25	-	1376	
	2		2.	10	20	-	1361	
	3		2.01	21	38	-	1417	
	4		2.01	13	20	-	1361	
4 45 P. M.	5		2.02	21	23	-	1369	
	Mean	"	2.	10 16	7 25	117.30	1377	

DATE.	No.	POWDER.		BALL.		Weight of ball and wad.	Height of charge.	VIBRATION.		Moment of musket pendulum.	Velocity of ball.
		Kind.	Weight.	Diameter.	Weight.			Musket.	Pendulum.		
1844.			Grs.	In.	Grs.	Grs.	In.	° ′	° ′		Feet.
July 5th,	1	A. 5	120	0.64	397.5	408.5	1.9	11 36	8 49	-	1636*
10 45 A.M.	2	"	"	"	"	"	"	11 44	8 58	-	1664
	3	"	"	"	"	"	"	12 03	9 26	-	1750*
	4	"	"	"	"	"	"	12 07	9 21	-	1734
11 20 A.M.	5	"	"	"	"	"	"	11 31	8 43	-	1617*
	Mean	A. 5	120	0.64	397.5	408.5	1.9	11 48	9 05	134.80	1680
3 P. M.	1	"	"	0.653	"	428.5	1.92	12 23	9 51	-	1745
	2	"	"	"	"	"	1.9	27	58	-	1765
	3	"	"	"	"	"	1.91	19	48	-	1736*
	4	"	"	"	"	"	"	26	51	-	1745
	5	"	"	"	"	"	1.92	39	10 10	-	1801
	Mean	A. 5	120	0.653	416.5	428.5	1.91	12 27	9 56	142.09	1758
	1	A. 4	"	"	"	"	2.10	11 36	8 39	-	1532*
	2	"	"	"	"	"	2.05	29	44	-	1547
	3	"	"	"	"	"	"	37	51	-	1568
	4	"	"	"	"	"	2.06	38	52	-	1571
4 P. M.	5	"	"	"	"	"	2.05	34	45	-	1550
	Mean	A. 4	120	0.653	416.5	428.5	2.06	11 35	8 46	132.29	1554
July 8th,	1	A. 5	"	0.64	397.5	408.5	1.9	11 39	8 51	-	1642†
	2	"	"	"	"	"	"	59	9 17	-	1722†
	3	"	"	"	"	"	"	49	05	-	1685†
	4	"	"	"	"	"	"	57	19	-	1727
5 P. M.	5	"	"	"	"	"	"	40	8 58	-	1665†
	Mean	A. 5	120	0.64	397.5	408.5	1.9	11 49	9 06	134.9	1688

* Face clamp of pendulum block fell off.

† Wads struck the pendulum.

The object of the experiments on the 5th July, was to compare the force of balls of diminished windage with that of the common musket balls. The large balls were made by compression, like the others, but they were not as accurate in their form; their mean weight was 414 grs., or very nearly 17 to 1 lb.; those selected for the experiments did not differ in weight more than $\frac{8}{10}$ths of a grain.

With these balls the paper wads were often carried into the pendulum block; but as it was not easy to estimate the weight of that part of the wad which struck the pendulum, no account has been taken of it in computing the velocity of the ball.

The falling off of the face clamp, in the experiments on the 5th, was caused by the reaction of a new leaden block in the core, which at first did not fit perfectly in its place, and therefore slipped, in the recoil of the pendulum; for this reason these experiments were repeated on the 8th, to verify the results.

In order to ascertain whether it would be practicable to use, in ordinary service, balls of the large size tried on the 5th, 100 rounds were fired from a musket altered to percussion, with a charge of 120 grs. of powder, A. 4.

The bore of this musket was 0.689 in. diameter, being a little under the regulation size of 0.69 in. The 100 rounds were fired without cleaning the barrel, which was cooled after every 20 rounds; the balls were wrapped, as usual, in cartridge papers, and no difficulty was experienced in loading the musket at any time.

July 8th, 1844.

COMPARATIVE TRIALS OF VARIOUS SMALL ARMS.

KIND OF ARM.	Kind of lock.	BORE.		REMARKS.
		Diam.	Length.	
		In.	In.	
Cadet's musket - - - -	Flint	0.57	35.5	Old pattern.
Common rifle - - - -	Percus'n	.54	32.5	1841, National Armory.
Hall's rifle (Loading at breech; moveable chamber.)	Flint	.52	35.1*	1826, National Armory.
Hall's carbine (Loading at breech; moveable chamber.)	Percus'n	.525	23.38*	1840, North's.
Jenks's carbine; loads at breech, with moveable breech plug.	Do.	.52	24.25	1844.

* Chamber included.

The balls for these arms were cast in the mould for Hall's carbine; they were nearly of the true diameter 0.525 in., and their average weight was 219 grs., or 32 to the pound.

For the arms loading at the breech, the balls were used naked. For the cadet's musket, they were wrapped in rifle cartridge papers, and the musket was loaded in the same manner as the pendulum musket barrel. The mean weight of the paper wads was 8.4 grs.

For the common rifle, the balls were wrapped in greased patches, the mean weight of which was 3.4 grs.; they were easily inserted with the rifle ramrod, and did not fit the bore quite as closely as balls prepared for ordinary service with the rifle. The patch was always carried with the ball into the pendulum block, and the weight of the patched ball is therefore used in computing the velocity.

The arms were held in a vice, to be fired at the pendulum block.

Rifle powder, A. 5, was used in these experiments. The chamber of Hall's rifle holds about 75 grains of powder, with the ball; that of Hall's carbine holds 100 grains. With 70 grains in the chamber of Jenks's carbine, the breech plug requires some force to bring it up to its place, and the powder is consequently compressed against the ball.

DATE.	No.	Kind of arm.	Charge.	Point struck.	Vibration of ballistic pendulum.	Velocity of ball by ballistic pendulum.	REMARKS.
1844.			Grs.	In.	° '	Feet.	
1 P. M.	1	Common rifle.	100	78.	5 44	1925	Rifle not clean; three caps flashed.
	2		“	79.	6	1989	
	3		“	79.2	6 07	2020	
	4		“	79.	6 11	2050	
	5		“	79.	6 04	2011	
	Mean	“	100	79.05	6 05	2018	Rejecting No. 1.
	1	Jenks's carbine.	70	78.5	5	1694	
	2		“	78.7	5 04	1712	
	3		“	78.7	4 57	1673	
	4		“	78.8	4 58	1677	
	5		“	79.	4 57	1667	
	Mean	“	70	78.74	4 59	1687	
	1	Hall's carbine.	70	78.9	3 27	1162	Several caps flashed.
	2		“	79.	4 12	1414	
	3		“	79.	3 37	1218	
	4		“	79.	3 37	1218	
	5		“	79.	3 32	1190	
	Mean	“	70	79.	3 41	1240	
	1	Cadet's musket.	70	79.	4 50	1628	
	2		“	78.9	5 04	1706	
	3		“	79.	4 55	1656	
	4		“	78.8	5 08	1730	
	5		“	79.	5 08	1729	
	Mean	“	70	78.94	5 01	1690	
	1	Hall's rifle.	70	79.	4 32	1527	
	2		“	79.1	4 36	1549	
	3		“	79.	4 26	1493	
	4		“	79.	4 25	1487	
	5		“	79.	4 08	1392	
	Mean	“	70	79.02	4 25	1490	
	1	Common rifle.	70	79.	5 18	1746	
	2		“	79.1	5 17	1752	
	3		“	79.	5 11	1719	
	4		“	79.	5 24	1791	Ball tight.
	5		“	79.1	5 20	1768	
	Mean	“	70	79.05	5 18	1755	

DATE.	No.	POWDER.		BALL.		Weight of ball and wad.	Height of charge.	VIBRATION.		Moment of musket pendulum.	Velocity of ball.
		Kind.	Weight.	Diameter.	Weight.			Musket.	Pendulum.		
1844.			Grs.	In.	Grs.	Grs.	In.	° ′	° ′		
July 9th, 3 P. M.	1	A. 4	100	0.64	397.5	408.5	1.85	9 13	6 54	-	1281
	2	"	"	"	"	"	"	39	7 27	-	1382
	3	"	"	"	"	"	1.82	42	30	-	1392
	4	"	"	"	"	"	"	35	27	-	1382
	5	"	"	"	"	"	"	45	33	-	1401
	Mean	A. 4	100	0.64	397.5	408.5	1.83	9 35	7 22	109.5	1368
July 17th, 2 30 P.M.	1	"	"	0.65	411.5	424.75	1.88	10 09	8 06	-	1451
	2	"	"	"	"	"	1.89	08	8	-	1434
	3	"	"	"	"	"	1.9	17	8 06	-	1452*
	4	"	"	"	"	"	1.88	9 59	7 46	-	1392
	5	"	"	"	"	"	1.9	10	7 54	-	1417
	Mean	A. 4	100	0.65	411.5	424.75	1.89	10 07	7 58	115.5	1429
	1	"	110	"	"	"	1.98	10 47	8 18	-	1487
	2	"	"	"	"	"	2.02	57	34	-	1535†
	3	"	"	"	"	"	2.02	45	11	-	1467
	4	"	"	"	"	"	1.98	52	30	-	1523†
	5	"	"	"	"	"	2.	55	32	-	1529‡
	Mean	A. 4	110	0.65	411.5	424.75	2.	10 51	8 25	123.95	1508
	1	"	"	0.64	397.5	408.5	1.99	10 33	7 59	-	1480
	2	"	"	"	"	"	2.	10	40	-	1423
	3	"	"	"	"	"	1.98	17	35	-	1407
	4	"	"	"	"	"	1.95	26	56	-	1472
4 P. M.	5	"	"	"	"	"	1.92	10	34	-	1404
	Mean	A. 4	110	0.64	397.5	408.5	1.97	10 19	7 45	117.88	1437

* Wad struck. † Ball fits tight. ‡ Ball enters easily.

The paper used for wrapping the balls of 0.65 in. happened to be rather thicker than usual; weight of wad 13.25 grains.

The balls, it will be seen, are a little reduced in size and weight from those used on the 5th; they are also more nearly spherical.

In order to test further the practicability of using, in ordinary service, the balls with diminished windage, Major Symington, the commanding officer of the Arsenal, caused the following trials to be made with balls similar to those of 0.65 in. diameter used in the experiments of the 17th instant.

Two muskets, of the smallest size of bore, were altered to percussion by inserting a cone in the top of the barrel, and adapting a hammer to the lock; each of them was fired 1000 rounds, as follows:

Bore of musket.	POWDER.		No. of rounds before cleaning the musket.	REMARKS.
	Kind.	Charge.		
Inch.		Grains.		
	A. 4	120	100	No difficulty in loading or firing.
0.688		130	100	Some balls required hard ramming.
	From old cartridges.	"	150	23d and 64th balls stuck fast, on account of the great quantity of dirt caused by the powder.
	A. 4	120	150	No difficulty in loading or firing; very little dirt remaining in the bottom of the barrel.
	"	"	50	
	"	"	50	
	"	"	100	
	"	"	200	
	"	"	100	
0.687	Old cartridges.	130	200	Barrel *very* dirty after these 200 rounds.
	A. 4	120	100	No difficulty in loading or firing.
	"	"	100	
	"	"	100	
	"	"	200	
	"	"	100	
	"	"	100	
	"	"	100	

DATE.	No.	POWDER.		BALL.		Weight of ball and wad.	Height of charge.	Point struck.	VIBRATION.		Moment of musket pendulum.	Velocity of ball.
		Kind.	Weight.	Diameter.	Weight.				Musket pendulum.	Ballistic pendulum.		
1844.			Grs.	In.	Grs.	Grs.	In.	In.	° ′	° ′		Feet.
Dec. 10	1	X.p.4	120	0.64	397.5	407.7	2.	78.65	11 02	8 13	–	1531
11 A.M	2	"	"	"	"	"	1.95	79.	10 53	8 04	–	1497
	3*	"	"	"	"	"	1.95	79.	11 18	8 33	–	1586
	4*	"	"	"	"	"	1.98	79.	11 15	8 27	–	1568
	5*	"	"	"	"	"	1.97	78.8	11 04	8 23	–	1559
	Mean	X.p.4	120	0.64	397.5	407.7	1.97	78.9	11 06	8 20	126.79	1548
Ball next the powder.	1	"	"	"	"	"	1.91	79.	10 25	7 29	–	1389
	2	"	"	"	"	"	"	"	20	10	–	1330
	3	"	"	"	"	"	"	"	25	15	–	1345
	†4	"	"	"	"	"	1.95	78.7	50	48	–	1449
	5	"	"	"	"	"	1.92	78.9	24	15	–	1344
	Mean	X.p.4	120	0.64	397.5	407.7	1.92	78.92	10 29	7 23	119.76	1371
	1	X.p.5	"	"	"	"	1.95	79.	11 43	9 06	–	1688
	‡2	"	"	"	"	"	1.98	78.8	12 16	45	–	1819
	3	"	"	"	"	"	1.98	78.8	12 12	37	–	1788
12 15 P.M.	‡4	"	"	"	"	"	1.96	79.	12 10	27	–	1753
	5	"	"	"	"	"	1.95	79.	11 59	10	–	1700
	Mean	X.p.5	120	0.64	397.5	407.7	1.96	78.92	12 04	9 25	137.79	1750
Dec. 12	1	X.p.4	110	"	"	"	1.92	79.	10 24	7 41	–	1425
10 20 A.M.	2	"	"	"	"	"	1.9	79.1	13	47	–	1444
	‡3	"	"	"	"	"	1.88	78.9	26	58	–	1478
	4	"	"	"	"	"	1.9	79.	12	32	–	1398
	5	"	"	"	"	"	1.95	79.	06	37	–	1413
	Mean	X.p.4	110	0.64	397.5	407.7	1.91	79.	10 16	7 43	117.3	1432

* Barrel not easily cleaned; balls enter hard. † Barrel foul.

DATE.	No.	POWDER.		BALL.		Weight of ball and wad.	Height of charge.	Point struck.	VIBRATION.		Moment of musket pendulum.	Velocity of ball.
		Kind.	Weight.	Diameter.	Weight.				Musket. pendulum.	Ballistic pendulum.		
1844.			Grs.	In.	Grs.	Grs.	In.	In.	° ′	° ′		Feet.
Dec. 12	1	X.p.4	100	0.64	397.5	407.7	1.80	79.	9 07	7	–	1299
	2	"	"	"	"	"	1.80	"	14	6 57	–	1290
	3	"	"	"	"	"	1.80	"	15	7 03	–	1308
	4	"	"	"	"	"	1.76	"	33	16	–	1348
Noon.	5	"	"	"	"	"	1.92	78.8	25	10	–	1333
	Mean	"	100	0.64	397.5	407.7	1.81	78.96	9 19	7 07	106.47	1316
1 20 P. M.	1	"	120	0.65	410.2	420.4	2.	79.	10 55	8 08	–	1462
	2	"	"	"	"	"	"	79.	11 17	35	–	1543
	3	"	"	"	"	"	"	78.8	14	34	–	1544
	4	"	"	"	"	"	"	78.9	09	25	–	1515
	5	"	"	"	"	"	2.03	79.	10 55	11	–	1471
	Mean	"	120	0.65	410.2	420.4	2.	78.92	11 06	8 23	126.79	1507
	1	"	110	"	"	"	1.93	78.8	10 18	7 52	–	1418
	2	"	"	"	"	"	1.92	79.	20	7 47	–	1399
	3	"	"	"	"	"	1.90	"	35	8 09	–	1465
	4	"	"	"	"	"	"	"	30	8 03	–	1447
	5	"	"	"	"	"	"	"	28	7 54	–	1420
	Mean	"	110	0.65	410.2	420.4	1.91	78.96	10 26	7 57	119.2	1430
	1	"	100	"	"	"	1.8	79.	9 35	7 20	–	1319
	2	"	"	"	"	"	1.8	"	30	17	–	1310
	3	"	"	"	"	"	1.82	"	34	16	–	1307
	4	"	"	"	"	"	1.8	78.9	33	21	–	1323
3 P. M.	5	"	"	"	"	"	1.78	78.8	47	33	–	1361
	Mean	"	100	0.65	410.2	420.4	1.8	78.92	9 36	7 21	109.7	1324

December 13*th*, 1844.

COMPARATIVE EXPERIMENTS IN FIRING WITH MATCH AND WITH A PERCUSSION LOCK.

The musket selected for to-day's experiments is a new Springfield Armory percussion musket, which was held in a vice, as in former trials. The diameter of the bore of this musket (by the gauge used for the balls) is 0.688. The balls are similar to those used yesterday.

In order to give the full force of the percussion powder, caps recently made at this Arsenal, and *not varnished*, were used; these caps contain about $\frac{6}{10}$ of a grain of percussion powder.

DATE.	No.	Mode of firing.	POWDER. Kind.	POWDER. Weight.	BALL. Diameter.	BALL. Weight.	Weight of ball and wad.	Height of charge.	Point struck.	Vibration of pendulum.	Velocity of ball.
1844.				Grs.	In.	Grs.	Grs.	In.	In.	° ′	Feet.
Dec'r 13	1	Percussion lock.	X. p. 4	110	0.65	410.2	420.4	2.	79.2	8 23	1503
2, P M.	2		"	"	"	"	"	1.9	78.9	22	1506
	3		"	"	"	"	"	1.9	78.8	17	1493
	4		"	"	"	"	"	1.88	79.	40	1558
	5		"	"	"	"	"	1.8	79.	32	1534
	Mean	"	X. p. 4	110	0.65	410.2	420.4	1.9	79.	8 27	1519
	1	Quick match.	"	"	"	"	"	1.8	79.2	7 58	1428
	2		"	"	"	"	"	1.9	79.	8 10	1477
	3		"	"	"	"	"	1.85	79.2	28	1518
3, P. M.	4		"	"	"	"	"	1.88	79.	11	1471
	Mean	"	X. p. 4	110	0.65	410.2	420.4	1.86	79.08	8 13	1474
	1	Percussion.	"	"	"	"	"	1.6	79.	9 03	1627*

* Charge rammed hard.

At the last round, the quick match failed, in repeated trials, to fire the charge, which was rammed several times, without success, to force the powder up into the cone; it was then fired with a percussion cap.

Experiments were also made to-day with the new model percussion pistol, of rifle calibre. Diameter of bore 0.54.

To ascertain the force of the charge, the ball was fired into the pendulum, the pistol being held 2 feet from the face of the block, in order that the ball should strike near the centre; in that position, the vibration of the pendulum was sensibly increased by the blast and by the wad striking it. To ascertain the correction to be made for this effect, several blank charges were fired, and it was found that the vibration caused by the charge, without a wad, was 12′; with a wad 20′. The latter quantity is therefore deducted from the arc of vibration, to obtain that which is due to the ball alone.

DATE.	No.	POWDER.		BALL.		Weight of ball and wad.	Point struck.	Vibration of pendulum.	Correction.	Vibration due to the ball.	Velocity of ball.
		Kind.	Weight.	Diameter.	Weight.						
1844.			Grs.	In.	Grs.	Grs.	In.	° ′	′	° ′	Feet.
Dec. 13	1	X. p. 5	35	0.525	218.5	224	78.7	3 05	20	2 45	932
	2	"	"	"	"	"	78.7	3 07	"	2 47	943
	3	"	"	"	"	"	79.3	3 02	"	2 42	908
	4	"	"	"	"	"	79.1	3 16	"	2 56	989
	5	"	"	"	"	"	79.	3 11	"	2 51	963
	Mean	X. p. 5	35	0.525	218.5	224	78.96	3 08	20	2 48	947

The balls with the paper fit close in the bore.

In firing the pistol, with various charges, it was found that although 40 grains of the powder used in the above experiments may be fired without serious inconvenience, 30 grains form a sufficient charge to be used with ease to the hand; with this charge, the ball retains great force after passing through a 1-in. board at 40 yards. Other trials were made on the 19th, with the same charge, when two balls, in five shots, were placed, at 80 yards, in a target 6 ft. × 3 ft.; the balls passed through a board 1 in. thick, and ranged to a considerable distance beyond the target.

December 19*th*, 1844.

Other comparative experiments were made to-day, on the effect of firing the musket with a match and with a percussion lock.

For these trials, a musket of the *largest* bore was selected from a box of 20 new percussion muskets; diameter of the bore 0.694 in.; it was held in a vice, as before, to be fired. The caps used to-day were of the same kind as those used on the 13th, except that they were varnished.

Experiments were also made with a new percussion rifle. The balls were wrapped in greased patches of linen cambric; but little force was required to ram them down with the rod belonging to the rifle. As the patch went with the ball into the pendulum block, its weight is included, in computing the velocity of the ball.

DATE.	No.	Kind of arm, &c.	POWDER. Kind.	POWDER. Weight.	BALL. Diameter.	BALL. Weight.	Weight of ball and wad.	Height of charge.	Point struck.	Vibration of pendulum.	Velocity of ball.
1844.				Grs.	In.	Grs.	Grs.	In.	In.	° ′	Feet.
Dec'r 19th 11, A. M.	1	Musket fired with match.	X. p. 4	110	0.65	410.2	420.4	1.8	79.1	7 49	1404
	2		"	"	"	"	"	"	79.	58	1432
	3		"	"	"	"	"	"	"	58	1432
	4		"	"	"	"	"	1.82	"	38	1373*
	5		"	"	"	"	"	"	"	46	1396*
	Mean	"	X. p. 4	110	0.65	410.2	420.4	1.81	79.	7 50	1407
	1	Musket fired with percussion.	"	"	"	"	"	1.86	79.	7 46	1396*
	2		"	"	"	"	"	1.8	78.9	57	1431
	3		"	"	"	"	"	1.85	79.	38	1373*
	4		"	"	"	"	"	1.8	"	8 15	1483†
	5		"	"	"	"	"	1.8	78.9	8	1440†
	Mean	"	X. p. 4	110	0.65	410.2	420.4	1.82	78.96	7 55	1425
	1	Percussion rifle.	X. p. 5	80	0.525	218.3	220.3	–	78.7	5 14	1758
	2		"	"	"	"	"	–	78.8	22	1801
	3		"	"	"	"	"	–	79.1	27	1821
12 30 P. M.	4		"	"	"	"	"	–	78.7	26	1825
	5		"	"	"	"	"	–	79.	27	1824
	Mean	"	X. p. 5	80	0.525	218.3	220.3	–	78.86	5 23	1806

* Ball enters easy. † Ball fits close.

The charge of 80 grains for the rifle was tried by firing at a target, 12 rounds at 130 yds., and 12 rounds at 200 yards distance; the accuracy of fire was satisfactory, and the force of this charge is, obviously, abundantly sufficient for the rifle. It can be used without the slightest inconvenience from the recoil.

With the musket, 20 rounds were fired with 110 grains of the musket powder X. p. 4, and balls of 0.65 in. The recoil with this charge can be borne without serious inconvenience, but it is considered that no greater charge of such powder can be advantageously used with these balls.

It should be remarked, that on account of unavoidable imperfections in the temporary arrangements for making balls by compression, to be used in these experiments, the balls are not quite uniform in size; the variation in the balls said to be of 0.65 in. diameter, is indicated by the difference of weight between those used in the late experiments, and those which were tried in July, the former being smaller and lighter than the latter.

January 14*th* to 16*th*, 1845.

Some experiments were made on the effect of firing the musket with the charge of 110 grains of musket powder X. p. 4., and balls of 0.04 in. windage; by ascertaining the depression of the ball, at different distances, when fired horizontally.

For this purpose the barrel of the new percussion musket was inserted in a heavy stock attached to a strong frame, in such a manner that it could either be placed level, or at an elevation.

A target was placed successively at different distances from the musket, and at each distance, a horizontal line was traced on it at the height of the axis of the barrel, which was about 3½ ft. above the general level of the ground. The target was 8 ft. long and 5 ft. high.

The musket barrel was loaded in the same manner as for the pendulum experiments, and it was fired with quick match.

The results of the experiments are given in the following table:

Experiments on the range of the musket.

Date.	No.	Distance of target.	Eleva-tion.	Ordinates of the trajectory.	REMARKS.
1845.		Yds.	Min.	In.	
January 14	1	80	0	—7.25	Weather calm and pleasant.
	2	"	"	10.	
	3	"	"	4.5	
	4	"	"	6.5	
	5	"	"	10.25	
	6	"	"	18.	Rejected.
	Mean	80	0	—7.7	
15	1	120	0	18.5	Weather clear; strong wind.
	2	"	"	22.	
	3	"	"	26.5	
	4	"	"	30.25	
	5	"	"	17.	
	6	"	"	26.25	Wind moderate.
	7	"	"	17.25	
	8	"	"	20.25	
	9	"	"	38.	
	10	"	"	14.25	
	Mean	120	0	—23.	
	1	150	"	25.9	Wind moderate; weather pleasant.
	2	"	"	30.25	
	3	"	"	40.5	
	4	"	"	31.75	
	5	"	"	28.4	
	6	"	"	26.	
	7	"	"	30.	
	8	"	"	43.	
	Mean	150	0	—32.	
16	1	200	30	–	Fell short of the target.
	2	"	40	–	Went over.
	3	"	36	—27.	
	4	"	"	0.	
	5	"	"	+18.25	
	6	"	"	— 5.5	4 balls missed the target, by lateral deviation.
	7	"	"	— 8.	
	8	"	"	+16.25	
	Mean	200	36	— 1.	

At 500 yards, an elevation of about 3° 15′ was required, to strike the target.

IV. EXPERIMENTS WITH THE 1-POUNDER GUN PENDULUM.

The object of these experiments was to compare the indications of the strength of powder by a 1-pounder gun, with those furnished by the 24-pounder gun, in order to determine whether a gun of the former calibre can be made to serve the purpose of an eprouvette for cannon powder.

The gun was made for the purpose, of cast iron, and it is suspended, by means of an iron frame and shaft, similar, in many respects, to those of the heavy gun pendulum. The knife edges of the shaft rest in V's of cast steel attached to the top of a wooden frame, which is braced in such a manner as to be perfectly steady; to this frame is secured a brass limb, on which a slider is moved by the index of the pendulum; the limb is divided into spaces of 10 minutes which are subdivided into minutes by a vernier on the slider; the radius of the graduated arc is 67.3 in.

The diameter of the bore of the gun is - - -	2.0 in.
Diameter of the vent - - - - - -	0.1 in.
Length of bore, including hemispherical bottom -	32.5 in.

The weight of the gun is about 300 lbs., and of the frame 130 lbs.; but, by some preliminary experiments, it was found that with this weight the recoil produced by a charge of $\frac{1}{4}$ lb. of the strongest powder was more than 20°, within which limit it was thought advisable to reduce the recoil; a supplementary weight was therefore attached to the gun, in such a manner as to bring its axis into a horizontal position when the pendulum was at rest. When finally adjusted, it was found that:

The weight of the pendulum - - -		p'=542.5 lbs.
Distance of centre of gravity from knife edges		g'= 75.5 in.
Distance of axis of gun from	do.	i'= 84.0 in.
Distance of centre of oscillation from	do.	o'= 83.69 in.

Hence,

$$\text{Log.}\ \frac{2\,p'\,g'\,\sqrt{G\,o'}}{12\,i'} = 4.1644178$$

A supply of 1-pounder cast iron balls was procured from the Columbia foundry, near Georgetown; these balls are smooth and nearly accurate in form; they are all between 1.93 in. and 1.96 in. diameter, and by a judicious selection of the iron, they were made to weigh almost exactly 1 lb. For the present experiments, balls were selected between 1.955 in. and 1.96 in. diameter, (true diameter, say 1.9525 in.) and between 0.99 lb. and 1.01 lb. in weight, none of the balls being so light as the former weight, and none so heavy as the latter. The journal of experiments shows the actual weight of each ball used, but as the variations are very small, the mean weight 1.0013 lb. has been used for all of them, in the calculation of the results, and therefore the particular weight of each ball is not here given.

The bags for the powder were made of musket cartridge paper, on a former 1.85 in. diameter, having a hemispherical bottom to fit the bore of the gun; their mean weight is 0.0038 lb. When filled, the mouth is neatly closed by folding down the surplus paper on the powder.

The balls are held in place in the gun by grommets made of a small strand of packing yarn formed into a ring of the full size of the bore; these grommets are readily inserted by means of a rammer, the head of which is hollowed out, to go partly over the ball. The mean weight of the grommets is 0.0045 lb.

The gun being charged, the cartridge is pricked, and the charge fired by means of a strand of quick match.

The gun is cleaned with a cylindrical wire brush, made of a piece of cotton card nailed on a staff; this brush scrapes off the dirt and removes the bottom of the cartridge bag which always remains in the gun after the discharge; the bore is then wiped with a sponge, or a sort of mop made of rags, and after 3 rounds it is washed.

As the force of the charge, or the velocity of the ball, is to be determined by the recoil of the gun pendulum only, the balls are fired into a long box filled with sand, the depth of which, in the direction of the line of fire, is 3 feet. With the charge of 4 oz., which was used in these experiments, the balls penetrated nearly through the sand and were taken out uninjured, from near the back part of the box, which was made to open at top for the convenience of recovering the balls. The box rested on rollers and by moving it a few inches endwise after each shot, the balls were prevented from striking together; they were a little scratched by the sand, but not sensibly altered in form, size or weight, and they might no doubt be used several times over, without impairing the accuracy of the results.

The apparatus was placed in a large building, where it was served with perfect convenience, and all the arrangements were found well adapted to the use of such a pendulum. The frame has sufficient strength and stiffness, and the motion of the pendulum is very slightly impeded by the friction of the knife edges, as will appear from the following observations, made in determining the centre of oscillation: the loss of motion in 500 oscillations, beginning in an arc of 2°, was 40 minutes; in 500 oscillations, beginning in an arc of 1° 20′, the loss was 20 minutes.

The velocity of the ball is computed by the formula heretofore given for the heavy gun pendulum. (Page 32.)

$$v' = \frac{\dfrac{2 \sin. \frac{1}{2} A' \times p' g' \sqrt{G o'}}{i'} - N c}{b' \dfrac{D^2}{d^2} + \frac{1}{2} c'}$$

the notation being the same as before.

In accordance with the remarks made, in the discussion of this formula, relative to the decrease in the value to be assigned to the quantity N, as the charge and the calibre of the piece are diminished, I have here assumed for N the value of 1400 feet.

By assigning to the other elements of the formula their constant mean values as above stated, we have, for computing the results of the following experiments:

b', the weight of the ball and wad $= 1.0013$ lb.$+0.0045$ lb. $= 1.0058$ lb.
c', the weight of powder and bag $= 0.25$ lb.$+0.0038$ lb. $= 0.2538$ lb.
D, diameter of the bore $= 2$ in.
d, diameter of the ball $= 1.9525$ in.
c, weight of the powder $= 0.25$ lb.

and the formula for the velocity of the ball, in feet, becomes:

$$v' = \frac{\sin.\frac{1}{2}A' \times 14602.2 - 350}{1.1822} = \sin.\tfrac{1}{2}A' \times 12351.7 - 296.1$$

which furnishes a very easy method of computing the velocity, when the weight and diameter of the balls are not different from those above stated. By selecting, for any set of experiments, balls which shall be nearly uniform in size and weight, though differing from the above, the same form may be always given to the expression for the velocity.

The greatest error which could arise from the use of these mean values, in computing the results of the present experiments, is about 14.5 ft. in a velocity of 1440 feet, or $\frac{1}{100}$th part; but this is on the supposition that the largest ball may be the lightest, or vice versa, a case which would rarely occur, if ever; this error too is, in a great measure, compensated by the fact that the formula, in this state, assigns too high a velocity to the heavier balls and too low a velocity to the lighter ones, so that a correction of the results to a uniform standard weight of ball is already made.

The greatest actual error, in these results, after making the correction for difference of weight in the balls, is found to be 6 feet.

The values of the term $\frac{2p'g'\sqrt{Go'}}{12i'} \times \sin.\frac{1}{2}A'$, heretofore denominated the moment of the gun pendulum, have been computed for these experiments and are given in the tables.

DATE.	No.	Kind of powder.	PENDULUM. Vibration.	PENDULUM. Moment.	Velocity of ball.	REMARKS.
1844.			° ′		Feet.	
November 29,	1	A.	15 48	2007.	1401	
	2	"	58	2028.1	1419	
	3	"	48	2007.	1401	
	Mean	A.	15 51	2014.	1407	
	1	B.	16 10	2053.3	1439	
	2	"	15	2063.8	1450	
	3	"	15	2063.8	1450	
	Mean	B.	16 13	2060.3	1446	
	1	C.	16 10	2053.3	1439	
	2	"	16	2065.9	1451	
	3	"	24	2082.7	1466	
	Mean	C.	16 17	2067.3	1452	
	1	D.	15 42	1994.4	1391	
	2	"	34	1977.6	1373	
	3	"	27	1962.8	1364	
	Mean	D.	15 34	1978.3	1376	
	1	E.	13 27	1710.	1150	
	2	"	38	1733.2	1170	
	3	"	34	1724.8	1163	
	Mean	E.	13 33	1722.7	1161	
	1	F.	16 40	2116.3	1494	
	2	"	40	2116.3	1494	
	3	"	34	2103.8	1483	
	Mean	F.	16 38	2112.1	1490	
December 3,	1	A. 1	15 18	1943.9	1341	
9 30 A. M.	2	"	38	1986.	1384	
	3	"	38	1986.	1384	
	Mean	A. 1	15 31	1972.	1370	

DATE.	No.	Kind of powder.	PENDULUM.		Velocity of ball.	REMARKS.
			Vibration.	Moment.		
1844.			° ′		Feet.	
December 3,	1	B. 1	15 31	1971.3	1371	
	2	"	40	1990.2	1387	
	3	"	39	1988.1	1386	
	Mean	B. 1	15 37	1983.2	1381	
	1	E. 1	13 03	1659.4	1108	
	2	"	04	1661.5	1109	
	3	"	06	1665.7	1113	
	Mean	E. 1	13 04	1662.2	1110	
	1	F. 1	16 11	2055.4	1439	
	2	"	28	2091.1	1472	
	3	"	25	2084.8	1467	
	Mean	F. 1	16 21	2077.1	1459	
	1	G. 1	15 36	1981.8	1380	
	2	"	59	2030.2	1421	
	3	"	56	2023.8	1416	
	Mean	G. 1	15 50	2011.9	1406	
	1	G. 6	18 17	2320.	1666	
	2	"	21	2328.4	1673	
	3	"	17	2320.	1666	
	Mean	G. 6	18 18	2322.8	1668	
	1	E. 5	15 55	2021.7	1414	
	2	"	16 06	2044.8	1434	
10 45 A. M.	3	"	16 09	2051.2	1439	
	Mean	E. 5	16 03	2039.2	1429	

DATE.	No.	Kind of powder.	PENDULUM.		Velocity of ball.	REMARKS.
			Vibration.	Moment.		
1844.			° ′		Feet.	
December 4th	1	A. 3	16 30	2095.3	1476	
1 50, P. M.	2	"	18	2070.1	1455	
	3	"	26	2086.9	1469	
	Mean	A. 3	16 28	2081.8	1467	
	1	B. 3	16 36	2108.	1487	
	2	"	24	2082.7	1466	
	3	"	37	2110.1	1489	
	Mean	B. 3	16 32	2100.3	1481	
	1	E. 3	14 23	1828.	1250	
	2	"	30	1842.8	1263	
	3	"	37	1857.6	1275	
	Mean	E. 3	14 30	1842.8	1263	
	1	F. 0	16 28	2091.1	1472	
	2	"	28	2091.1	1472	
	3	"	34	2103.	1483	
	Mean	F. 0	16 30	2095.1	1476	
	1	A. 0	16 17	2068.	1453	
	2	"	20	2074.3	1459	
	3	"	30	2095.3	1476	
	Mean	A. 0	16 22	2079.2	1463	
	1	A. 4	17 27	2215.	1577	
	2	"	19	2198.3	1563	
2 50, P. M.	3	"	29	2219.3	1581	
	Mean	A. 4	17 25	2210.9	1574	

DATE.	No.	Kind of powder.	PENDULUM.		Velocity of ball.	REMARKS.
			Vibration.	Moment.		
1844.			° ′		Feet.	
December 5th	1	K. 1. r.	15 48	2007.	1401	
10 40 A. M.	2	"	34	1973.	1373	
	3	"	49	2009.1	1403	
	Mean	K. 1. r.	15 44	1996.3	1392	
	1	K. 1. g	15 25	1958.6	1361	
	2	"	29	1967.	1368	
	3	"	29	1967.	1368	
	Mean	K. 1. g	15 28	1964.2	1366	
	1	R. 15′	16 11	2055.4	1439	
	2	"	24	2082.7	1466	
	3	"	30	2095.3	1476	
	Mean	R. 15′	16 22	2077.8	1460	
	1	R. 90′	16 40	2116.3	1494	
	2	"	43	2122.7	1500	
	3	"	50	2137.3	1512	
	Mean	R. 90′	16 44	2125.4	1502	
	1	X. p	16 35	2105.8	1485	
	2	"	41	2118.4	1496	
	3	"	35	2105.8	1485	
	Mean	X. p	16 37	2110.	1489	
	1	X. p. 4	17 05	2168.9	1539	
	2	"	16 56	2150.	1523	
	3	"	17 06	2171.	1540	
	Mean	X. p. 4	17 02	2163.3	1534	
	1	X. p. 5	17 40	2242.3	1601	
	2	"	59	2282.2	1634	
11 45 A. M.	3	"	18 19	2324.1	1670	
	Mean	X. p. 5	17 59	2282.9	1635	

V. EXPERIMENTS WITH AN 8-INCH MORTAR.

The mortar used in these experiments was a new, light 8-inch iron mortar, with a Gomer chamber; its principal dimensions are as follows:

	Inches.	
Diameter of the bore - - -	8.02	
Length of bore, exclusive of chamber -	12.	
Diameter of chamber, at bottom of shell	6.08	Chamber holds 2.5 lbs. of powder.
Inferior diameter of chamber - -	4.	
Length of chamber - - -	4.	
Diameter of the vent - - -	0.175	
Weight of mortar - - -	925 lbs.	

The mortar was mounted on a solid cast iron bed, which was placed on a horizontal platform, 6 feet square, formed of timbers 8 in. square. It was pointed at 45° elevation.

The shells are 1.4 in. thick; they were filled with sand, so as to weigh 48 lbs. These shells were selected with gauges of the diameters 7.8 in. and 7.85 in.; they are therefore considered to be of a mean diameter of 7.83 in., having 0.19 in. windage.

The charge of powder was 12 oz.; it was contained in paper cartridge bags, and fired with a strand of quick match.

The ground on which the shells fell was dry and hard, and they did not bury themselves; penetrating generally but little more than half a diameter.

The times of flight were observed by means of a very delicate *michronometer*, (made by Mr. Montandon, of Washington,) which marks the sixtieth part of a second, and which was used in many of these experiments, for noting small portions of time.

DATE.	Kind of powder.	RANGE.				TIME OF FLIGHT.			
		1	2	3	Mean.	1	2	3	Mean.
1844.		Yds.	Yds.	Yds.	Yds.	" '''	" '''	" '''	" '''
June 25th,	A. 1	391	426	447	421	9 15	9 38	10 21	9 45
1 30 P. M.	B. 1	521	541	547	536	10 58	10 56	11 08	11 01
	C. 1	500	527	527	518	10 22	11 11	10 37	10 43
	D. 1	445	449	479	458	10 10	10 14	9 48	10 04
	E. 1	459	453	454	455	10 06	9 58	10 28	10 11
	F. 1	696	693	696	695	12 36	12 26	12 34	12 32
	G. 1	562	629	570	587	11 04	12 02	11 36	11 34
	A. 3	326	330	410	355	8 12	8 33	9 23	8 43
	B. 3	538	595	598	577	11 06	11 38	11 28	11 24
	C. 3	615	559	618	597	11 42	11 30	12 03	11 45
3 45 P. M.	D. 3	550	581	630	587	11 20	11 11	12 02	11 31
June 26th,	F. 2	748	712	705	722	13 14	12 56	12 37	12 56
2 30 P. M.	G. 6	672	682	448*	677	11 41	12 50	10 56*	12 16
	E. 5	206	255	215	225	6 54	7 24	6 50	7 03
	F. 0	520	538	516	525	10 25	10 25	10 40	10 30
	A. 0	539	543	538	540	11 04	11 16	10 44	11 01
	H.	565	591	593	583	11 06	11 38	11 30	11 25
	K. 1. r.	479	492	492	488	10 20	10 06	10 46	10 24
	K. 1. g.	426	491	411	443	9 46	10 28	9 31	9 55
	L. 1	439	455	459	451	10 04	9 52	10 16	10 04
	M. 1	499	498	494	497	10 38	10 46	10 54	10 46
	N.	574	517	537	543	11 04	10 49	11	10 58
	R. 15′	559	540	575	558	11 22	11 02	10 52	11 05
5 45 P. M.	R. 90′	569	596	576	580	11 22	11 20	11 20	11 21

* Rejected.

VI. EXPERIMENTS WITH THE U. S. 24-POUNDER MORTAR EPROUVETTE.

The principal dimensions of this mortar are as follows :

Diameter of bore - - -	5.655 in.	
Length of bore, exclusive of chamber	11.5 in.	=2 diameters.
Diameter of chamber - -	1.5 in.	Holds 1 oz. of powder.
Length of chamber - - -	1.35 in.	
Diameter of vent - - -	0.15 in.	
Weight - - - - -	220 lbs.	
Windage of ball - - -	0.025 in.	
Weight of ball - - - -	24 lbs.	

The mortar is of iron, cast with a sole which is fitted into a bed plate, in such a manner as to prevent recoil; the bed plate is secured to a platform established on a foundation of solid masonry. The mortar is fixed at an elevation of 45°.

In these experiments, eprouvette No. 16 was used, always with the same ball, No. 4, belonging to that mortar. After trying each kind of powder, the mortar was washed and then dried with a blowing charge; the first charge with ball generally giving a low range, the mean result of the proof is deduced in almost all the cases from the 2nd and 3d charges; but the relative force of the different samples would have appeared very nearly the same if the mean of the three rounds had been taken.

The dimensions of the chamber of the mortar being calculated for powder of medium density, 1 oz. of the lighter kinds, the gravimetric density of which is below 830, is not easily contained in the chamber, and has to be settled in by rocking the mortar on its bed, whilst it is held in a vertical position. On the other hand, 1 oz. of the heavier kinds of powder, of the gravimetric density of 930, leaves a considerable vacant space between the powder and the ball.

DATE.	Kind of powder.	RANGE. 1	2	3	Mean of 2 highest	REMARKS.
1843.		Yds	Yds	Yds	Yds.	
Sept. 7th,	A.	*266	279	280	280	*No blowing charge fired.
9 45 A. M.	B.	282	301	302	302	Samples taken from the barrels.
	C.	246	264	267	266	
	D.	246	260	262	261	
	A.	288	300	301	301	The remaining samples, to F. 0, were dried in the sun on the 1st Sept., and have been kept in glass bottles.
	B.	278	304	305	305	
	C.	249	277	287	282	
Noon.	D.	252	270	281	276	
1 15 P. M.	E.	188	212	212	212	Large vacancy in chamber.
	F.	290	297	303	300	Chamber overfilled.
	A. 1	275	278	273	277	
	B. 1	270	296	287	292	
	C. 1	223	242	237	240	
	D. 1	248	261	260	261	
	E. 1	180	197	190	194	
	F. 1	*308	299	298	304	*Neglected to wash the mortar.
	G. 1	244	263	257	260	
	A. 2	279	300	287	294	
	B. 2	282	299	294	297	
	C. 2	257	279	277	278	
5 15 P.M.	D. 2	267	293	284	289	
Sept. 8th,	E. 2	192	196	206	201	
8 40 A. M.	F. 2	294	313	310	312	
	G. 6	300	315	316	316	
	E. 5	223	234	239	237	
	A. 3	296	311	313	312	
	B. 3	290	312	311	312	
	C. 3	278	297	295	296	

DATE.	Kind of powder.	RANGE. 1	RANGE. 2	RANGE. 3	RANGE. Mean of 2 highest	TIME OF FLIGHT. 1	TIME OF FLIGHT. 2	TIME OF FLIGHT. 3	TIME OF FLIGHT. Mean of 2&3
1843.		Yds	Yds	Yds	Yds.				
	D. 3	297	298	308	303				
	E. 3	199	224	217	221				
	F. 0	290	260	301	296				
Noon.	English Cannon	244	266	267	267				
	English Musket	303	326	328	327				
1 15 P.M.	English Rifle*	300	318	320	319				
	French Cannon*	294	310	312	311				
2 05 P.M.	French Musket*	294	302	313	308				
Sept. 20th,	A. 0*	290	232	296	293				
1844.	H.	280	287	293	290				
June 20th, 9 30 A.M.	A. 4	303	319	313	316				
	K. 1. r.	279	288	288	288				
	K. 1. g.	257	272	279	276				
	L. 1	240	243	240	242				
11 A.M. †	M. 1	258	280	282	281				
11 45 "	N.	281	300	300	300				
	R. 15′	290	308	310	309				
	R. 30′	298	314	320	317	″ ‴	″ ‴	″ ‴	″ ‴
	R. 60′	300	311	316	314	7 56	8 24	8 20	8 22
	R. 90′	279	296	303	300	7 33	8	8 10	8 05
2 30 P.M.‡	S.	282	300	300	300	7 59	8 17	8 08	8 13
4 15 "	T.	56	56	52	56	–	3 17	3 04	3 11
	C. 5	288	310	316	313	7 52	8 14	8 18	8 16
	French sporting	296	321	325	323	8 27?	8 19	8 25	8 22
	Swedish musket	247	272	273	273	7 19	7 35	7 36	7 36
5 45 "	Old cartridges	267	284	289	287	7 49	8 02	8 10	8 06

* Chamber overfilled. † Shower of rain. ‡ Rain.

VII. EXPERIMENTS WITH THE FRENCH MORTAR EPROUVETTE.

The principal dimensions of the mortar are as follows:

Diameter of bore - - - - - -	7.53 in.
Length of bore, exclusive of chamber - -	9.48
Diameter of chamber - - - - -	1.95
Length of chamber - - - - -	2.58
Diameter of vent - - - - - -	0.13
Weight of mortar - - - - - -	257 lbs.
Windage of ball - - - - - -	0.0666 in.
Weight of ball - - - - - -	64.6 lbs.

Charge of powder, 92 grammes = 1420 grs. = $3\frac{1}{4}$ oz. nearly.

The mortar is of bronze, cast with a sole which is bolted to a wooden bed. It is placed on a level platform of timber, and is allowed to recoil freely. It is fired at an elevation of 45°.

The service of the eprouvette was conducted according to the instructions in the Aide Mémoire d'Artillerie, and the mean results are taken in the same manner as with the U. S. eprouvette.

The mortar and globe used in these experiments were received from the French War Department, and have been adjusted at the "Atelier de précision" in Paris. The globe is of iron; but although the ground on which it fell was free from stones, its great weight causes it to be much bruised, even by small pebbles.

DATE.	Kind of powder.	RANGE. 1	2	3	Mean of 2 highest.	REMARKS.
1843.		Yds.	Yds.	Yds.	Yds.	
Sept. 18th	A.	211	211	219	215	Powder taken from the barrels.
7 40 A. M.	B.	240	249	251	250	
	C.	206	214	227	221	
	D.	216	211	229	223	
	A.	221	241	237	239	Remaining samples, to F. 0, taken from the powder dried in the sun on 1st Sept'r.
Noon	B.	242	256	263	260	
1 35 P. M.	C.	230	234	236	235	
	D.	230	243	245	244	
	E.	159	173	172	173	Large vacancy in the chamber.
	F.	254	267	268	268	Chamber full.
	A. 1	208	221	253	237	
	B. 1	230	238	241	240	
5 30 "	C. 1	181	192	192	192	
Sept. 19th	D. 1	226	242	214	234	
4 P. M.	E. 1	150	165	161	163	
	F. 1	251	264	264	264	Do.
5 45 "	G. 1	199	216	216	216	
Sept. 20th	A. 2	233	227	246	240	
7 40 A. M.	B. 2	251	252	242	252	
	C. 2	226	249	223	238	
	D. 2	241	262	261	262	
	E. 2	158	174	168	171	
	F. 2	241	258	255	257	Do.
	G. 6	241	254	255	255	Chamber about $\frac{2}{3}$ds full.
	E. 5	231	220	244	238	
11 45 "	A. 3	257	247	278	268	
1 10 P. M.	B. 3	246	261	268	265	
	C. 3	233	268	259	264	

DATE.	Kind of powder.	RANGE. 1	2	3	Mean of 2 highest	REMARKS.
		Yds	Yds	Yds	Yds.	
1843. Sept. 20th	D. 3	251	253	266	260	
	E. 3	175	191	208	200	
	F. 0	251	257	260	259	Chamber full.
4 P. M.	A. 0	238	257	255	256	
	G. 6	274	–	–	274	Space over the powder in the chamber filled up with saw dust.
	E. 5	278	–	–	278	
	E. 3	236	–	–	236	
Sept. 13th	French Cannon	257	256	257	257	Powder as taken from canister.
19th	French Ditto	–	274	259	267	The other samples of French and English powder dried in the sun on 16th Sept'r.
1 30 P. M.	French Musket	251	264	249	258	
	English Cannon	203	231	223	227	
	English Musket	255	268	271	270	
	English Rifle	243	257	268	263	

DATE.	Kind of powder.	RANGE. 1	2	3	Mean of 2 highest	TIME OF FLIGHT. 1	2	3	Mean.
		Yds	Yds	Yds	Yds.	'' '''	'' '''	'' '''	'' '''
1844. June 21st Noon	H.	222	239	232	236	6 38	6 56	7 20	7 08
	A. 4	248	267	265	266	7 31	7 44	7 50	7 47
1 P. M.	K. 1. r.	230	240	239	240	7 24	7 16	7 07	7 11
	K. 1. g.	206	214	214	214	6 47	6 58	7 04	7 01
	L. 1	196	216	209	213	6 40	7 20	6 58	7 09
	M. 1	224	232	230	231	7 18	7 12	7	7 06
	N.	226	239	238	239	7 08	7 12	7 18	7 15
	R. 15′	250	260	260	260	7 34	7 52	7 42	7 47
	R. 90′	222	234	239	237	7 08	7 12	7 16	7 14
	S.	242	244	240	243	7 30	7 36	7 36	7 33
4 45 P. M.	T.	49	48	70	59	3 11	3 17	4 08	3 40

VII. EXPERIMENTS WITH THE ENGLISH HALF-POUND GUN EPROUVETTE.

This eprouvette consists of a brass gun suspended as a pendulum; it is fired without ball or wad over the powder, and the force of the charge is estimated by the extent of recoil expressed in degrees and tenths.

The diameter of the bore of the gun is - -	1.75 in.
Length of bore - - - - -	27.2
Distance from the axis of bore to axis of shaft -	31.45
Charge for proof of powder - - -	2 oz.

The journals of the suspension shaft are cylindrical, 0.5 in. in diameter and 1 in. long. The friction of these journals is such, that when the pendulum is set in motion in an arc of 10°, it does not make more than 80 vibrations before the extent of them becomes insensible.

The instrument used in these experiments was received from the British Ordnance Department. The service of the eprouvette was conducted according to the instructions contained in Griffith's Artillerist's Manual. When, by repeated firings, the gun became unduly heated, it was filled with water and allowed to cool; after the trial of each kind of powder, it was washed, and dried with a blowing charge.

DATE.	Kind of powder.	VIBRATION OF EPROUVETTE. 1	2	3	Mean.	REMARKS.
1843.		°	°	°	°	
Sept. 4th	A.	17.90	18.4	19.1	18.47	Powder just taken from the barrels.
10 30 A.M.	B.	21.40	21.3	21.4	21.37	
Noon.	C.	20.1	20.7	20.9	20.57	
1 P.M.	D.	19.8	19.9	20.15	19.95	
	A.	19.15	19.85	19.45	19.48	Remaining samples, to F. 0, dried in the sun on the 1st Sept'r.
	B.	21.4	21.9	21.7	21.67	
	C.	21.7	21.9	21.7	21.77	
2 30	D.	20.4	21.3	21.4	21.03	Gun much heated.
4 15	D.	21.1	–	–	21.1	Gun cool.
	E.	20.7	20.7	21.1	20.83	
	F.	22.5	23.	23.	22.83	
	A. 1	18.1	18.3	18.35	18.25	
	B. 1	19.8	19.7	19.75	19.75	
	C. 1	18.2	18.3	18.6	18.37	
5 30	D. 1	18.2	19.	19.3	18.83	
Sept. 5th	E. 1	19.9	20.18	20.2	20.09	
7 A. M.	F. 1	21.9	22.1	22.12	22 04	
	G. 1	20.7	20.8	21.1	20.87	
	A. 2	19.2	19.2	19.2	19.2	
	B. 2	20.8	20.4	20.6	20.6	
	C. 2	19.75	19.9	20.	19.88	
9 30	D. 2	20.9	21.4	21.3	21.2	
10 15	E. 2	20.4	20.75	21.	20.72	
	F. 2	23.6	23.75	24.	23.78	
	G. 6	27.	27.8	27.	27.27	
	E. 5	21.7	21.3	22.55	21.85	
11 15	A. 3	20.9	21.05	21.2	21.05	
1 P. M.	B. 3	22.3	22.5	22.9	22.67	
	C. 3	22.4	22.5	21.9	22.27	
	D. 3	22.6	22.7	23.	22.77	
	E. 3	21.	21.85	22.2	21.68	
2 10	F. 0	16.7	17.10	17.4	17.07	
	English Cannon	22.4	22.	21.5	21.97	
5	English Musket	25.9	25.9	26.3	26.03	
5 30	English Rifle	28.	28.	27.8	27.93	
Sept. 6th	French. Cannon	23.3	23.	23.1	23.13	
11 30 A.M.	French. Musket	24.75	24.6	24.65	24.67	

Experiments with the English half-pound gun eprouvette—(Continued.)

DATE.	Kind of powder.	VIBRATION OF EPROUVETTE. 1	2	3	Mean.	REMARKS.
1844.		°	°	°	°	
June 19th	A. 0	14.9	14.1	14.5	14.5	
10 20 A.M.	H.	22.	22.2	22.2	22.13	Powder just taken from the barrel.
	A. 4	22.1	21.8	22.	22.	
	K. 1. r.	18.45	18.8	19.	18.75	
	K. 1. g.	19.2	19.4	19.1	19.23	
	L. 1	19.	19.	19.15	19.05	
11 45 A.M.	M. 1	20.25	20.15	20.3	20.23	
1 15 P. M.	N.	19.7	19.95	20.4	20.02	
	R. 15′	20.05	20.3	20.55	20.3	
	R. 30′	20.7	20.4	20.6	20.57	
	R. 60′	21.	21.05	20.9	21.	
	R. 90′	20.6	20.4	20.	20.33	
	S.	19.65	20.	19.8	19.82	
	T.	11.2	11.7	11.5	11.47	
	C. 5	21.8	22.1	22.8	22.23	
	French sporting	26.4	26.3	–	26.35	
	Swedish musket	22.8	22.7	–	22.75	
3 30 P. M.	Old cartridges	21.05	21.2	21.3	21.18	

In firing a charge of the powder T. a sheet of thick paper, held about 4 ft. in front of the muzzle of the gun, was perforated as if with a charge of small shot; with a charge of French sporting powder, the paper was blown into fragments, but was scarcely discolored.

IX. EXPERIMENTS WITH ALGER'S EPROUVETTE.

This eprouvette, made by Mr. Alger, of the South Boston foundry, is an iron mortar, or rather a short howitzer, the chamber of which is intended to hold *half an ounce* of powder. Its principal dimensions are as follows:

Diameter of bore - - - - - - -	6 in.
Length of bore, including hemispherical bottom,	27
Diameter of chamber - - - - - -	1.5
Depth of do. - - - - - -	0.7
Diameter of vent - - - - - - -	0.1
Weight of ball - - - - - - -	30 lbs.
Charge of powder - - - - - -	$\frac{1}{2}$ oz.

The piece is furnished with trunnions, by means of which it is supported on a cast iron bed with high cheeks, at an elevation of 60°.

The windage of the ball is scarcely appreciable, being just sufficient to admit it into the bore.

The chamber is formed in a breech plug of wrought iron, which is screwed into the bottom of the bore. This plug is 2.6 in. in diameter; it is perforated in the axis, to receive a moveable plunger 0.35 in. in diameter, which contains the vent. At right angles to the axis of this vent, which is not bored through the whole length of the plunger, holes are bored through the plunger and through a projecting part of the breech of the gun, which holes correspond with each other when the inner end of the plunger is flush with the bottom of the chamber; hence a priming tube inserted in the exterior part of the vent communicates its fire to the charge, but as soon as the charge explodes, the plunger recoils and the communication with the vent in the gun is cut off, so that no escape of gas takes place from the vent. The recoil of the plunger is checked, at the proper distance, by its striking against the bed of the piece. Although the distance from the exterior vent to the bottom of the chamber, or the length of the vent in the plunger, is 4.25 in., the fire from the tube rarely fails to ignite the charge in the gun.

The powder is contained in cylinders of thin paper made to fit the chamber, and closed at the top by discs of paper or pasteboard, of different thicknesses, according to the density of the powder, so that there may be no vacancy left between the cartridge and the ball. The bottom of the cartridge is pricked with a pin, before it is inserted in the chamber.

The eprouvette was established on a solid stone platform, on Dorchester point, near Boston; and as other business called me in that direction, I took with me samples of the powder to be tried, put up in close tin canisters. The cartridges were prepared, and the gun was served by the person who had been generally employed for that purpose, in other trials of the instrument.

The anomalies which will be remarked in the ranges with this eprouvette are attributed, in a great measure, to the small windage of the ball, in consequence of which a slight scratch, or a minute portion of dirt, which might adhere to the ball or the gun, notwithstanding great care in cleaning both, would keep the ball off from the mouth of the chamber and permit the escape of gas around it.

The experiments are considered worthy of record, because the arrangements of the eprouvette embrace several of the modifications which have been suggested, by writers on the subject, for improving the common mortar eprouvette: such as increasing the length of bore, reducing the windage, and closing the vent.

It does not appear that these modifications are of any value in correcting the inherent defects of the instrument.

Experiments with Alger's eprouvette.

Date.	Kind of powder.	RANGE. 1	2	3	REMARKS.
1843.		Yds.	Yds.	Yds.	
October 6th, 9 A. M.	A.	131	95	88	Wind N. W., brisk; Barometer 29.908 in.; Thermometer 50°.
	B.	142	88	93	During the experiments to-day the gun became very damp after firing; it was dried by heating it, before firing the two rounds marked *.
	C.	96	100	105	
	F.	100	145*	137	
	E.	100	112	113	
Noon.	G. 6	160	126	124	
1 P. M.	E. 5	154*	147	144	
	A. 1	138	140	138	
3 P. M.	B. 1	97	144	90	Barometer 29.818; Thermom. 63°.
October 7th, 10 A. M.	C. 1	126	128	128	Wind N. E.; Barometer 30 inches; Thermometer 53°.
	D. 1	132	131	131	
	E. 1	110	108	111	
	F. 1	143	114	139	
	G. 1	122	138	138	
	F. 0	128	130		
Noon.	A. 0	113	109		
12 40 P. M.	A.	151	155	157	Powder that had been dried on 1st September.
	B.	152	152	118	
	C.	141	148	129	
	D.	145	149	105	
	A. 2	141	155	113	
	A. 3	162	155	158	
	E. 2	120	123	119	
3 P. M.	F. 2	157	155	148	Barometer 29.97 in.; Thermometer 52°; Rain at 3½ P. M.

X. EXPERIMENTS IN DETERMINING THE RELATIVE DENSITIES OF VARIOUS KINDS OF GUNPOWDER.

Gravimetric densities.

The term *gravimetric density* is used to signify the weight of a given bulk of powder. It is here expressed by the weight of a cubic foot, in ounces.

The measure used for determining the gravimetric densities in these trials, is a cylindrical brass vessel 4.1625 in. in diameter and 8.464 in. high, containing, therefore, *one fifteenth* part of a cubic foot. Its capacity was adjusted by the weight of rain water which it should contain.

The powder is poured into it from a hopper in the form of a truncated pyramid, the smaller end of which has an opening about 1 in. in diameter, which is closed when necessary, by a sliding valve. This hopper is supported on a frame, so that its lower end is about 2 in. above the mouth of the powder measure; by withdrawing the valve, the powder is allowed to run until the measure becomes heaped, when it is carefully striked with a straight edge and weighed.

In determining the weight of the powder when it is settled, as in a cartridge, about one pound at a time was poured into the measure, which was shaken and the bottom struck carefully on a block of wood, until the powder nearly or quite ceased to settle.

The two trials with each kind of powder were, with very few exceptions, made with different parcels.

This method of determining the gravimetric density is the same as that practised at the English and French government powder works; except that in England the *gravimeter* is a vessel containing a cubic foot, (according to Braddock,) and in France it is a *litre*, which holds 61 cubic inches nearly.

Gravimetric densities.

DATE.	Kind of powder.	WEIGHT OF 1-15th OF A CUBIC FOOT.						WEIGHT OF A CUBIC FOOT.	
		LOOSE.			SETTLED.				
		1	2	Mean	1	2	Mean.	Loose.	Settled
1843.		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Oz.	Oz.
Aug. 30th	A.	3.875	3.866	3.871	4.298	4.362	4.330	929	1039
	B.	3.765	3.765	3.765	4.205	4.232	4.219	904	1012
31st	C.	3.936	3.927	3.932	4.493	4.470	4.482	944	1076
	D.	4.027	4.027	4.027	4.505	4.496	4.501	966	1080
30th	A.	3.851	3.881	3.866	4.340	4.317	4.329	928	1039
	B.	3.790	3.775	3.783	4.227	4.265	4.246	908	1019
31st	C.	3.933	3.925	3.929	4.460	4.485	4.473	943	1074
	D.	4.045	4.030	4.038	4.518	4.531	4.525	969	1086
	E.	3.980	3.995	3.988	4.613	4.618	4.616	957	1108
	F.	3.243	3.252	3.248	3.752	3.726	3.739	780	897
	A. 1	3.818	3.815	3.817	4.366	4.358	4.362	916	1047
	B. 1	3.675	3.679	3.677	4.160	4.172	4.166	882	1000
	C. 1	3.815	3.810	3.813	4.352	4.342	4.347	915	1043
	D. 1	3.880	3.885	3.883	4.350	4.370	4.360	932	1046
	E. 1	3.912	3.900	3.906	4.512	4.521	4.517	937	1084
	F. 1	3.228	3.230	3.229	3.725	3.750	3.738	775	897
Sept. 1st	G. 1	3.997	3.983	3.990	4.510	4.536	4.523	958	1086
Aug. 31st	A. 2	3.798	3.818	3.808	4.340	4.342	4.341	914	1042
	B. 2	3.666	3.656	3.661	4.192	4.190	4.191	879	1006
Sept. 1st	C. 2	3.740	3.730	3.735	4.241	4.271	4.256	896	1021
Aug. 31st	D. 2	3.845	3.837	3.841	4.345	4.343	4.344	922	1043
Sept. 1st	E. 2	3.952	3.950	3.951	4.600	4.581	4.591	948	1102
	F. 2	3.134	3.125	3.130	3.628	3.636	3.632	751	872
	G. 6	4.357	4.367	4.362	4.983	4.993	4.988	1047	1197
	E. 5	4.353	4.345	4.349	4.901	4.899	4.900	1044	1176
	A. 3	3.864	3.860	3.862	4.383	4.383	4.383	927	1052
Aug. 31st	B. 3	3.771	3.762	3.767	4.283	4.294	4.289	904	1029
	C. 3	3.913	3.919	3.916	4.432	4.445	4.439	940	1065
	D. 3	3.895	3.883	3.889	4.390	4.400	4.395	933	1055
	E. 3	4.157	4.147	4.152	4.762	4.742	4.752	996	1140

The first 4 samples, as taken from the barrel; the remainder, (on this page,) dried in the sun.

Table of gravimetric densities—(Continued.)

DATE.	Kind of powder.	WEIGHT of 1-15th OF A CUBIC FOOT.						WEIGHT OF A CUBIC FOOT.	
		LOOSE.			SETTLED.				
		1	2	Mean.	1	2	Mean.	Loose.	Settled
1844.		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Oz.	Oz.
Sept. 1st	F. 0	3.178	3.173	3.176	3.601	3.583	3.592	762	862
14th	A. 0	3.403	3.437	3.420	3.861	3.852	3.857	821	916
June 27th	H.*	3.640	3.640	3.640	4.150	4.122	4.136	874	993
	A. 4	3.740	3.730	3.735	4.215	4.220	4.218	896	1012
	K. 1. r.	3.735	3.733	3.734	4.235	4.230	4.233	896	1016
	K. 1.g.	3.812	3.818	3.815	4.292	4.315	4.304	916	1033
	L. 1	3.990	3.960	3.975	4.463	4.463	4.463	954	1071
	M. 1	3.850	3.855	3.853	4.333	4.316	4.325	925	1038
	N.	3.737	3.745	3.741	4.245	4.218	4.233	898	1016
	R. 15′	3.304	3.304	3.304	3.740	–	3.740	793	898
	R. 30′	3.510	–	3.510	3.950	–	3.950	842	948
	R. 60′	3.515	–	3.515	3.980	–	3.980	844	955
	R. 90′	3.610	3.620	3.615	–	–	–	868	
	S.	3.820	–	3.820	4.315	–	4.315	917	1036
	T.	3.808	–	3.808	4.307	–	4.307	914	1034
	C. 5	3.890	–	3.890	4.475	–	4.475	934	1074
July 24th	*a.*	3.790	3.800	3.795	4.320	–	4.320	911	1037
	W.	4 058	4.023	4.041	4.660	–	4.660	970	1118
	X.	3.767	3.767	3.767	4.300	4.290	4.295	904	1031
	X. p.	3.880	3.874	3.877	4.423	4.421	4.422	930	1061
	X. p.4.	3.905	3.905	3.905	4.535	4.545	4.540	937	1090
	X. p.5.	3.985	3.970	3.978	4.660	4.650	4.655	955	1117

* Powder dried in the sun.

Specific gravities of several samples of powder.

Some experiments were tried in determining the specific gravity of gunpowder, by weighing it in water saturated with saltpetre, according to the method used in the French service, and described in the Ordnance Manual, *page* 153.

The vessel used for this purpose, in the experiments of the 11th and 12th of September, 1843, was a glass bottle having a well fitted ground glass stopper. In the other experiments, there was used a straight glass jar, about 2.5 in. in diameter, and 7 in. deep, the top of which was ground true and covered with a plate of ground glass.

The following tabular statement exhibits the results of these trials:

DATE.	Contents of glass vessel.	Kind of powder.	WEIGHT. 1	2	3	Mean	Specific gravity.
			Lbs.	Lbs.	Lbs.	Lbs.	
1843. Sept. 11 & 12	Bottle empty -	–	–	–	–	1.14086	
	Distilled water* -	–	–	–	–	3.38133	1000
	Saltpetre water -	–	–	–	–	3.69674	1141
Temperature of room 65°.	Saltpetre water and 0.5 lb. of gunpowder.	G. 1	3.87856	–	–	3.87856	1793
		G. 6	3.89186	–	–	3.89186	1871
		F. 0	3.89400	–	–	3.89400	1884
1844. July 25th	Jar empty -	–	–	–	–	1.3729	
	Distilled water -	–	2.6284	2.6278	2.6279	2.62803	1000
Temp. 80°.	Saltpetre water -	–	2.80754	2.8079	2.8079	2.80778	1143
	Saltpetre water and 0.2 lb. of gunpowder.	A. 1	2.91407	2.9148	–	2.91444	1774
		B. 1	2.9208	2.9120	–	2.9164	1792
		E. 1	2.9176	2.9257	–	2.92165	1843
		F. 1	2.9213	2.9273	–	2.9243	1869
July 31st	Distilled water -	–	–	–	–	2.6284	1000
	Saltpetre water -	–	2.8357	–	–	2.8357	1165
Temperature 77° to 78°.	Saltpetre water and 0.3 lb. of powder.	R. 15′	2.9325	–	–	2.9325	1720
		R. 90′	2.9304	–	–	2.9304	1703

*Four trials.

It will be observed, that notwithstanding the care which was taken to keep the saltpetre water in a state of saturation, there is a sensible variation in its density, the heavier portion being that from near the bottom of the vessel which contained it. This method of determining the specific gravity of gunpowder seems liable to inaccuracy from the above cause, and still more from the error which may be introduced by a slight change of temperature during the experiment, causing the solution to deposit some of its saltpetre, or else to take up some of that in the powder; another cause of error may be found in the difficulty of ascertaining when the moisture in the powder is expelled, so as not seriously to affect the results. By being poured into the saltpetre water, the powder is almost immediately reduced to the state of paste, from which it is not always easy to expel the air completely.

Owing to these circumstances, it appears to me that this method cannot give correct indications of the influence of different modes of manufacture, &c., on the density of gunpowder.

Having observed that gunpowder is not apparently altered by immersion in highly rectified alcohol, I made other experiments on the specific gravities of several kinds of powder, by weighing them under alcohol; using for this purpose the same glass jar that was used in the experiments with saltpetre water.

The results of these experiments are exhibited in the following table :

DATE.	Contents of vessel.	Kind of powder.	Weight.	Specific gravity.	REMARKS.
1844.			Lbs.		
July 30th	Jar empty.	–	1.3729	–	Temperature of room 76°.
	Distilled water.	–	2.6286	} 1000	
	Do.	–	2.6282		
	Alcohol.	–	2.4011	} 821	
	Do.	–	2.4015		
July 31st	Do.	–	2.4007		Temp. 77° to 78°.
July 30th	Alcohol and 0. 3 lb. of powder	C. 1	2.5756	1957	
		D. 1	2.5678	1843	
	"	G. 6	2.579	2012	
	"	G. 1	2.5755	1955	
July 31st	"	E. 5	2.5768	1977	
	"	F. 0	2.57	1874	
	"	A. 0	2.5747	1944	
	"	H.	2.5764	1970	
	"	A. 4	2.5772	1983	
	"	B. 1	2.5725	1910	
	"	E. 1	2.577	1980	
	"	F. 1	2.5773	1985	
	"	K. 1. g.	2.5752	1951	
	"	L. 1	2.5725	1910	
	"	M. 1	2.5716	1897	
	"	N.	2.5787	2007	
	"	R. 15'	2.5721	1905	
	"	R. 90'	2.5769	1978	
Aug. 2nd	"	A. 1	2.5726	1912	

The powder for these trials was well dried in the sun, but some differences in the results are undoubtedly due to the difference in the degree of moisture left in the powder, as this would necessarily be greater in the large grains than in the small. From the specific gravity of the alcohol it will be seen, that although not perfectly pure, it contains but a small proportion of water; the powder, dried after immersion, shewed slight traces of water, in the efflorescence of minute crystals of nitre on the surface of the grains. The principal difficulty in the use of this method of determining the specific gravity, or the *absolute density* of gunpowder, is that of expelling all the air from the interior of the grains; for this purpose it is necessary that the powder should remain a considerable time under the alcohol, and that it should be occasionally stirred, to let the air escape. Some of the above results are probably affected by this cause of error, which, for want of practice, I could not always avoid in these first experiments; but they are thought worthy to be recorded in this report for future reference and comparisons, and as affording near approximations to the true densities of the samples of powder tried.

The following statement shows the results obtained by direct measurement and weight of two pieces of mill cake, similar to that used in making powder G, which I have had in my possession since 1837, and which have been kept dry.

		No. 1.	No. 2.
Length - - -	Inches	3.342	2.937
Breadth - - -	"	2.593	2.173
Thickness - -	"	0.339	0.2592
Cubic contents - -	"	2.9377	1.6542
Weight - - -	Grs.	1415.5	812
Specific gravity - -	-	1903	1939

XI. COMPARATIVE SIZES OF GRAIN OF VARIOUS SAMPLES OF GUNPOWDER.

Number of grains of powder in a given weight.

DATE.	Kind of powder.	Quantity weighed.	Number of grains of powder in quantity weighed. 1	2	3	Mean	Mean number of grains of powder in 10 grs. troy.	REMARKS.
1843.		Grs.						
Aug't 19 to 22	A.	10	122	132	108	121	118	
	"	40	491	433	484	469		
	B.	10	416	364	435	405	405	
	C.	10	261	238	230	243	275	
	"	20	525	674	551	583		
	D.	10	206	212	202	207	207	
	E.	10	163	148	145	152	152	
	F.	10	152	150	154	152	166	
June	"	30	–	–	–	537		Counted at the powder mills.
August	A. 1	10	84	76	78	79	77	
	"	20	153	149	145	149		
	B. 1	20	216	203	212	210	105	
	C. 1	20	250	221	205	225	113	
	D. 1	20	182	176	176	178	89	
	E. 1	20	224	221	222	223	110	
June	"	30	–	–	–	324		Do.
	F. 1	30	–	–	–	324	105	Do.
August	"	20	213	195	194	201		
	G. 1	20	183	172	175	177	95	
June	"	30	–	–	–	300		Do.
August	A. 2	20	295	311	297	301	151	
	B. 2	20	388	389	368	382	191	
	C. 2	20	406	386	359	384	192	
	D. 2	20	336	328	330	331	166	
	E. 2	20	320	333	325	326	163	
	F. 2	20	661	609	540	603	242	
	"	20	457	418	436	437		
June	"	30	–	–	–	651		Do.
August	G. 6	0.5	3768	–	–	3,768	72,800	
June	"	10	–	–	–	72,680		Do.
	E. 5	30	–	–	–	16,000	5,344	Do.
August	"	5	2679	–	–	2,679		

Number of grains of powder in a given weight—(Cont'd.)

DATE.	Kind of powder.	Quantity weighed.	Number of grains of powder in the quantity weighed.				Mean number of grains of powder in 10 grs. troy.	REMARKS.
			1	2	3	Mean.		
1843.		Grs.						
August	A. 3	10	605	605	497	569	569	
	B. 3	10	948	776	584	769	769	
	C. 3	10	1,544	1401	1316	1420	1420	
	D. 3	10	981	712	733	809	809	
	E. 3	10	282	282	620	395	333	
	"	10	278	274	259	270		
	F. 0	100	99	–	–	99	11	
Sept. 1	"	310	349	–	–	349		
14	A. 0	1000	743	745	–	744	7½	
6	English Cannon	100	1,666	1819	–	1743	174	
	English Musket	5	1,416	–	–	1416	2,832	
	English Rifle	3	3,480	–	–	3480	11,600	
	French Cannon	100	3,163	–	–	3163	316	
	French Musket	20	4,820	–	–	4820	2,410	
1844. June 27	H.	100	2,693	–	–	–	269	
	A. 4	20	2,268	–	–	–	1134	
	K. 1. r.	100	904	–	–	–	90	
	K. 1. g.	100	914	–	–	–	91	
	L. 1	100	950	–	–	–	95	
	M. 1	100	883	–	–	–	88	
	N.	100	1,723	–	–	–	172	
	R. 15′	100	970	–	–	–	97	
	R. 30′	100	922	–	–	–	92	
	R. 60′	100	906	–	–	–	91	
	R. 90′	100	963	–	–	–	96	
	S.	100	2,954	–	–	–	295	
	T.	100	1,003	–	–	–	100	
	A. 5	10	6,174	–	–	–	6,174	
	C. 5	10	2,378	–	–	–	2,378	
Dec'r 9	X.	100	1,252	–	–	–	125	
	X. p.	100	817	–	–	–	82	
	X. p. 4	10	1,642	–	–	–	1,642	
	X. p. 5	10	13,152	–	–	–	13,152	

The sizes of grain of some of the powders were compared by means of the standard gauges for gunpowder.

The diameters of the holes in the sieves which serve for powder gauges are nearly as follows:

No. of sieve - -	1	2	3	4	5	6	7	8
	In.	In.	In.	In.	In.	In.	In.	In.
For cannon powder - -	0.10	0.085	0.07					
For musket powder - -	–	–	0.07	0.06	0.05			
For rifle powder - -	–	–	–	–	–	0.035	0.03	0.025

When one pound of powder is sifted by these gauges, not more than 1 oz. should remain on the largest gauge; not more than 3 oz. should pass through the smallest, and not more than half the remainder should pass through the medium gauge.

Of the *rifle powder* A. 5, when sifted in this way, too much remains on No. 6, whilst a due proportion passes through No. 8. It contains therefore too many large grains.

Of the *rifle powder* C. 5, much remains on No. 5, and a few grains even on No. 4; only a few grains pass through No. 8, and very little through No. 7. This powder is therefore altogether too coarse for rifle powder.

Of the *English musket powder*, all passes through No. 4,
very nearly all through No. 5,
and some portion through No. 8.

Of the *English rifle powder*, all passes through No. 6,
nearly all through No. 7,
and a due proportion thro' No. 8.

Of the *musket powder* X. p. 4, all passes through No. 4,
much remains on No. 5,
very little passes through No. 6.

Of the *rifle powder* X. p. 5, a small proportion remains on No. 6,
and a like proportion passes through No. 8.

XII. EXPERIMENTS ON THE RELATIVE QUICKNESS OF BURNING OF DIFFERENT KINDS OF GUNPOWDER.

The quickness of the powder was tested by observing the time occupied in burning a train laid in an open groove. For this purpose, two semi-cylindrical grooves were cut in the opposite sides of a bar of iron, 40 ft. 4 in. long; the diameter of one groove is 0.8 in., that of the other 0.4 in., or one-fourth of the capacity of the first. The powder was laid in the grooves by means of a funnel with a sliding valve at the bottom, by which the escape of powder could be regulated; and the surface of the powder in the groove was levelled, when necessary, with a straight edge. The coarser kinds of powder cannot easily be laid smoothly or uniformly in the grooves, but the circumstances are nearly equal, in cases where the size of grain of different samples is the same.

The quantity of powder which the grooves will contain was ascertained, for three samples, as follows:

Kind of powder.	In the large groove.	In the small groove.
	Lbs.	Lbs.
A.	2.46	0.62
F. 1	2.14	0.53
G. 6	3.21	0.92

For greater convenience, the iron bar was, at first, bent in the middle, so as to place the two parts parallel to each other, 7.5 in. apart; to prevent the flame from communicating across, from one part to the other, a partition of boards was placed between them, but as this precaution was not found to be always effectual, the bent part was cut off after the first experiments, and its place supplied by a straight piece of the same length, making a straight bar 40 ft. 4 in. long, which was used in the experiments in July, 1844.

The bar containing the grooves was placed level, on trestles of a convenient height, and the experiments were made in a large building which could be closed on all sides, to prevent the wind from affecting the results.

The time of burning was observed by means of the michronometer before mentioned, which marks sixtieths of a second.

As the results of the experiments with the same kind of powder in the two grooves, and with samples of the same powder, differing but little in the size of grain, appeared to correspond well together, it was not thought necessary to verify them by a repetition of the experiments.

Experiments in burning trains of powder in the large groove.

DATE.	Kind of powder.	Time of burning.		DATE.	Kind of powder.	Time of burning.	
1843.		Sec.	Thirds.	1843.		Sec.	Thirds.
April 26th	A.	9	03	May 1st,	G. 6	3	16
" 29th	C.	5	42		E. 5	10	
11 A. M.	D.	5	22				
				2 15 P. M.	B. 3	6	44
Noon.	F.	6	22	3 45 "	A. 3	11	11
					C. 3	6	24
1 30 P. M.	A. 1 & 2	8	42		D. 3	5	40
	B. 1	6	20				
	C. 1	5	48		A. 0	5	32
	D. 1	5	40		H.	5	
	E. 1	6	11	5 "	A. 4	6	53
3 15 "	B.	7	22	1844.			
				July 3d,			
May 1st	D. 2	5	45	3 45 P. M.	F. 0	6	33
10 30 A. M.	F. 1	6	12				
	G. 1	5	16		K. 1. r.	5	58
	A. 2	8	59		K. 1. g.	7	32
	B. 2	6	57				
11 30 "	C. 2	6	20		L. 1	7	24
1 15 P. M.	E. 2	6	40		M. 1	7	18
	F. 2	6	08	4 45 "	N.	7	53

Experiments in burning trains of powder in the small groove.

DATE.	Kind of powder.	Time of burning. Sec.	Thirds.
1843.			
April 26th	G. 6	6	46
May 2nd	"	6	08
9 40 A. M.	E. 5	16	40
	E. 3	13	05
	D. 3	11	11
	C. 3	12	16
	B. 3	14	14
	A. 3	18	28
	H.	9	12
Noon.	A. 4	14	02
1 15 P. M.	F. 2	11	54
	E. 2	13	46
	D. 2	11	36
	C. 2	11	20
	B. 2	14	10
2 10 "	A. 2	17	04
	G. 1	10	29
2 40 "	F. 1	11	15
3 30 "	E. 1	14	16
	D. 1	11	56
	C. 1	11	45

DATE.	Kind of powder.	Time of burning. Sec.	Thirds.
1843.			
May 2nd	B. 1	12	24
	A. 1	18	20
	F.	10	58
	D.	11	12
	C.	11	44
	B.	13	45
5 P. M.	A.	17	32
1844.			
July 1st.	K. 1. r.	9	36
3 P. M.	K. 1. g.	12	03
	L. 1	12	12
	M. 1	13	10
3 40 "	N.	13	42
	R. 15′	13	44
	R. 30′	12	01
	R. 60′	11	
	R. 90′	12	48
	S.	13	40
	T.	18	14
	A. 5	9	10
5 "	C. 5	13	08
July 3d.	K. 1. r.	10	38

XIII. COMPARATIVE HYGROMETRIC TEST OF DIFFERENT KINDS OF GUNPOWDER.

The first comparison of the relative quantities of moisture absorbed by different kinds of powder was made by exposing samples of them to the damp air of a vault. For this purpose the powders were dried in the sun, on the 2d September, 1843, at a temperature of about 125°; one pound of each kind was then placed in a shallow dish of glazed earthenware, about 10 in. diameter, and these samples were deposited in a vaulted cellar under one of the storehouses of the Arsenal. In order to observe the progressive increase of weight, or the rate of absorption of moisture, the weight of each dish, with its sample of powder, was ascertained by the small platform balance used for weighing charges in the ballistic experiments with heavy guns, and the increase of weight was determined by the same balance at intervals of six days; but it was found that, after the first six days, the apparent increase of weight was too small to be accurately indicated by this balance, and the results are therefore not here given. The total increase of weight was determined by means of the same balance with which the samples were first weighed; the powders were then again dried for several hours in the sun, and their weights determined, as a check on the operation.

The temperature of the air in the vault was observed every day at 9 A. M. and 3 P. M.; these two observations differed from each other only on the 11th and 12th of September, and then but 1°; a comparison of these observations with those in the Meteorological Register, for the same period, shows that, after the first seven days, the temperature of the air in the vault was generally above that of the external air:

Temperature of air in the vault, on the 4th September, 73°; 5th, 6th and 7th, 72°; 8th and 9th, 71°; 10th, 70°; 11th to 19th, 68°.

Table showing the increase of weight in samples of one pound of powder exposed in a vault, from the 2nd to the 19th of September, 1843.

Kind of powder.	Weight. Sept. 19	REMARKS.	Weight of sample dried.
	Lbs.		Lbs.
A.	1.0364	These samples are a little caked on the surface, and when examined with a lens there appears an efflorescence of minute crystals of nitre on the surface of the grains.	0.9994
A. 1	1.0277		0.9979
A. 2	1.02865		0.9956
A. 3	1.0535		0.9973
Mean	1.03156	. . . .	0.9975
B.	1.0282	Powder *very* slightly caked; efflorescence of nitre very slight.	1.0007
B. 1	1.0215		0.9983
B. 2	1.02685		0.9955
B. 3	1.0275		0.9980
Mean	1.02601	. . . .	0.9981
C.	1.0658	Powder very much caked; efflorescence of nitre very great.	1.0018
C. 1	1.06265		0.9998
C. 2	1.0667		1.0015
C. 3	1.0666		1.0050
Mean	1.06544	. . . .	1.0020
D.	1.0523	Ditto ditto	1.0013
D. 1	1.0473		0.9990
D. 2	1.0546		0.9988
D. 3	1.0518		0.9975
Mean	1.0515	. . . .	0.9992
E.	1.0247	Very little caked; efflores. almost imperceptible	1.0007
E. 1	1.0258	Ditto efflorescence considerable.	1.0000
E. 2	1.0361	Much caked; ditto very little.	0.9998
E. 3	1.0237	Ditto ditto ditto	0.9997
Mean	1.0276	. . . .	1.0001
F.	1.0209	Not at all caked; efflorescence of nitre *very* slight, with yellowish crystals.	1.0011
F. 1	1.0191		0.9995
F. 2	1.0295		0.9986
Mean	1.0232	. . . .	0.9997
E. 5	1.0355	Much caked; efflorescence of nitre slight.	0.9990
G. 1	1.0296	Caked hard; do. do. considerable.	1.0005
G. 6	1.0442	Do. very hard; do. do. considerable.	0.9986

Other comparisons of the hygrometric qualities of various samples of powder were made by exposing them to air saturated with moisture; according to the method laid down in the French regulations for the proof of powder.

For this purpose, a tub, about 25 in. diameter and 15 in. deep, was filled with water to the depth of 9 in. In it were placed three piles of bricks, the tops of which stood about an inch above the surface of the water, and on each of these piles was a shallow rectangular tin pan, 9 in. × 6 in., containing 1,500 grains of powder, which had been previously well dried in the sun. The powder was spread in a layer of uniform thickness of $\frac{1}{10}$ inch. The tub was then closed with a tight cover of boards, having a circular stuffed leather pad nailed on it at the part which bears on the tub ; this cover was pressed down by a heavy weight.

Four of these tubs were prepared, and they were placed in a room at the south end of the artillery storehouse at the Arsenal. This room is flagged with stone and has windows only in the upper part of the walls, but it was found to be warmer than would have been desired for this purpose. Two self-registering thermometers indicated the highest and lowest temperatures during the intervals between the several weighings of the samples of powder.

The first samples were placed in the tubs on the 27th June, 1844. The increase of weight was determined, the first and second times, by removing the powder from the pans ; but, as the quantity of moisture increased, the removal of the powder without loss became impracticable, and the pans having been carefully weighed, the subsequent weighings of the powder were made without emptying them.

The three samples enclosed in braces respectively, in the following tabular statement, were placed in the same tub. After the first 24 hours there was no apparent change in any of the samples except in that of sporting powder G. 6, which was caked hard, but easily broken up again into grains.

June 28th; Temp. 85° to 88°.		July 1st; Temperature 79° to 90°.			July 3d; Temperature 83° to 87°.		
Kind of powder.	Increase of weight.	Increase of weight.	Condition.	Efflorescence of nitre.	Increase of weight.	Condition.	Efflorescence of nitre.
	Grs.	Grs.			Grs.		
A. 1	40.5	127.5	Not caked.	Very slight.	178.1	Caked.	Great.
B. 1	36.8	126.		Still less.	182.8		Less than the preceding.
C. 1	69.	175.6	Caked; grain softened.	Slight.	240.9		Not great.
D. 1	61.8	174.5			236.		
E. 1	38.	122.2	Not caked.	Very small.	175.8		Very slight.
F. 1	32.8	121.5		Just perceptible.	173.2	Not caked.	Just perceptible.
G. 1	44.	140.5	Caked hard.	Very great	204.5	Hard caked.	Very great; grains almost white, and much swelled.
G. 6	33.5	98.			143 8		
E. 5	34.5	133.3	Very little caked.	Just perceptible.	191.2		Not very great.
H.	39.3	140.5	Slightly do.	Slight.	194.7	Slightly caked.	Very slight.
K. l. r.	33.2	133.3	Not caked.	None.	175.8		
K. l. g.	27.	115.4		Scarcely perceptible	168.8		

	July 5th; Temp. 78° to 84°.	July 8th; 79° to 83°.	REMARKS.	Weight of sample dried.
	Increase of weight.			
	Grs.	Grs.		Grs.
A. 1	241.1	313 2	Efflorescence of nitre very great—grains firm.	1512.5
B. 1	246.5	324.9	Do. small—grain soft.	1505.
C. 1	312.3	385.8	Do. not very great—grain very soft, nearly melted.	1547.7
D. 1	308.1	401.9		1558.2
E. 1	248.6	332.6	Efflorescence small—grain soft.	1501.5
F. 1	244.6	312.5	Do. very slight—grain soft; not caked.	1498.9
G. 1	292.7	383.	Powder white with crystals of nitre—grain not soft.	1526.
G. 6	214.5	292.9		1498.9
E. 5	261.9	346.6	Efflorescence not great—grain soft and damp.	1500.1
H.	250.7	315.8	Do. do grain firm and not much caked.	1510.6
K. l. r.	253.5	348.	Do. very small; crystals dirty yellow—grain soft.	1498.
K. l. g.	228 3	301.1	Efflorescence greater than the preceding—grain less soft.	1500.8

The weights of the samples of powder dried were taken on the 8th July, after they had been exposed 5 hours to the sun.

The grain of all the powder is swollen and permanently increased in size; that of sample F. 1 less so than the others. A large proportion of nitre was separated, in drying, from the powder in which the efflorescence of nitre was very great, especially from samples A. 1 and G. 1. The powder G. 6, when broken up into grain, after drying, assumed a reddish brown color, being nearly that of the charcoal with which it was made.

July 9th, 1844. Twelve samples of other kinds of powder were exposed to the hygrometric test, in the same manner as the preceding. The quantity of powder in each was 1500 grains, as before, weighed after having been well dried in the sun.

The bottoms of the pans were scarcely covered by the 1500 grains of the coarse grained powders A. 0 and F. 0.

After the first 24 hours' exposure, no change was perceived in the appearance of any of the powders.

Kind of powder.	JULY 10TH; Temperature 82° to 85°.	JULY 13TH; Temperature 84° to 87°		JULY 15TH; Temperature 85° to 89°.	
	Increase of weight.	Increase of weight.	Efflorescence of nitre.	Increase of weight.	Efflorescence of nitre.
	Grs.	Grs.		Grs.	
A. 5	32.2	91.0	Just perceptible	148.5	Very slight.
A. 4	30.1	77.7	Do. do. -	121.9	Do.
S.	21.	89.6	Do. do. -	150.6	Greater than the preceding.
L. 1	30.1	103.3	Slight, - -	164.6	
M. 1	26.6	81.9	None, - -	125.4	
N.	39.9	107.8	Slight, - -	164.6	Still greater.
R. 15′	16.1	67.9	Just perceptible	104.4	*Very* slight.
R. 30′	32.9	91.7	Slight, - -	131.2	Greater than the preceding.
R. 60′	23.8	79.1	Do. - -	128.2	
R. 90′	32.9	96.6	Do. - -	147.8	Still greater.
F. 0	9.8	62.7	None, - -	105.5	Very slight.
A. 0	17.5	67.2	Do. - -	117.	Scarcely percep.

Hygrometric test of gunpowder—(Continued.)

Kind of powder.	July 17th; Temperature 86° to 90°. Increase of weight.	July 19th; Temperature 84° to 89°. Increase of weight.	Remarks.
	Grs.	Grs.	
A. 5	220.6	297.6	Caked; grain soft.
A. 4	182.5	251.8	Not caked.
S.	224.5	301.1	Efflorescence of nitre considerable.
L. 1	240.2	316.5	Do. do. do. do.
M. 1	190.5	274.2	powder caked and softened.
N.	232.5	310.2	Efflorescence very great; grain hard.
R. 15′	154.1	224.1	Efflorescence slight; grain soft & crumbling.
R. 30′	202.4	267.9	Do. do. do. do.
R. 60	190.5	268.6	Efflorescence very great; grain dry and
R. 90′	222.	301.8	hard.
F. 0	162.9	236.4	Very minute crystals of nitre;
A. 0	163.9	229.7	grains somewhat softened.

July 22nd; temperature 86° to 94°.

Kind of powder.	Increase of weight.	Remarks.	Weight of samples dried.
	Grs.		Grs.
A. 5	405.8	Powder caked; grain soft.	1505.7
A. 4	348.7	Efflorescence of nitre great; not caked.	1504.3
S.	417.		1522.5
L. 1	435.5	Powder quite soft; almost melted.	1505.7
M. 1	371.8	Do. do. cyrstals of nitre yellowish.	1505.7
N.	404.7	Grains white with crystals of nitre; powder not caked.	1554.
R. 15′	315.1	Efflorescence slight; powder quite soft and	1504.7
R. 30′	357.8	crumbling to the touch.	1505.7
R. 60′	376.7	Efflorescence great; powder softened.	1504.3
R. 90′	403.3		1527.1
F. 0	338.9	No efflorescence of nitre; powder soft.	1502.9
A. 0	322.8	Small crystals of nitre on some grains; less soft than the preceding.	1601.6

The last twelve samples of powder exposed to moisture were dried on the 23d and 24th July, by exposure to the sun, but the weather was not perfectly favorable for the purpose, as will be seen by the constant excess of weight over that of the original sample.

A sample of 1 lb. of the Waltham powder H, dried in the sun, from $9\frac{1}{2}$ to $11\frac{1}{2}$ A. M. on the 27th June, 1844, was found to weigh 0.99 lb., being a loss of 1 per cent.

Samples of 1 lb. each of powders *a* and A, dried in the sun, from 1 to $2\frac{3}{4}$ P. M. on the 24th of July, 1844, were found to weigh each 0.993 lb., having lost about $\frac{7}{10}$ths of 1 per cent.

Trial with the musket pendulum of powder dried after exposure to air saturated with moisture.

In order to form an idea of the relative effect of the exposure to moisture, on the strength of the different kinds of powder, they were proved by firing two rounds of each kind from the pendulum musket, with a charge of 120 grains and a ball of 0.64 in. diameter, as before.

The results of these trials are given in the following table:

DATE.	Kind of powder.	Height of charge.	VIBRATION.		Moment of musket pendulum.	Velocity by ballistic pendulum.
			Musket pendulum.	Ballistic pendulum.		
1844.		In.	° ′	° ′		Feet.
July 9th. 3 30 P. M.	A. 1	2.4	7 26	4 52	–	903
	"	2.28	7 19	4 44	–	879
	Mean	2.34	7 23	4 48	84.32	891
	B. 1	2.28	9 12	6 27	–	1197
	"	2.3	9 02	6 22	–	1182
	Mean	2.29	9 07	6 25	104.20	1190
	E. 1	2.38	9 05	6 24	–	1188
	"	2.36	9	6 11	–	1148
	Mean	2.37	9 03	6 18	103.34	1168

Trial of powder dried after exposure to moisture. (Continued.)

DATE.	Kind of powder.	Height of charge.	VIBRATION OF Musket pendulum.		VIBRATION OF Ballistic pendulum.		Moment of musket pendulum.	Velocity by ballistic pendulum.
1844.		In.	°	′	°	′		Feet.
July 9th.	F. 1	2.3	9	54	7		–	1299
	"	2.28	10	02	7	10	–	1330
	Mean	2.29	9	58	7	05	114.27	1315
	G. 6	2.25	10	42	7	45	–	1438
	"	2.25	10	58	8	07	–	1506
	Mean	2.25	10	50	7	56	123.75	1472
	E. 5	2.2	10	54	7	57	–	1475
	"	2.18	10	54	7	55	–	1469
	Mean	2.19	10	54	7	56	124.50	1472
	H.	2.32	8	53	6		–	1114
	"	2.4	8	26	5	37	–	1043
	Mean	2.36	8	40	5	49	99.	1079
	K.1.g.	2.4	8	02	5	28	–	1015
	"	2.26	8	18	5	36	–	1039
4 45 P. M.	Mean	2.33	8	10	5	32	93.34	1027
July 24th. 3 P. M.	A. 5	2.04	10	50	8	05	–	1500
	"	2.06	11	08	8	15	–	1531
	Mean	2.05	10	59	8	10	125.46	1516
	A. 34	2.25	10	43	7	47	–	1444
	"	2.31	10	56	8	10	–	1515
	Mean	2.28	10	50	7	59	123.75	1480
	S.	2.26	7	53	5	20	–	990
	"	2.18	7	30	4	55	–	913
	Mean	2.22	7	42	5	08	87.92	952
	L. 1	2.2	7	39	5	09	–	956
	"	2.2	8	10	5	37	–	1042
	Mean	2.2	7	55	5	23	90.59	999

Trial of powder dried after exposure to moisture. (Continued.)

DATE.	Kind of powder.	Height of charge.	VIBRATION OF Musket pendulum.		VIBRATION OF Ballistic pendulum.		Moment of musket pendulum.	Velocity by ballistic pendulum.
1844.		In.	°	′	°	′		Feet.
	M. 1	2.21	8	46	5	59	–	1111
	"	2.19	9	41	6	50	–	1268
	Mean	2.2	9	14	6	25	105.42	1190
	N.	2.11	9	07	6	22	–	1182
	"	2.15	8	13	5	23	–	999
	Mean	2.13	8	40	5	53	99.05	1091
	R. 15′	2.13	9	59	7	06	–	1318
	"	2.13	9	56	7	06	–	1318
	Mean	2.13	9	58	7	06	113.78	1318
	R. 30′	2.16	9	04	6	15	–	1160
	"	2.21	9	28	6	36	–	1225
	Mean	2.19	9	16	6	26	105.90	1198
	R. 60′	2.25	8	35	5	54	–	1095
	"	2.27	8	48	5	58	–	1108
	Mean	2.26	8	42	5	56	99.34	1102
	R. 90′	2.	8	06	5	24	–	1002
	"	2.18	7	40	4	58	–	922
	Mean	2.09	7	53	5	11	90.11	962
	F. 0	2.3	9		6	17	–	1166
	"	2.22	8	44	6	02	–	1120
	Mean	2.26	8	52	6	10	101.33	1143
	A. 0	2.	5	19	3	50	–	712
	"	1.98	5	30	3	55	–	727
5 P. M.	Mean	1.99	5	25	3	53	62.04	720

XIV. METEOROLOGICAL REGISTER.

This table is extracted from the Register kept at the Depôt of charts and instruments of the Navy Department, in Washington.

The barometric observations are reduced, by Schumacher's Tables, to the standard temperature of 32° Fahrenheit.

The thermometer in the sun is placed 4 feet from the ground.

The dew point was directly observed only at 9 A. M. and 3 P. M.; for other periods, it is deduced from the temperature of the wet bulb, by Apjohn's formula; the results (which are marked *) were obtained by means of an ingenious graphical construction of the formula, prepared by Mr. S. W. Hall, of Philadelphia.

DATE.	HOUR. A. M.	HOUR. P. M.	Barometer.	THERMOMETER. Sun.	THERMOMETER. Shade.	THERMOMETER. Wet bulb.	Dew point.	Wind.	Weather.
1843.			In.						
April 7	10	-	30.124	74	50	48	46*	N. W.	Clear.
	–	3	30.093	84	58	56	35?	Strong	"
17	10	-	29.869	84	66	61	58*	Calm	
	12	M	29.835	74	73	64	58.5*	S. E. light	Rain at 12 15′.
May 3	–	4	30.28	80	59	50	41*	N.N.E. light	Cloudy.
5	10	-	30.389	77	56	48	40*	Calm	Clear.
	–	3	30.257	91	65	54	48	S. light	
	–	6	30.247	66	65	60	56.5*	Calm	Cloudy.
16	12	M	29.957	96	78	73	70.5*	N. W. brisk	Clear.
19	12	M	30.168	68.5	60	55	51*	N. E. mod.	Cloudy.
July 15	10	-	30.110	99	84	82	81.5*	N. W. light	Clear.
	–	3	30.023	99	85	74	72		
	–	4	29.997	111	88	76	71*	–	Gust from N.E. at 5.
17	9	-	30.064	81	78	73	70	S. E. light	
	–	3	30.016	96	87	78	65	–	Cloudy.
20	–	3	30.003	100	77.5	62	46	N. E. brisk	Clear.
28	–	6	29.825	102	95	75	56*	S. light	"
Augt. 1	–	3	29.913	90	76.5	63	54	N. E.	
	–	6	29.911	87	75	64	57*	Very light	"
2	10	-	29.865	90	73	68	65.5*	–	
	–	3	29.825	90	81	72	60	Calm	Light clouds.

DATE.	HOUR. A. M.	HOUR. P. M.	Barometer.	THERMOMETER. Sun.	THERMOMETER. Shade.	THERMOMETER. Wet bulb.	Dew point.	Wind.	Weather.
1843.			In.						
Augt. 3	–	3	30.100	94	81.5	66	62	E.	
	–	6	30.108	80	79.5	67	60*	Light	Cloudy.
4	9	–	30.147	79	75	68	65	N. E.	
	–	3	30.229	98	82	67	59	Moderate	"
8	9	–	29.980	87	82	76	67	Airs	
	12	M	29.958	104	86	74	68.5*	W.	
	–	3	29.839	76	84	74	70	S. S. E.	Rain.
11	–	2	30.000	101	79	70	65.5*	N. W. light	
12	9	–	30.064	86	75	70	67	Calm	
	12	M	29.968	93	81	71.5	67*		
26	9	–	30.070	78	78	73	73	S. light	
Sept. 4	9	–	29.853	100	82.5	75	72	N. W. light	
	12	M	29.787	107	85	75	70.5*	"	
	–	3	29.761	110	87	76	66	"	Clear.
	–	6	29.759	85	87·5	73	66*	Calm	
5	9	–	29.913	96	80·5	70	63	N. W.	
	12	M	30.024	106	86	72	65*	Light	
	–	3	29.975	111	87	72	68	N.	
	–	6	30.024	77.5	83·5	72	66.5*	Calm	
6	9	–	30.064	84	78	71	70.5	N. E.	
	12	M	30.071	82	81	72	68*	Light	
	–	3	30.042	91	82	72	69		
7	9	–	29.943	93	76	70	68	N. W. mod.	
	–	3	30.030	85	76	68	66	N. E.	
8	9	–	29.993	74	71	64	62	Calm	
	–	3	29.995	90	88	68	64	"	
9	9	–	30.008	90	74	64	62	N. W.	
	–	3	30.070	97	74·5	62	57	Light	
11	9	–	29.974	51	55·5	50	49	N. W.	Rain.
	–	3	29.950	53	56	53	48	N.	"
12	9	–	30.062	54	55	51	50	N. E.	
	–	3	30.065	67	64·5	54	52	S. E. light	
13	9	–	30.155	70	61	56	54	S. E.	
	–	3	30.145	64	66	60	58	Light	
14	9	–	30.075	60	63	62	61	S. E.	
	–	3	30.003	64	67	64	60	"	"
15	9	–	29.752	84	75·5	70	69	"	
	–	3	29.789	98	79	72	62	"	
16	9	–	29.918	90	72	66	58.5	Calm	
	–	3	29.888	104	98	71	66	"	

DATE.	HOUR. A. M.	HOUR. P. M.	Barometer.	THERMOMETER. Sun.	THERMOMETER. Shade.	THERMOMETER. Wet bulb.	Dew point.	Wind.	Weather.
1843.			In.						
Sept. 18	9	–	30.040	84	74.5	71	67	Calm	Foggy.
	–	3	30.032	106	87.5	76	71	"	
	–	6	30.015	80	84	75	71*		
19	9	–	30.141	96	80	73	69	N. W. light	
	12	M	30.136	111	88	75	69*		
	–	3	30.119	102	88	76	69		
	–	6	30.117	78	85	74	69*	Calm	
20	9	–	30.250	78	75	68	64	"	
	12	M	30.363	102	81	70	64.5*	E. S. E.	
	–	3	30.297	107	82	72	68	S. E. light	
	–	6	30.262	72	79	69	63.5*	"	
21	–	3	29.998	110	86.5	77	74	S. light	
Nov'r 1	10	–	30.418	54	42	38	32.5*	Calm	Cloudy.
	12	M	30.341	62	48.5	43	36.5*	E. S. E.	"
	–	2	30.292	49	50	45	39.5*	light	"
2	12	M	29.935	78	54	46	37*	N. W. mod.	Clear.
1844.									
Feb'y 2	–	2	30.098	46	43.5	40	35.5*		
	–	3	30.110	43	42.5	39	22	Calm	Cloudy.
Mar. 12	–	4	30.090	48	52.5	50	48*	S. light	"
	–	6	30.053	48	52.5	49.5	47*	"	
14	–	2	30.013	56	56.5	52	48*	N. light	
	–	3	30.017	54	56	52	40	"	"
	–	4	30.020	52	55	50	45*		
20	–	2	29.670	67	60	52	45*	S. brisk	
	–	3	29.668	64	61.5	54	45	"	"
	–	4	29.644	48	52	49	46*		Squall.
22	9	–	29.775	55	37.5	32	22*	N. W.	Clear.
	12	M	29.706	70	42.5	37	29*	very light	
	–	3	29.645	68	49.5	44	36		
	–	6	29.650	42	47	40.5	32*		
26	10	–	30.043	62	59.5	55	515*	Calm	Hazy.
	12	M	30.009	64	65	59	55*		
	–	3	29.969	74	70.5	63	43		
27	–	2	29.969	82	68	59	52.5*	"	"
	–	3	29.966	79	68	59	36	N. E. light	
28	12	M	29.810	85	62.5	56.5	52*		"
	–	3	29.622	98	70.5	64	42	"	
April 4	12	M	30.102	96	73.5	61	52*	Calm	"

DATE.	HOUR.		Barometer.	THERMOMETER			Dew point.	Wind.	Weather.
	A. M.	P. M.		Sun.	Shade.	Wet bulb.			
1844.			In.						
April 4	–	3	30.032	100	71.5	59	41	S. W. light	
	–	6	29.885	66	69	58	49.5*		
17	–	3	29.872	82	75	63	50	N. W.	Cloudy.
	–	6	29.870	68	72.5	62	55*	Moderate	
22	10	–	30.059	88	63.5	62	54*	S.	
	–	3	30.038	98	69	65	56	Light	
23	10	–	30.181	61	64.5	61	58.5*	S. E.	
	–	3	30.090	94	70.5	66	54	Light	
25	–	3	30.057	99	72.5	61	43	N. W.	Clear.
	–	6	30.036	74	70	61	55*	Light	
29	10	–	30.196	84	61.5	55	49.5*	N.	Clear.
	–	3	30.124	94	68	61	48	Light	
May 1	10	–	30.130	85	71.5	65	61*	S. E.	Cloudy.
	–	3	30.006	95	78.5	69	42	Mod.	
	–	6	29.980	73.5	74.5	67	62.5*		
2	10	–	29.908	79	75.5	69	65.5*	S.	Rain at 12—wind N. W.
	–	3	29.945	62	70	67	65.5*	Calm	"
	–	6	29.920	58	69	65	62.5*	S.	
June 6	–	3	29.897	107	78	74	68	S. mod.	
7	10	–	29.883	99	79	75	73.5*	Calm	
	–	2	29.851	90	83	76	73*	W. light	Rain.
	–	4	29.853	66	76	69	65.5*		"
10	10	–	29.932	94	77.5	69	64.5*	N. W. mod.	
	–	3	29.918	97	78	68	62.5*		
	–	6	29.905	82	79	70	65.5*	Calm	
11	10	–	30.282	78	62.5	52	42*	N. light	
	–	3	30.256	97	69.5	59.5	42	Calm	
	–	6	30.262	63 ?	72.5	61	53*	"	
12	10	–	30.354	86	69.5	62	57*	N. W.	
	–	3	30.290	98	74.5	64	46	Light	
	–	6	30.267	84	73.5	63	56.*	E.	
15	9	–	30.241	73	67.5	62.5	35 ?	Calm	Cloudy.
	12	M	30.292	80	69	62	57.5*	N. E. light	
	–	3	30.276	73	69	63	43		
17	12	M	29.877	82	76	71	68.5*	S. E.	
	–	3	29.833	84	79	73	50	Mod.	
	–	6	29.894	78	77	71	68*		
18	10	–	29.878	98	79.5	73	70*	S. light	
	–	2	29.872	100	81	74	71*		

DATE.	HOUR. A. M.	HOUR. P. M.	Barometer.	THERMOMETER Sun.	THERMOMETER Shade.	THERMOMETER Wet bulb.	Dew point.	Wind.	Weather.
1844.			In.						
June 19	10	-	29.892	94	81.5	75	72*	S. E.	
	–	3	29.805	108	86	77	54	Light	
20	9	-	29.879	91	80.5	73	54	W. light	
	–	2	29.850	85	80	73.5	70.5*	Calm	Rain.
	–	6	29.826	79	79.5	74	71.5*	"	
21	10	-	29.837	90	77.5	70.5	67*	N. W.	
	–	3	29.786	96	82	71	52	Light	
25	12	M	29.948	100	83.5	72	66.5*	S. W.	Clear.
	–	3	29.920	98	83.5	72	53	Light	
	–	6	29.892	94	84	73	68*		
26	–	3	29.935	103.5	87	73	53	S. light	"
	–	6	29.893	97	87.5	73	66*	Calm	
27	–	3	29.832	111	90	75	60	S. mod.	
28	9	-	29.937	86	81.5	74	64	S. light	
	–	3	29.922	113	88.5	73	62	N. W. mod.	
29	9	-	30.098	82	76	64	60	N. light	
	–	3	30.040	110	83	68	59	N. W.	
July 1	9	-	29.973	86	78	71	62	S. mod.	Cloudy.
	–	3	29.879	92	86	77	60	S. W.	
2	9	-	30.023	92	84	76	62	Calm	
	–	3	29.874	79	82	74	51	"	
3	9	-	29.760	78	71.5	67	64.5*	S. W.	Rain.
	–	3	29.769	107	81.5	73	56	N. W. light	
4	9	-	30.050	76	71	63	51	"	Clear.
	–	3	30.034	100	74.5	63	58		
5	9	-	30.115	74	69.5	62	54	S. light	
	–	3	30.016	86	75	66	46	S. cloudy	
6	9	-	29.826	78	75	70	51	–	Cloudy.
	–	3	29.698	85	81.5	77	75.5*	S.	Rain at 3 30 P. M.
8	9	-	30.044	84	74.5	64	50	N.	
	–	3	29.967	101	78	71	60	S. W.	Cloudy.
9	9	–	29.918	88	77.5	72	58	S. W.	
	–	3	29.910	106	82.5	74	50	S.	Cloudy.
10	9	–	29.772	89	80	75	46	W.	
	–	3	29.644	88	84	78	60	S. light	
11	9	–	29.722	89	82.5	73	52	N. W. mod.	
	–	3	29.729	111	85	71	56	"	
12	9	–	29.946	86	77.5	69	58	N. W.	
	–	3	29.947	112	84	69	48	"	
13	9	–	30.065	92	79	70	48	N. W. light	
	–	3	30.007	112	86	73	67*	S. W.	
15	9	–	29.851	96	86.5	77	56	N. W. mod.	
	–	3	29.844	99	87.5	76	52	S.	Cloudy.

DATE.	HOUR. A. M.	HOUR. P. M.	Barometer.	THERMOMETER Sun.	THERMOMETER Shade.	THERMOMETER Wet bulb.	Dew point.	Wind.	Weather.
1844.			In.						
July 16	9	–	29.694	96	84.5	77	49	S. light	
	–	3	29.618	106	85.5	77	59	W. light	
17	9	–	29.920	88	78	70	58	N. E. light	
	–	3	29.917	100	83.5	71	58	N. "	
18	9	–	29.963	82	79	74	71.5*	S. "	
	–	3	29.890	99	82.5	74	60	S. E.	
19	9	–	29.803	96	82.5	76	73.5*	S. E. light	
	–	3	29.714	116	90	76	62	"	
20	9	–	29.699	92	85	77	60	S. light	
	–	3	29.727	94	90.5	77	70	N. W. mod.	
22	9	–	30.018	86	82	75	69	S. E. light	
24	9	–	29.894	87	79.5	75	60	Calm	Cloudy.
	–	3	29.856	95	83	77	61	S.	
Aug. 9	12	M	29.887	102	86.5	74	68*	S. light	Cloudy.
		2	29.821	104	88	75	69*	"	"
Dec. 9	9	–	30.268	34.5	34	34	31	N. W.	Clear.
	–	3	30.111	55.5	40.5	37	32	"	"
10	9	–	30.059	56	34	32	27.5	N.	"
	–	3	30.007	70	45	41	35	N. W.	"
12	9	–	30.092	62	37	31	17	Calm	
	–	3	29.973	40	43.5	40	40	S.	Cloudy.
13	9	–	29.809	49.5	46	43	43	E.	Hazy.
	–	3	29.682	49	49.5	46.5	42	E.	"
19	9	–	30.226	38.5	28	–	–	W.	Light clouds.
	–	3	29.909	66.5	42	40	37	E.	" "

PART SECOND.

Having, in the first part of this Report, presented a full narrative account of my experiments on gunpowder, with all the details which have an influence on the results of them, I now proceed to condense those results, under their appropriate heads, and to offer some remarks and suggestions which have occurred to me in the course of analyzing and comparing the facts developed by these experiments.

Whilst, therefore, the preceding part of the report affords the means for a minute examination of the circumstances attending each of the experiments, this second part will present the general results, in a convenient form for reference, to those who may desire to examine the grounds on which my deductions are based, or to pursue, further than I have done, the investigation of any of the subjects embraced in this course of experiments.

I. OF THE DENSITY OF GUNPOWDER.

For the reasons given in the Journal of experiments, I do not place entire confidence in the result of my experiments in determining the *specific gravity* of gunpowder, and therefore no summary of them is here given.

It appears to me that by immersing gunpowder in any liquid sufficiently thin to penetrate all the pores of the grain, it must be in a great measure disintegrated, and thus we shall obtain not so much the specific gravity of the mixture which forms the powder, as the combined specific gravity of the ingredients themselves; the results would consequently depend less on the intimacy of the mixture, than on the trituration of the ingredients, whether before or after being mixed together; for we know that the specific gravity of charcoal may be increased fourfold by trituration, and that sulphur, on the contrary, is rendered less dense by the same operation.

It is only in this way that I can explain the small increase of density which is apparently produced by long working or by great pressure; as in comparing the specific gravities (obtained by alcohol) of powders R. 15′, R. 90′ and G, which have been worked under the rollers 15 minutes, $1\frac{1}{2}$ hours, and 4 hours respectively; or those of A. 4 and E. 5, the former not pressed except by the rollers, and the latter pressed exceedingly hard.

The determination of the *gravimetric density* of gunpowder offers an easy and useful practical method of ascertaining its relative density, when the comparison is made between powders of similar kind and size of grain. It will be seen by the journal of experiments, that, by conducting this operation with care, a very satisfactory uniformity may be obtained in the results of trials with the same powder, and I may further state that these results appear to agree very nearly with those obtained with similar powders in England and France. In my remarks, therefore, on the subject of the densities of the different kinds of powder, I shall refer generally to the following table of gravimetric densities. In this table the densities of the several powders, loose and settled, are compared together, as affording some indication of the relative irregularities in the form of the grain, since the most angular and irregular grain will show the greatest difference of weight by settling. The weight of the powder thus settled in the gravimeter shows also the space which a given charge will occupy in a cartridge.

Table showing the gravimetric densities of various kinds of gunpowder.

Kind of powder.	Weight of a cubic foot.			Kind of powder.	Weight of a cubic foot.		
	Loose.	Settled.	Ratio.		Loose.	Settled.	Ratio.
	Oz.	Oz.			Oz.	Oz.	
a.	911	1037	1.138	F.	780	897	1.150
A.	929	1039	1.118	F. 1	775	897	1.158
A. 1	916	1047	1.143	F. 2	751	872	1.160
A. 2	914	1042	1.140	F. 0	762	862	1.131
A. 3	927	1052	1.135	G. 1	958	1086	1.134
A. 4	896	1012	1.129	G. 6	1047	1197	1.143
A. 0	821	916	1.116	H.	874	993	1.136
B.	906	1016	1.121	K. 1. r.	896	1015	1.133
B. 1	882	1000	1.134	K. 1. g.	916	1033	1.128
B. 2	879	1006	1.145	L. 1	954	1071	1.123
B. 3	904	1029	1.136	M. 1	925	1038	1.122
C.	944	1075	1.139	N.	898	1016	1.131
C. 1	915	1043	1.140	R. 15′	793	898	1.132
C. 2	896	1021	1.140	R. 30′	842	948	1.126
C. 3	940	1065	1.133	R. 60′	844	955	1.131
C. 5	934	1074	1.150	R. 90′	868		
D.	968	1083	1.119	S.	917	1036	1.130
D. 1	932	1046	1.122	T.	914	1034	1.131
D. 2	922	1043	1.131	W.	970	1118	1.153
D. 3	933	1055	1.131	X.	904	1031	1.140
E.	957	1108	1.158	X. p.	930	1061	1.141
E. 1	937	1084	1.157	X. p. 4.	937	1090	1.163
E. 2	948	1102	1.162	X. p. 5.	955	1117	1.170
E. 3	996	1140	1.145				
E. 5	1044	1176	1.127				

II. RELATIVE SIZE OF GRAIN OF DIFFERENT KINDS OF GUNPOWDER.

Table showing the number of grains of gunpowder contained in a given weight.

KIND.	Number of grains in 10 grs. troy.	KIND.	Number of grains in 10 grs. troy.
A.	141	F. 2	163
A. 1	77	F. 0	11
A. 2	151	G. 1	92
A. 3	569	G. 6	72,808
A. 4	1,134	H.	269
A. 5	6,174	K. 1. r.	90
A. 0	7.4	K. 1. g.	91
B.	426	L. 1	95
B. 1	105	M. 1	88
B. 2	191	N.	172
B. 3	769	R. 15′	97
C.	291	R. 30′	92
C. 1	113	R. 60′	91
C. 2	192	R. 90′	96
C. 3	1,420	S.	295
C. 5	2,378	T.	100
D.	205	English. Cannon	174
D. 1	89	English. Musket	2,832
D. 2	166	English. Rifle	11,600
D. 3	809	French. Cannon	316
E.	152	French. Musket	2,410
E. 1	111	X.	125
E. 2	163	X. p.	82
E. 3	275	X. p. 4	1,642
E. 5	5,344	X. p. 5	13,152
F.	166		
F. 1	103		

III. RELATIVE QUICKNESS OF VARIOUS KINDS OF GUNPOWDER.

Table showing the relative time of burning of trains of gunpowder laid in open grooves.

	Kind of powder.	RELATIVE TIME OF BURNING. Large train.	Small train.	Mean.	Kind of powder.	RELATIVE TIME OF BURNING. Large train.	Small train.	Mean.
	A.	277	272	275				
	A. 1	266	284	275	E. 1	189	221	205
	A. 2	275	265	270	E. 2	204	213	209
	A. 3	342	286	314	E. 3	–	203	203
Mean	A.	290	277	284	E.	197	212	206
	A. 4	210	218	214				
	A. 5	–	142	142	E. 5	306	258	282
	A. 0	169	–	169				
	B.	225	213	219				
	B. 1	194	192	193	F.	195	170	183
	B. 2	212	220	216	F. 1	190	174	182
	B. 3	203	221	212	F. 2	188	184	186
Mean	B.	209	211	210	F.	191	176	184
	C.	174	182	178	F. 0	200	–	200
	C. 1	178	181	180	G. 1	161	163	162
	C. 2	194	176	185	G. 6	100	100	100
	C. 3	196	190	193	H.	153	143	148
					K.1.r.	183	157	170
Mean	C.	186	182	184	K.1.g.	224	188	206
					L. 1	227	189	208
	C. 5	–	204	204	M. 1	223	204	214
					N.	241	212	227
	D.	164	174	169	R. 15′	–	213	213
	D. 1	173	185	179	R. 30′	–	186	186
	D: 2	176	180	178	R. 60′	–	171	171
	D. 3	173	173	173	R. 90′	–	198	198
					S.	–	212	212
Mean	D.	172	178	175	T.	–	281	281

The size of grain exerts necessarily a great influence on the rapidity of communication of the flame, as well as on the rapidity of combustion of the grains; and it seems that the greater quickness with which the small grains are consumed does not always compensate for the impediment which they offer to the rapid communication of the flame through the whole mass. The point at which this compensation takes place appears to depend chiefly on the density of the powder. Thus, the quickness of the powder A decreases with the size of grain, until we reach the musket grain A. 4, when there is a decided increase of quickness; whilst the very dense powder E still diminishes in quickness when reduced to the size of rifle grain E. 5. The quickness of the light and porous powder F is little affected by variations in the size of grain; but the combustion of this powder is impeded by the quantity of dust which adheres to the surface of unglazed powder of this low density and hardness. The effect of glazing in impeding the combustion of powder, when free from dust, is shown by comparing the quickness of samples K. 1. r. and K. 1. g.; but this advantage of rough powder is more than compensated by its greater liability to be reduced to dust.

Thorough incorporation of the ingredients increases the quickness of burning, unless the density is too great; but there appears to be nothing gained in this respect by 24 hours' work, in the pounding mill, over 14 hours' work. The effect of different degrees of working in the rolling mill, on the quickness of burning, is seen by comparing the powders R, from which it would appear that the quickness increases with the quantity of working only to a very limited extent; in consequence, no doubt, of the concomitant increase of density.

The very fine grained sporting powder G. 6 being thoroughly incorporated, free from dust, and composed of angular grains, although highly glazed, far surpasses all the other kinds in quickness.

Among the cannon powders, the Waltham powder H occupies the first rank in this respect; but it must be observed that a fair comparison of the relative quickness of burning of different kinds of powder can be made in this way only by sifting them to a nearly uniform size of grain.

IV. HYGROMETRIC TEST OF GUNPOWDER.

Table showing the increase of weight in 1 lb. of various kinds of gunpowder exposed to the moist air of a cellar, from 2nd to 19th September, 1843.

Kind of powder.	Increase of weight.	Kind of powder.	Increase of weight.	Kind of powder.	Increase of weight.
	Per cent.		Per cent.		Per cent.
A.	3.64	C.	6.58	E.	2.47
A. 1	2.77	C. 1	6.265	E. 1	2.58
A. 2	2.865	C. 2	6.67	E. 2	3.61
A. 3	3.35	C. 3	6.66	E. 3	2.37
				Mean	2.51
Mean	3.156	Mean	6.54	E. 5	3.55
B.	2.82	D.	5.23	F.	2.09
B. 1	2.15	D. 1	4.73	F. 1	1.91
B. 2	2.685	D. 2	5.46	F. 2	2.95
B. 3	2.75	D. 3	5.18	Mean	2.32
Mean	2.601	Mean	5.40	G. 1	2.96
				G. 6	4.42

The powders A and B were very slightly caked by this exposure to moisture; E more so, especially the finer grains E. 3 and E. 5; powders F were not at all caked; all the others were very much caked; the fine grained powder G. 6, became hard caked on the surface, after 6 days' exposure.

At the end of 11 days, and still more plainly after the 17 days' exposure, there could be discerned, with a lens, an efflorescence of the crystals of nitre on the surface of the grains of all the powders. This efflorescence was very slight indeed in the powders F, and the crystals were of a dirty yellowish color; in the other powders, the crystals were of a brilliant white. The efflorescence of nitre was slight on the powders B and E, but in considerable quantity on the remaining samples.

Table showing the increase of weight (per cent.) *in* 1500 *grs. of various kinds of gunpowder exposed to air saturated with moisture.*

Number of days		1	4	6	8	11	Weight of sample after being dried.
Temperature of room		85° to 88°	79° to 90°	83° to 87°	78° to 84°	79° to 83°	Grs.
From June 27 to July 8, 1844.	A. 1	2.70	8.51	11.87	16.07	20.88	1512.5
	B. 1	2.45	8.40	12.19	16.43	21.66	1505.
	C. 1	4.60	11.71	16.06	20.82	25.72	1547.7
	D. 1	4.12	11.63	15.73	20.54	26.79	1558.2
	E. 1	2.53	8.14	11.72	16.57	22.17	1501.5
	F. 1	2.19	8.10	11.55	16.31	20.83	1498.9
	G. 1	2.93	9.37	13.63	19.51	25.53	1526.
	G. 6	2.23	6.54	9.59	14.30	19.53	1498.9
	E. 5	2.30	8.89	12.75	17.46	23.11	1500.1
	H.	2.62	9.37	12.98	16.71	21.05	1510.6
	K. 1. r.	2.21	8.89	11.72	16.90	23.20	1498.0
	K. 1. g.	1.80	7.65	11.25	15.22	20.07	1500.8
No. of days		1	4	6	8	10	13
Temp. of the room		82° to 85°	84° to 87°	85° to 89°	86° to 90°	84° to 89°	86° to 94°
From July 9 to July 22, 1844.	A. 4	2.01	5.18	8.13	12.17	16.79	23.25	1504.3
	A. 5	2.15	6.07	9.90	14.71	19.84	27.05	1505.7
	A. 0	1.17	4.48	7.80	10.93	15.31	21.52	1601.6
	F. 0	0.65	4.18	7.03	10.86	15.76	22.59	1502.9
	L. 1	2.01	6.89	10.97	16.01	21.10	29.03	1505.7
	M. 1	1.77	5.46	8.36	12.70	18.28	24.79	1505.7
	N.	2.66	7.19	10.97	15.50	20.68	26.98	1554.
	R. 15′	1.07	4.53	6.96	10.27	14.94	21.01	1504.7
	R. 30′	2.19	6.11	8.75	13.49	17.86	23.85	1505.7
	R. 60′	1.59	5.27	8.55	12.70	17.91	25.11	1504.3
	R. 90′	2.19	6.44	9.85	14.80	20.12	26.89	1527.1
	S.	1.40	5.97	10.04	14.97	20.07	27.80	1522.5

Remarks.—After 24 hours' exposure to air saturated with moisture, there was no apparent change in any of the powders except the fine grained, G. 6, which was caked hard, although it had absorbed less moisture than several of the other samples.

On the fourth day, the samples C and D were caked, and the grains softened; samples G. 1 and G. 6 were also caked, but the grains were hard and dry; samples A. 5, E. 5 and H, were slightly caked; the rest not at all so.

An efflorescence of nitre was discernible on all the samples except the following: K. 1. r., M. 1. A. 0 and F. 0; it was scarcely perceptible on samples F. 1 and K. 1. g., but very great on samples G. 1 and G. 6.

After 11 days' exposure the efflorescence of nitre appeared on the surface of all the powders; but it was still very inconsiderable on the powders F, K and A. 0, whilst most of the dense powders A, G, N, &c., were completely disintegrated by it, and lost a great portion of their saltpetre.

The powders C and D must not be compared, in this respect, with the other kinds; for in consequence of the impurity of the saltpetre in these powders, a great quantity of moisture is rapidly absorbed by them; the deliquescent salts in the nitre are dissolved, the grains become so moist as to hold in solution the nitre which becomes separated from the other components, and the powder is soon rendered completely unserviceable. In confirmation of this result I may refer to the fact reported to the Ordnance office in July, 1844, by the military storekeeper at Apalachicola Arsenal in Florida: that ninety barrels of cannon powder and forty-seven of musket powder, of the same kind as powder C, which were sent to that Arsenal in 1838, had become caked, so that the contents of each barrel appeared to be a solid mass; whilst all the rest of the powder in the magazine, (consisting chiefly of powder

A,) made and sent to the Arsenal at the same time, was in good order.

On comparing the effect of exposure to moisture on the other samples of powder, it appears that, in general, water is absorbed less rapidly, and in smaller quantity, by the more light and porous pounding mill powders, than by dense rolling mill powders; a similar effect of diminished density is observed in comparing the two powders, R. 15′ and R. 90′. Not only is a smaller quantity of moisture absorbed by the less dense powders in the same time, but the absorption of an equal proportion of moisture is less injurious to them, and it is more readily and completely expelled by the same exposure to heat.

An exception to this remark occurs in the case of powder, such as E, the density and hardness of which are so great as to impair its combustibility and materially diminish its force, unless it is reduced to very minute grains, finer than those of rifle powder.

This fact, with regard to the relative quantity of moisture absorbed by light and by dense powder, is so different from the general impression on that subject, that I may be excused for mentioning that it is fully corroborated by the French experiments heretofore alluded to.

Owing to the influence of the temperature of the place of exposure on the quantity of moisture absorbed by the powder, the comparison of the results contained in the above tables can be accurately made only between the samples tested at the same time, and in the same manner.

Although charcoal is the chief absorbent ingredient in gunpowder, it is not perceived that the mere difference in the proportion of coal exercises such an influence on the absorption of moisture as to counterbalance other causes of variation. Of these, the size of grain is one of the most obvious; since, other circumstances being equal, the small grains, presenting a greater surface in the same weight of powder, will absorb more moisture than the large grains, or rather, will absorb it more rapidly; but even this effect seems to be counteracted, sometimes, by other circumstances.

The slow and moderate absorption of moisture by the powder S must be considered remarkable; since that powder contains 15 per cent. of coal, and has a very large proportion of fine grain.

Among the dense powders, the superiority of the powder B, with regard to the absorption of moisture, appears in all the tests to which I have subjected it. This may be owing, in part, to the more thorough charring of the coal, which in that powder is black, and not of the reddish hue of cylinder coal generally.

The fine state of preservation of the Waltham powder H, which, after 33 years, lost but 1 per cent. of weight by exposure to a hot sun, seems to leave nothing to desire on that score.

The very coarse grained powders, A. 0 and F. 0, absorb moisture slowly, as was to be expected from the comparatively small surface exposed. But they part with their moisture very differently from each other; for whilst the powder F. 0 returned very nearly to its original weight after drying, the powder A. 0, exposed to the same heat, still retained $\frac{1}{15}$th of its whole weight of moisture.

In order to form some idea of the relative destructibility of different kinds of powder, from the absorption of moisture, samples of many of them were tried by the musket pendulum, after having been dried. The results of this trial, and its comparison with the original trial of the same powders, before exposure to moisture, are presented in the following table of experiments with the musket pendulum.

Table showing the relative force, by the musket pendulum, of various kinds of gunpowder in good order, and of the same powders dried after exposure to air saturated with moisture.

Kind of powder.	POWDER IN GOOD ORDER. Initial velocity of ball.	POWDER DRIED AFTER EXPOSURE TO MOISTURE. Quantity of moisture absorbed.	Quantity of absorbed moisture retained by the powder after drying.	Initial velocity of ball.	Loss of force by exposure to moisture.	REMARKS.
	Feet.	Per cent.	Per cent.	Feet.	Per cent.	
A. 1	1256	20.88	0.83	891	29.06	
A. 4	1499	23.25	0.29	1480	1.27	
A. 5	1684	27.05	0.31	1516	9.98	
A. 0	1348	21.52	6.77	720	46.59	
B. 1	1269	21.66	0.33	1190	6.23	
E. 1	1098	22.17	0.10	1168	–	6.38 } Gain.
E. 5	1351	23.11	0.	1472	–	8.96 } Gain.
F. 1	1404	20.83	0.	1315	6.34	
F. 0	1373	22.59	0.20	1143	16.75	
G. 6	1856	19.53	0.	1472	20.69	
H.	1318	21.05	0.71	1079	18.13	
K. 1. g.	1207	20.07	0.05	1027	14.91	
L. 1	1229	29.03	0.38	999	18.71	
M. 1	1287	24.79	0.38	1190	7.54	
N.	1425	26.98	3.60	1091	23.44	
R. 15′	1376	21.01	0.31	1318	4.22	
R. 30′	1471	23.85	0.38	1198	18.56	
R. 60′	1434	25.11	0.29	1107	22.80	
R. 90′	1387	26.89	1.81	962	30.64	

From this table it will be seen, that, in general, the least dense powders return nearest to their original strength; this is partly owing to the circumstance of their parting more readily with the moisture they had absorbed, and partly to not losing their saltpetre by efflorescence. The powders A, G, N, R. 90′, in which the efflorescence of saltpetre had been very great, became necessarily disintegrated, and they actually lost, as I have said, a notable proportion of their saltpetre. The powder A. 0, which lost nearly half its force, retained, it will be recollected, about 7 per cent. of moisture.

The remarkable result furnished by the powder E, in this trial, cannot fail to attract notice; on being dried after having absorbed about 23 per cent. of moisture, it has *increased* in strength, when fired in the musket. This seems to be easily explained when we consider that the density of this powder was, in its original state, so very great as to impede its combustion, although the materials were incorporated by an unusual degree of working. In drying, after exposure to moisture, the grain has become porous and remained permanently swollen; by this diminution of density, its combustibility has been increased in a greater degree than its strength has been impaired by the moisture, and hence results an actual increase in the force of the charge; the result would not be the same probably in a large charge, such as that of a 24-pounder gun.

V. ANALYSIS OF THE EXPERIMENTS WITH THE CANNON PENDULUMS.

Although great care was taken, in the course of these experiments, to avoid, as far as practicable, those causes of irregularity which occur in ordinary practice, there still remain some minor variations, in the weight and windage of the balls, which could not have been prevented without a degree of labor and expense disproportionate to the object which would have been attained.

Before making a summary of the results of the experiments, for the purpose of comparison, it will be proper to reduce all of the experiments of similar kind to a common standard, and the means of effecting these reductions are furnished by the special experiments made with balls of different diameters and weights. At the same time, in order to make an accurate comparison between the results given by the ballistic pendulum and those by the gun pendulum, the velocity with which the ball strikes the pendulum block will be reduced to that with which it issued from the muzzle of the gun, by adding to the former velocity, as indicated by the ballistic pendulum, the loss occasioned by the resistance of the air, whilst the ball is passing from the gun to the pendulum block.

We will begin with the last mentioned correction, and estimate:

1. *The loss of velocity of the ball in passing from the gun to the pendulum block.*

The resistance on a plane surface moving parallel to itself, through an incompressible fluid, is equal to the pressure of a column of fluid whose base is that of the moving surface, and its height that which is due to the velocity with which the surface is moved through the fluid; the resistance, on a given area, is therefore proportional to the square of the velocity. But the resistance on the surface of a sphere is half of that on the area of its great circle. Hence it is easily shown that, if

D represent the diameter of a ball;
v its velocity at any moment of its flight;
a the density of the air, } that of water being unity;
s the density of the ball, }
G the measure of the force of gravity;

the retarding force f, acting on the ball, will be represented by $\frac{3\,a\,v^2}{8\,G\,D\,s}$, on the supposition that the ball moves through a perfect and incompressible fluid.—(See Hutton's Tracts, or any elementary work on Ballistics.)

But Hutton's experiments have shown that this supposition does not apply to the case of a ball moving through the air, and that in order to obtain the true resistance to such motion, it is necessary to multiply the theoretic resistance by a coefficient which varies with the velocity, according to a certain law determined from the experiments.

Calling this coefficient n, we have, for the retarding force,

$$f = \frac{3\,n\,a\,v^2}{8\,G\,D\,s}.$$

By the laws of retarded motion, $v\,d\,v = -G\,f\,d\,x$; x being the space passed over when the velocity has been reduced to v; substituting the above value of f, we have:

$$v\,d\,v = -\frac{3\,n\,a\,v^2}{8\,D\,s}\,d\,x = -n\,e\,v^2\,d\,x; \text{ putting } e = \frac{3\,a}{8\,D\,s}.$$

$$\text{Hence, } \frac{d\,v}{v} = -n\,e\,d\,x;$$

and by integration,

$$\text{Hyp. log. } v = C - n\,e\,x;$$

but when $x = 0$, $v = V$, the first, or initial velocity of the ball; therefore $C =$ hyp. log. V; this value, substituted in the preceding equation, gives:

$$\text{Hyp. log. } V - \text{hyp. log. } v = \text{hyp. log. } \frac{V}{v} = n\,e\,x;$$

and if we put $A = 2.718281828$, &c., the number whose hyperbolic logarithm is 1, we have, $\frac{V}{v} = A^{n\,e\,x}$;

consequently, $$V = v\,A^{n\,e\,x};$$

a formula by which the initial velocity of the ball, or its velocity at the muzzle of the gun, may be determined by knowing the velocity with which it strikes the pendulum block.

In applying this formula to our experiments, I have taken $x = 45$ ft., which is a little less than the true distance (47.35 ft.) between the muzzle of the gun and the face of the pendulum block; because, as Hutton remarks, the resistance of the air is counterbalanced at first by the pressure of the elastic fluid which accompanies the ball when it issues from the muzzle of the piece.

The value of the quantity $e = \frac{3}{8} \frac{a}{D\,s}$ may be conveniently expressed in terms of the weight and diameter of the ball; for, D being the diameter in inches, and w the weight in pounds, we have:

$$s = \frac{1728 \times 16\,w}{1000\,D^3 \times .5236};$$

and the density of the atmospheric air, at a mean temperature, near the level of the sea, being generally estimated at about $\frac{1}{850}$th part of the density of water, we may put $a = \frac{1}{850}$.

Therefore,

$$e = \frac{3\,a}{8\,s} \times \frac{12}{D} = \frac{3 \times 12 \times 523.6\,D^2}{8 \times 850 \times 1728 \times 16\,w} = 0.00010026\,\frac{D^2}{w}.$$

The formula for the initial velocity of the ball,

$$V = v\,A^{n\,e\,x}$$

is readily calculated, for any given values of v, n, e, and x; for, by taking the logarithms, it becomes:

$$\text{Log. } V = \text{log. } v + n\,e\,x \text{ log. } A.$$

In this manner the following table of the loss of velocity of the ball, between the gun and the pendulum block, for the cases occurring most frequently in these experiments, has been computed.

The distance x is taken at 45 feet, as before mentioned; and to the coefficient n is assigned its appropriate value, varying with the velocity, according to the law determined by Hutton. The distance between the gun and the pendulum block is so small that the results of the calculations will not be sensibly affected by neglecting the change which occurs in the value of this variable coefficient, during the flight of the ball.

Log. A $= 0.4342945$; Log. log. A $= -1.6377892$

Table for reducing the velocities of balls at the ballistic pendulum to the velocities at the muzzle of the gun.

	Velocity at the pendulum - -			1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
	Value of coefficient n - - -			1.77	1.84	1.91	1.98	2.03	2.06	2.08	2.07	2.06	2.03	2.
	BALL.		$45e \times \text{Log.} A.$	Velocity lost by the ball in 45 feet.										
	Diameter.	Weight.												
	Inches.	Lbs.												
32-pdr.	6.26	32.3	0.002377	10	11	13	14	16	17	18	19	20	21	22
	6.26	23.9	.003213	13	13	17	19	21	23	25	26	27	29	30
	6.42	35.6	.002269	9	11	12	14	15	16	17	18	19	20	21
	6.18	31.6	.002369	10	11	13	14	16	17	18	19	20	21	22
24-pdr.	5.68	24.25	.002607	11	12	14	16	17	19	20	21	22	23	24
	5.68	18.	.003512	14	16	19	21	23	25	27	28	30	31	32
	5.68	30.88	.002047	8	10	11	12	13	14	15	16	17	18	19
	5.68	27.68	.002284	9	11	12	14	15	16	17	18	19	20	21
	5.68	21.08	.002299	12	14	16	18	20	22	23	24	25	27	28
	5.808	25.08	.002636	11	13	14	16	17	19	20	21	22	23	24
	5.46	24.08	.002426	10	12	13	14	16	17	19	20	21	22	23

2. *To correct the velocities of balls for variations in weight.*

The data for determining the relation between the velocities of balls of various weights, propelled by a given charge of powder, are furnished by those experiments, with both 32-pounder and 24-pounder guns, in which the weight alone of the ball varies, the windage and the charge of powder being the same.

The following table presents a summary of such experiments, the particulars of which may be found by reference to the Journal, or to the Synopsis which will presently be given. The velocities in this table are those obtained by means of the ballistic pendulum, reduced for the distance to the gun, by the rule just given. In order to extend the comparison to a greater variety of cases, I have introduced into this summary the results of some experiments in which corrections are made for small variations in the weight and windage of the balls, by the rules yet to be determined; but these corrections are too small to affect the general accuracy of the deductions.

DATE.	Calibre of gun.	No. of rounds.	POWDER.		BALL.			Value of exponent m.	Velocities computed for $m=2$.
			Kind.	Weight.	Windage.	Weight.	Velocity.		
				Lbs.	In.	Lbs.	Feet.		Feet.
1843. July 15th	32-pdr.	3	A.	4	0.173	32.3	1244	-	-
Aug. 26th	"	"	"	"	"	28.1	1314	2.54	1334
" 1st	"	"	"	"	"	23.9	1433	2.13	1446
July 17th	"	3	A.	5.333	"	32.3	1433	-	-
Aug. 26th	"	"	"	"	"	28.1	1514	2.53	1536
July 28th	"	"	"	"	"	23.9	1631	2.33	1666
1844. Mar. 14th	24-pdr.	3	A.	4	0.135	24.25	1451	-	-
June 18th	"	"	"	"	"	30.88	1285	2.	1285
Mar. 28th	"	"	"	"	"	27.68	1339	1.65	1358
" "	"	"	"	"	"	25.88	1378	1.26	1405
Mar. 28th / April 4th	"	5	"	"	"	21.08	1544	2.26	1556
Mar. 28th -	"	3	"	"	"	17.68	1674	2.21	1699
Do. & April 17th	"	"	"	"	"	9.29	2235	2.22	2344
Mar. 26th	"	2	A. 1	6	"	24.25	1710	-	-
April 4th	"	"	"	"	"	18.08	1966	2.10	1980

Now, to determine from these experiments the relation sought for between the velocities and weights of the balls:

We will suppose that this relation may be expressed by an exponential function, and since the velocity diminishes as the weight increases, if we represent by m the exponent of that power of the velocity which is inversely proportional to the weight, and by V, v, the velocities of balls of which the weights are W, w, respectively, we shall have

$$\left(\frac{V}{v}\right)^m = \frac{w}{W};$$

consequently, $m = \dfrac{\text{Log. } w - \text{Log. } W}{\text{Log. } V - \text{Log. } v}$.

By applying to this equation the values of V, v, W, w, furnished by experiments with balls of the same windage, &c., the values of the exponent m may be obtained.

In this way those values have been computed for the several series of experiments embraced in the foregoing table, by comparing the first term of each series with all the others in succession.

Notwithstanding some anomalies in the values of the exponent m, deduced from these experiments, the mean of the whole (2.11) differing but little from $m = 2$, tends to confirm the rule which has been generally received, that *the velocities of balls of different weights, propelled by the same charge of powder, are nearly inversely proportional to the square roots of the weights.*

The velocities computed according to this rule, which are contained in the last column of the above table, agree with the experimental velocities, (except in one or two cases,) as nearly as will generally occur in experiments of this nature.

In the 4th No. of the Mémorial de l'Artillerie, there is a memoir of Col. Duchemin on the initial velocities of projectiles, containing *formulæ deduced from experiments*, which have been considered worthy of insertion in the new edition (1844) of the Aide-Mémoire d'Artillerie. According to one of these formulæ, the initial velocities of balls of various weights, other circumstances being equal, are inversely proportional to the *fourth roots of the weights*. This relation between the velocities and weights is so far from representing correctly the results of the foregoing experiments, that we must suppose the author to have been led into error by deducing his formula from experiments which were not sufficiently numerous or varied to furnish the requisite data for an accurate solution of the question.

We shall have occasion to recur to this subject, after having prepared a synopsis of all the experiments.

In the mean time, we may safely conclude that, at least within the limits of variation in the weights of balls which occur in our experiments, the velocities may be reduced to those of a ball of standard weight, by correcting them according to the inverse proportion of the square roots of the weights. On this principle, therefore, the following table has been prepared for the purpose of facilitating such reductions, and of exhibiting, at the same time, the amount of correction in the cases that most frequently occur.

Table for reducing the initial velocities of balls of various weights (w) to those of a ball of standard weight (W.)

$W = 32.31$ lbs.	$W = 23.9$ lbs.	$W = 24.25$ lbs.	$\sqrt{\frac{w}{W}}$	REDUCTION FOR A VELOCITY OF									
w.	*w.*	*w.*		1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
Lbs.	Lbs.	Lbs.		Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet
32.57	24.10	24.45	1.0041	+ 4	+ 5	+ 5	+ 6	+ 6	+ 7	+ 7	+ 7	+ 8	+ 8
.50	.05	.40	1.0031	3	3	3	4	5	5	5	6	6	6
.43	24.00	.35	1.0020	2	2	2	3	3	3	3	4	4	4
.37	23.95	.30	1.0010	1	1	1	1	2	2	2	2	2	2
.23	.85	.20	0.9989	— 1	— 1	— 1	— 2	— 2	— 2	— 2	— 2	— 2	— 2
.17	.80	.15	.9979	2	2	3	3	3	3	4	4	4	4
.10	.76	.10	.9970	3	3	4	4	5	5	5	5	6	6
.03	.70	.05	.9959	5	5	5	6	6	7	7	7	8	8
31.97	.65	24.00	.9948	6	6	6	7	8	8	9	9	10	10
.90	.60	23.95	.9938	7	7	8	9	9	10	11	11	12	12
.83	.55	.90	.9927	8	9	9	10	11	12	12	13	14	15
.77	.51	.85	.9917	9	10	11	12	13	14	14	15	16	17
–	–	18.	.8616	152	166	180	193	207	222	235	249	263	277
23.90	–	–	.8602	154	168	182	196	210	224	238	252	266	280

3. *To correct the velocities for variations in the windage of the balls.*

Numerous experiments have been made by me, with great care, on the effect of varying the windage of balls; but the question now under consideration is of so complicated a nature, that a complete mathematical solution of it (if indeed it be at all practicable) would require still a vast number of experiments to furnish the requisite data. This will appear evident, when we consider that the loss of velocity by a given increase of windage probably depends on:

1. The degree of windage;
2. The calibre of the gun;
3. The length of bore;
4. The kind of gunpowder;
5. The charge of powder;
6. The weight or density of the ball.

The influence of some of these causes, however, is no doubt inconsiderable, and we may derive, from our experiments, an estimate of the loss of velocity which is occasioned by such increase of windage as occurs in ordinary practice with 32-pounder and 24-pounder guns. For this purpose, the experiments have been made with balls of such diameters as to represent the least and the greatest windages which could occur with new guns and balls, of diameters within the prescribed limits; and also the greatest windage of the ball in a 24-pounder gun, the bore of which should be so much enlarged as to cause its rejection from service. Some experiments have likewise been made with balls having but little more windage than would just allow them to enter the bore of the gun; but these experiments were too hazardous to be often repeated, or to be tried with large charges of powder.

In the following synopsis of these experiments on windage, the velocities of the balls have been reduced to those of a ball of standard weight, by the rule before established. The balls of each calibre might have been made to correspond actually in weight, as was done in some of the experiments with the 24-pounder gun; but it was apprehended at first, that the accuracy of the experiments might be impaired by the irregularity in the place of the centre of gravity of the ball, (with reference to its centre of figure,) which would have been occasioned by the use of shells partially filled up.

Summary of experiments on windage, with the 32-pounder gun.

DATE.	Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OF THE BALL. By ballistic pendulum. By experiment.	By ballistic pendulum. Reduced.	By gun pendulum. By experiment.	By gun pendulum. Reduced.	REMARKS.
1843.		Lbs.	In.	Lbs.	Feet.	Feet.	Feet.	Feet.	
Sept. 16	A. 1	4	0.253	31.85	1163	1167	1166	1157	Velocities reduced to the gun, and to a ball of 32.3 lbs. weight.
	"	"	"	"	1168	1172	1176	1167	
	"	"	"	"	1168	1172	1172	1163	
	"	"	0.133	33.60	1258	1296	1276	1300	
	"	"	"	"	1267	1305	1281	1305	
	"	"	"	"	1261	1299	1282	1306	
	"	"	0.028	35.50	1324	1411	1356	1415	Reduced to windage of 0.013. in.
	"	"	0.013	"	1330	1403	1363	1422	
	"	"	"	"	1315	1388	1351	1410	
21	F. 1	"	0.253	31.85	1122	1127	1112	1104	
	"	"	"	"	1129	1134	1126	1118	
	"	"	0.133	33.60	1171	1208	1182	1206	
	"	"	"	"	1187	1224	1199	1223	
	G. 1	"	0.253	31.85	1142	1145	1129	1120	
	"	"	"	"	1150	1153	1147	1138	
	"	"	0.133	33.60	1241	1278	1239	1263	
	"	"	"	"	1250	1287	1247	1271	
Means	A. 1	4	0.253	32.3	–	1170	–	1162	
Means	"	"	.133	"	–	1300	–	1304	
Means	"	"	.013	"	–	1401	–	1416	
Means	F. 1	"	.253	"	–	1131	–	1111	
Means	"	"	.133	"	–	1216	–	1215	
Means	G. 1	"	.253	"	–	1149	–	1129	
Means	"	"	.133	"	–	1283	–	1267	

Summary of experiments on windage with the 24-pdr. gun.

DATE.	Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OF THE BALL. By ballistic pendulum. By experiment.	By ballistic pendulum. Reduced.	By gun pendulum. By experiment.	By gun pendulum. Reduced.	REMARKS.
1844.		Lbs.	In.	Lbs.	Feet.	Feet.	Feet.	Feet	
Mar. 27	A. 1.2	4	0.355	24.08	1189	1199	1188	1184	Velocities by the pendulum are reduced for the distance to the gun, and all the velocities are reduced to those of a ball of 24.25 pounds weight.
	"	"	"	"	1186	1196	1203	1199	
	"	"	"	"	1186	1196	1202	1198	
	"	"	.245	"	1322	1333	1332	1328	
	"	"	"	"	1317	1328	1326	1322	
	"	"	"	"	1324	1335	1336	1332	
	"	"	.115	"	1437	1449	1472	1467	
	"	"	"	"	1446	1458	1478	1473	
	"	"	"	"	1456	1469	1476	1471	
28	"	"	.007	25.06	1538	1581	1581	1606	
	"	"	"	"	1532	1575	1574	1599	
22	"	6	.355	21.78	1530	1468	1536	1455	
	"	"	"	"	1525	1463	1534	1453	
	"	"	"	"	1527	1465	1545	1464	
	"	"	.245	23.01	1620	1597	1649	1606	
	"	"	"	23.48	1602	1596	1623	1597	
	"	"	"	"	1602	1596	1618	1592	
	"	"	.115	25.08	1615	1663	1633	1661	Rejected.
	"	"	"	"	1678	1728	1703	1732	
	"	"	"	"	1711	1761	1742	1771	
	"	"	"	"	1707	1757	1739	1761	
20	F. 1. 2	"	0.355	21.78	1378	1323	1381	1308	
	"	"	"	"	1400	1345	1421	1348	
	"	"	"	"	1385	1330	1366	1293	
	"	"	0.245	23.48	1450	1445	1469	1446	
	"	"	"	"	1473	1468	1501	1478	
	"	"	"	"	1423	1418	1416	1393	
	"	"	"	"	1443	1438	1451	1428	
22	"	"	0.115	25.08	1518	1563	1522	1548	
20	"	"	"	"	1503	1548	1520	1546	

Mean results of the experiments on windage, with the 24-pdr. gun.

Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OF THE BALL. By the ballistic pendulum.	VELOCITY OF THE BALL. By the gun pendulum.	REMARKS.
	Lbs.	In.	Lbs.	Feet.	Feet.	
A. 1. 2	4	0.007	24.25	1578	1603	
"	"	.115	"	1459	1470	
"	"	.245	"	1332	1327	
"	"	.355	"	1197	1194	
"	6	.115	"	1749	1755	
"	"	.245	"	1596	1598	
"	"	.355	"	1465	1457	
F. 1. 2	"	.115	"	1556	1547	
"	"	.245	"	1442	1436	
"	"	.355	"	1333	1316	

We will now bring these results into one view, as in the following table:

Calibre of gun.	POWDER.		BALL.		DIFFERENCES		RATIO OF DIFFERENCE		$m = \frac{V-v}{V\,(D-d)}$
	Kind.	Weight.	Windage.	Velocity.	Of windage $(D-d)$	Of velocity $(V-v.)$	Of windage.	Of velocity.	
		Lbs.	In.	Feet.	In.	Feet.			
32-pdr.	A. 1	4	0.013	1401					
"	"	"	.133	1300	0.12	101	–	–	.60
"	"	"	.253	1170	0.24	231	2.	2.31	.69
"	F. 1	"	.133	1216					
"	"	"	.253	1131	0.12	85	–	–	.58
"	G. 1	"	.133	1283					
"	"	"	.253	1149	0.12	134	–	–	.87
24-pdr.	A. 1.2	"	0.007	1578					
"	"	"	.115	1459	0.108	119	–	–	.70
"	"	"	.245	1332	.238	246	2.28	2.07	.66
"	"	"	.355	1197	.348	381	3.22	3.20	.70
"	"	6	.115	1749					
"	"	"	.245	1596	0.13	153	–	–	.67
"	"	"	.355	1465	.24	284	1.85	1.86	.68
"	F. 1.2	"	.115	1556					
"	"	"	.245	1442	0.13	114	–	–	.56
"	"	"	.355	1333	.24	223	1.85	1.96	.60

By taking the difference between the first windage and each of the others, in each set of experiments, and the corresponding differences of velocity, and then dividing each of these differences by the first of its series, we obtain the ratios between the several differences of windage, and between the corresponding differences of velocity. These ratios approach so nearly to equality as to authorize the conclusion that the differences in the velocities of balls of different diameters are proportional to the differences of windage; or, in other words, that *the loss of velocity by windage is proportional to the windage.*

This relation between the windage and the loss of velocity, corresponds with the rule laid down by Hutton, and it appears to be consistent with reason. For the force exerted on the ball by a given charge of powder, is proportional to the quantity of the inflamed fluid which acts on the ball; but the force is also proportional to the square of the velocity. Therefore the difference of the squares of the velocities imparted to balls of different diameters, is proportional to the difference in the quantities of inflamed fluid acting on the balls, or to the loss of fluid by the difference of windage; and this loss is as the area of the opening through which the fluid escapes, or as the difference between the areas of the great circles of the balls, that is to say, as the difference of the squares of their diameters. Therefore, if V, v, v' represent the velocities of balls, the diameters of which are D, d, d', we shall have:

$$V^2 - v^2 : V^2 - v'^2 - :: D^2 - d^2 : D^2 - d'^2;$$

consequently,

$$(V+v')(D+d)(V-v')(D-d) = (V+v)(D+d')(V-v)(D-d').$$

But since the velocity increases with the diameter of the ball, and since the variations in the values of v and d are generally small, we may consider the terms $(V+v')(D+d)$ and $(V+v)(D+d')$ as being nearly equal; therefore, the remaining terms are also equal; that is to say,

$$(V-v')(D-d) = (V-v)(D-d');$$

from which it follows that the loss of velocity is proportional to the difference of windage. Or, if V represent the velocity of a ball whose diameter D is equal to that of the bore, then the total loss of velocity by windage will be proportional to the windage, other circumstances being equal.

In order to apply this principle to the reduction of the velocities obtained in our experiments, with balls having slightly different diameters, divide the last equation by $V\,(D—d)$, and it becomes

$$\frac{V—v'}{V}=(D—d')\,\frac{V—v}{V\,(D—d)};$$

if, therefore, we determine by experiment the value of the factor $\frac{V—v}{V\,(D—d)}$, for any difference of windage or difference of diameter, $D—d$, and denote this value by m, we shall have, for any other difference of diameter, (all other circumstances being equal,)

$$V—v'=V\times m\,(D—d').$$

The experiments above recited show that the value of the coefficient m varies with the kind of powder used; that is to say, that the loss of velocity by the same difference of windage is not the same for different kinds of powder. There can be no doubt, too, that the value of m varies with the calibre of the gun and with the charge of powder; but the calibres and charges used in these experiments on windage do not differ from each other sufficiently to develope the law of this variation, and as the same charges were employed in most of the experiments, the results of which we are now preparing to reduce, I have thought that it would be safe to use, in these reductions, a mean value of m for each kind of powder, applying to each kind the coefficient obtained for the powder A, F, or G, most nearly resembling it.

Having had occasion to mention Col. Duchemin's practical formulæ for determining the initial velocities of balls, I may remark that, in estimating the loss of velocity by windage, he appears to have been again led to an erroneous conclusion by the want of sufficient data; for he makes the loss of velocity proportional to the *square root* of the windage, other circumstances being equal; which ratio is far from representing the results of my experiments. According to Col. Duchemin's formula, also, the ratio of the loss of velocity to the total velocity is independent of the calibre of the piece. Now, although, as before remarked, the difference between the bores of the 32-pounder and the 24-pounder is not sufficiently great to produce a decided change in the proportional loss of velocity by a given windage in those guns, yet, if we compare these experiments with others, made with guns of much smaller calibre, we shall find that the value of the coefficient m, which expresses the proportional loss of velocity, varies decidedly with the calibre of the piece. For this purpose I may refer to the very experiments quoted by Col. Duchemin in support of the truth of his formula, being indeed the only experiments of the kind which have been published; I mean those made by Hutton and by Gregory, at Woolwich, with the ballistic pendulum.

The following is a summary of the results of those experiments, the particulars of which may be found in the authors' reports. In order to facilitate the comparison of the results with each other, the initial velocities are reduced to a common measure, in the proportion of the square root of the weight of the ball inversely, and the square root of the charge of powder directly. The kind of powder used in these experiments may be considered as similar to the powder A in my experiments.

Experiments on windage.

By whom made.	Kind of gun.	Charge of powdcr.	Ball. Windage.	Ball. Weight.	Initial velocity.	Difference of Windage (D—d.)	Difference of Velocity (V—v.)	$m = \frac{V-v}{V(D-d.)}$
		Lbs.	In.	Lbs.	Feet.	In.	Feet.	
Hutton	1-pounder gun; diam. of bore 2.02 in.; length 57.7in.	0.25	0.05	1.0547	1346			
		"	0.10	1.008	1244			
		"	0.15	0.9453	1225			
		0.5	0.05	1.0547	1815			
		"	0.10	1.0117	1728			
		"	0.15	0.9453	1662			
Gregory	12-pounder; diam. 4.62 in. length 74.25 inches.	3.336	0.0775	12.711	1545			
		4.	0.2015	11.717	1550			
Reduced to a common measure, in the weight of powder and ball.	1-pdr.	0.25	0.05	1.	1382			
			0.10	"	1249	0.05	133	1.93
			0.15	"	1191	0.1	191	1.38
		0.5	0.05	"	1864			
			0.10	"	1738	0.05	126	1.35
			0.15	"	1616	0.1	248	1.33
	12-pdr.	4.	0.0775	12.2	1727			
		"	0.2015	"	1519	0.124	208	0.97

If there should even be an error in the rule for the correction of velocity which I have deduced from my experiments, it fortunately happens that the variations of windage of the balls used in the experiments to which this rule will be applied, are too small to produce, in the results, any error of sufficient magnitude to impair the correctness of the deductions which may be made from those experiments. According to this rule, therefore, the following table has been computed for reducing the initial velocities to a common standard of windage.

Table showing the reduction of velocity of 32-pounder and 24-pounder balls for a given difference of windage.

Kind of powder.	m.	D—d	m(D—d)	REDUCTION FOR A VELOCITY OF									
				1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
		In.		Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet
		0.1	0.067	74	80	87	94	101	107	114	121	127	134
		.02	.0134	15	16	17	19	20	21	23	24	25	27
		.015	.00905	11	12	13	14	15	16	17	18	19	20
		.012	.00804	9	10	10	11	12	13	14	15	15	16
		.011	.00737	8	9	10	10	11	12	13	13	14	15
		.010	.00670	7	8	9	9	10	11	11	12	13	13
		.009	.00603	7	7	8	8	9	10	10	11	11	12
A.	0.67	.008	.00536	6	6	7	8	8	9	9	10	10	11
		.007	.00469	5	6	6	7	7	7	8	8	9	9
		.006	.00402	4	5	5	6	6	6	7	7	8	8
		.005	.00335	4	4	4	5	5	5	6	6	6	7
		.004	.00268	3	3	3	4	4	4	4	5	5	5
		.003	.00201	2	2	3	3	3	3	3	4	4	4
		.002	.00134	1	2	2	2	2	2	2	2	3	3
		.001	.00067	1	1	1	1	1	1	1	1	1	1
		0.1	0.087	96	104	113	122	131	139	148	157	165	174
		.02	.0174	19	21	23	24	26	28	30	31	33	35
G.	0.87	.015	.01305	14	15	17	18	20	21	22	24	25	26
		.01	.0087	10	10	11	12	13	14	15	16	17	17
		.005	.00435	5	5	6	6	7	7	7	8	8	9
		0.1	0.058	64	70	75	81	87	93	99	104	110	116
		.02	.0116	13	14	15	16	17	19	20	21	22	23
F.	0.58	.015	.0087	10	11	11	12	13	14	15	16	17	17
		.01	.0058	6	7	8	8	9	9	10	10	11	12
		.005	.0029	3	4	4	4	4	5	5	5	6	6

Reduction of the experimental velocities of cannon balls to a uniform standard of comparison.

Having thus obtained the means of reducing to a common standard the results of the experiments with the cannon pendulums, I shall now present a synopsis of them, showing the principal elements of each case, the velocity of the ball obtained from experiment by the gun pendulum as well as by the ballistic pendulum, and the corresponding velocity reduced to a uniform standard of weight and windage, and corrected, when necessary, for the distance between the gun and the pendulum.

In adopting a standard weight for the balls of each calibre, I have regarded the grommet wad as forming a part of the weight of the ball, since the wad is propelled from the gun with a velocity not less than that of the ball; the standard weight adopted is therefore the mean weight of the ball and grommet together.

The date of each experiment is given, for the purpose of easy reference to the Journal, in which all the particulars of the case may be found.

Reduction of the experiments with the 32-pounder gun.

Note.—The velocity with which the ball strikes the pendulum block is reduced to that with which it issues from the muzzle of the gun.

All the velocities are reduced to those of a ball of the windage of 0.173 in. and of the standard weight noted in the column of remarks.

DATE.	Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OF THE BALL. By ballistic pendulum. Experimental.	By ballistic pendulum. Reduced.	By the gun pendulum. Experimental.	By the gun pendulum. Reduced.	REMARKS.
1843.		Lbs.	In.	Lbs.	Feet.	Feet.	Feet.	Feet.	
April 7	a.	4.	0.165	32.73	–	–	1225	1226	Standard weight of ball 32.3 lbs.
	"	"	.165	.60	–	–	1235	1233	
17	"	"	.168	.50	–	–	1179	1174	
	"	"	.165	.62	–	–	1233	1232	
22	"	"	.183	31.90	1152	1167	1200	1201	
May 3	"	"	.168	32.35	1204	1215	1218	1215	
	"	"	.165	.45	1219	1229	1247	1243	
April 7	"	5.333	.173	.30	–	–	1404	1404	
	"	"	.173	.25	–	–	1387	1386	
May 3	"	"	.173	.32	1337	1352	1358	1358	
5	"	"	.167	.12	1381	1390	1402	1394	
April 7	"	6.4	.178	.18	–	–	1462	1465	
	"	"	.178	.28	–	–	1484	1489	
17	"	"	.178	.35	–	–	1430	1436	
	"	"	.178	.30.	–	–	1470	1475	
29	"	"	.183	.40	1450	1476	1468	1476	
May 5	"	"	.173	.07	1460	1467	1481	1472	
	"	"	.175	.195	1427	1444	1451	1451	
April 7	"	8.	.180	.40	–	–	1578	1588	
	"	"	.183	.34	–	–	1578	1591	
17	"	"	.183	.54	–	–	1580	1598	
	"	"	.178	.18	–	–	1552	1555	
29	"	"	.198	.43	1513	1557	1526	1551	
May 5	"	"	.183	.17	1525	1552	1548	1556	
	"	"	.178	.35	1546	1572	1574	1581	
Aug. 26	"	"	.181	.11	1555	1580	1585	1590	
April 7	"	10.666	.188	.34	–	–	1684	1705	
	"	"	.188	.42	–	–	1698	1721	
May 5	"	"	.185	.22	1676	1710	1712	1725	
16	"	"	.185	.276	1705	1740	1720	1734	
19	W.	8.	.165	.22	1562	1571	1593	1582	
27	"	"	.183	31.84	1556	1577	1589	1590	
	"	"	.175	.86	1548	1558	1594	1585	

DATE.	Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OF THE BALL. By ballistic pendulum. Experi-mental.	Reduced.	By the gun pendulum. Experi-mental.	Reduced.	REMARKS.
1843.		Lbs.	In.	Lbs.	Feet.	Feet.	Feet.	Feet.	
July 15	A.	4.	0.165	32.48	1241	1250	1243	1239	
	"	"	.165	.54	1256	1267	1274	1272	
	"	"	.173	.48	1199	1215	1212	1215	
Nov'r 1	"	"	.173	.42	–	–	1200	1202	
	"	"	.173	.37	–	–	1212	1213	
	"	"	.173	.32	–	–	1226	1226	
July 17	"	5.333	.173	.41	1415	1433	1425	1427	
	"	"	.173	.28	1418	1434	1435	1434	
	"	"	.175	.42	1411	1432	1435	1440	
Nov'r 1	"	"	.173	.41	–	–	1414	1416	
	"	"	.173	.43	–	–	1408	1411	
	"	"	.173	.30	–	–	1407	1407	
July 20	"	8.	.178	.13	1606	1626	1637	1639	
	"	"	.183	.21	1616	1645	1660	1671	
Nov'r 1	"	"	.173	.43	–	–	1660	1664	
	"	"	.173	.39	–	–	1668	1671	
	"	"	.173	.29	–	–	1627	1627	
Aug't 3	"	10.666	.185	.33	1739	1776	1792	1809	
Nov'r 1	"	"	.173	.32	–	–	1868	1868	
	"	"	.173	.56	–	–	1811	1818	
	"	"	.173	.29	–	–	1823	1823	
July 15	B.	4.	.165	.31	1189	1195	1194	1187	
	"	"	.165	.62	1173	1183	1190	1187	
	"	"	.165	.33	1186	1193	1162	1156	
17	"	5.333	.173	.14	1317	1328	1335	1332	
	"	"	.173	.23	1356	1369	1378	1376	
	"	"	.175	.39	1324	1342	1351	1355	
20	"	8.	.178	.26	1531	1553	1597	1602	See Journal
	"	"	.183	.25	1498	1525	1552	1562	
15	C.	4.	.165	31.97	1176	1176	1184	1171	
	"	"	.165	32.09	1201	1203	1210	1199	
	"	"	.173	.39	1179	1194	1190	1192	
17	"	5.333	.173	.47	1358	1377	1376	1380	
	"	"	.173	.29	1361	1376	1383	1383	
	"	"	.173	.47	1362	1381	1376	1380	

DATE.	Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OF THE BALL. By ballistic pendulum. Experimental.	By ballistic pendulum. Reduced.	By the gun pendulum. Experimental.	By the gun pendulum. Reduced.	REMARKS.
1843.		Lbs.	In.	Lbs.	Feet.	Feet.	Feet.	Feet.	
July 20	C.	8.	0.178	32.35	1558	1583	1610	1617	
	"	"	.183	.20	1550	1579	1610	1621	
15	D.	4.	.164	.10	1204	1205	1216	1204	
	"	"	.167	.25	1192	1199	1202	1196	
	"	"	.173	.44	1212	1228	1226	1229	
17	"	5.333	.173	31.90	1401	1408	1417	1408	
	"	"	.173	32.22	1375	1389	1395	1393	
	"	"	.173	.35	1374	1391	1395	1396	
20	"	8.	.177	.41	1588	1614	1628	1636	
	"	"	.183	.16	1557	1584	1608	1617	
Aug't 8	E.	4.	.168	.08	1126	1130	1133	1125	
	"	"	.183	.65	1098	1124	1114	1128	
	F.	"	.165	.43	1156	1164	1174	1170	
	"	"	.183	.41	1135	1156	1147	1156	
11	A. 1	"	.173	.46	1245	1261	1260	1263	
	"	"	.173	.43	1227	1243	1245	1248	
12	B. 1	"	.173	.45	1206	1222	1201	1204	
	"	"	.173	.18	1209	1220	1213	1211	
	C. 1	"	.173	.45	1176	1192	1186	1189	
	"	"	.173	.10	1183	1192	1187	1183	
	D. 1	"	.173	.42	1216	1232	1227	1230	
	"	"	.173	.24	1214	1226	1230	1229	
8	E. 1	"	.163	.19	1104	1106	1129	1119	
	"	"	.181	.40	1094	1114	1115	1123	
	F. 1	"	.183	.41	1134	1155	1147	1156	
	"	"	.168	.32	1166	1175	1180	1176	
	G. 1	"	.173	.42	1196	1211	1201	1203	
	"	"	.173	.40	1221	1236	1220	1222	
12	A. 2	"	.173	.27	1238	1250	1245	1244	
	"	"	.173	.41	1229	1245	1246	1249	

DATE.	Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OT THE BALL.				REMARKS.
					By ballistic pendulum.		By the gun pendulum.		
					Experi-mental.	Reduced.	Experi-mental.	Reduced.	
1843.		Lbs.	In.	Lbs.	Feet.	Feet.	Feet.	Feet.	
Aug. 12	B. 2	4	0.173	32.31	1195	1208	1200	1200	
	"	"	.173	.40	1192	1207	1199	1201	
	C. 2	"	.173	.37	1170	1185	1187	1189	
	"	"	.173	.31	1183	1196	1194	1194	
	D. 2	"	.173	.33	1220	1232	1227	1228	
	"	"	.173	.36	1216	1230	1226	1227	
Aug. 8	E. 2	"	.173	.37	1122	1135	1131	1132	
	"	"	.178	.42	1125	1143	1136	1142	
	F. 2	"	.165	.36	1149	1156	1163	1158	
	"	"	.175	.41	1110	1125	1118	1121	
11	E. 5	"	.173	.26	1175	1187	1184	1183	
	"	"	.173	.71	1191	1212	1197	1205	
8	G. 6	"	.173	.41	1253	1268	1256	1258	
	"	"	.173	.31	1243	1256	1246	1246	
Sept. 15	A. 0	"	.173	.25	1200	1212	1211	1210	Balls without grommets.
	"	"	.173	.25	1211	1223	1229	1228	
	"	"	.173	.25	1240	1252	1254	1253	
	"	5.333	.173	.25	1396	1411	1421	1420	
	"	"	.173	.25	1400	1415	1431	1430	
	F. 0	4	.173	.25	1195	1217	1211	1210	
	"	"	.173	.25	1187	1199	1203	1202	
	"	"	.173	.25	1199	1212	1216	1215	
	"	5.333	.173	.25	1326	1339	1349	1348	
	"	"	.173	.25	1348	1362	1372	1371	
Aug. 26	A.	4	0.173	28.1	1302	1318	1309	1309	Standard weight 28.1 lbs.
	"	"	"	"	1289	1305	1303	1303	
	"	"	"	"	1302	1318	1316	1316	
	"	5.333	"	"	1494	1514	1517	1517	
	"	"	"	"	1493	1513	1512	1512	
	"	"	"	"	1496	1516	1517	1517	

DATE.	Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OF THE BALL. By ballistic pendulum. Experi-mental.	Reduced.	By gun pendulum. Experi-mental.	Reduced.	REMARKS.
1843.		Lbs.	In.	Lbs.	Feet.	Feet.	Feet.	Feet.	
Aug. 1	A.	4	0.183	23.95	1408	1441	1407	1419	Standard weight of ball 23.9 lbs.
	"	"	.168	24.02	1397	1416	1415	1413	
	"	"	.183	24.05	1406	1442	1416	1431	
July 28	"	5.333	.170	23.95	1609	1632	1621	1619	
	"	"	.173	24.04	1593	1623	1607	1612	
	"	"	.173	24.02	1608	1638	1624	1629	
Aug. 4	E.	4	.173	23.95	1274	1294	1295	1296	
	"	"	.183	23.86	1269	1295	1291	1298	
	"	5.333	.168	23.86	1470	1487	1495	1488	
	"	"	.183	23.74	1468	1497	1494	1500	
	"	"	.185	23.91	1459	1495	1488	1501	
	F.	4	.183	23.78	1335	1361	1352	1359	
	"	"	.185	23.89	1352	1384	1361	1373	
	"	"	.183	23.83	1328	1355	1346	1354	
	"	5.333	.173	23.76	1519	1537	1541	1536	
	"	"	.183	23.83	1486	1518	1514	1523	
	"	"	.178	23.79	1527	1553	1546	1549	
3	E. 1	4	.183	23.81	1246	1271	1266	1273	
	"	"	.173	23.96	1260	1281	1288	1290	
	"	5.333	.185	23.70	1469	1498	1492	1499	
	"	"	.173	23.81	1464	1483	1502	1499	
2	F. 1	4	.175	23.76	1350	1368	1361	1359	
	"	"	.173	23.81	1334	1351	1351	1348	
	"	"	.185	23.80	1326	1352	1338	1345	
	"	5.333	.173	23.85	1502	1523	1515	1513	
	"	"	.168	23.83	1532	1548	1549	1542	
	"	"	.183	23.91	1483	1515	1493	1502	

Experiments with the 32-pounder gun—(Continued.)

DATE.	Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OF THE BALL. By ballistic pendulum. Experimental.	VELOCITY OF THE BALL. By ballistic pendulum. Reduced.	VELOCITY OF THE BALL. By gun pendulum. Experimental.	VELOCITY OF THE BALL. By gun pendulum. Reduced.	REMARKS.
1843.		Lbs.	In.	Lbs.	Feet.	Feet.	Feet.	Fget.	
Aug. 1	G. 1	4	0.178	23.92	1375	1402	1384	1391	
	"	"	.165	24.01	1389	1403	1396	1389	
	"	"	.178	23.89	1394	1421	1396	1402	
	"	5.333	.178	.93	1570	1602	1586	1594	
	"	"	.173	.86	1573	1596	1586	1585	
	"	"	.183	.89	1564	1602	1580	1594	
3	E. 5	4	.178	.92	1342	1368	1361	1367	
	"	"	.183	.96	1342	1374	1361	1373	
	"	5.333	.173	.86	1541	1563	1571	1570	
	"	"	.173	.94	1555	1578	1584	1585	
2	G. 6	4	.173	.83	1458	1478	1454	1452	
	"	"	,183	.79	1453	1482	1451	1458	
	"	"	.183	.81	1455	1485	1450	1458	
	"	5.333	.173	.85	1663	1687	1658	1656	
	"	"	.173	.80	1664	1687	1668	1665	

Reduction of the experiments with the 24-pounder gun.

N. B. The velocity of the ball at the pendulum block is reduced to that at the muzzle of the gun. All the velocities are reduced to those of a ball of the windage of 0.135 in., and of the standard weight noted in the column of remarks.

DATE.	Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OF THE BALL. By ballistic pendulum. Experimental.	By ballistic pendulum. Reduced.	By gun pendulum. Experimental.	By gun pendulum. Reduced.	REMARKS.
1844.		Lbs.	In.	Lbs.	Feet.	Feet.	Feet.	Feet.	
Feb'y 2	A.	4	0.135	23.95	–	–	1437	1428	Standard weight of ball 24.25 lbs.
	"	"	"	24.09	–	–	1451	1447	
	"	"	"	.29	–	–	1475	1474	
	"	6	"	.25	–	–	1712	1712	
	"	"	"	.12	–	–	1742	1737	
	"	"	"	.09	–	–	1740	1734	
	"	8	"	.18	–	–	1902	1899	
	"	"	"	.11	–	–	1864	1859	
	"	"	"	.05	–	–	1868	1860	
March 12	"	3	"	23.83	1230	1233	1239	1228	
	"	"	"	24.08	1240	1250	1249	1245	
	"	"	"	.51	1248	1269	1254	1247	
14	"	4	"	.24	1436	1453	1450	1450	
	"	"	"	.09	1448	1460	1456	1451	
	"	"	"	.38	1420	1441	1432	1436	
	"	6	"	.23	1680	1700	1717	1716	
	"	"	"	.28	1690	1712	1711	1713	
	"	"	"	.18	1690	1708	1722	1720	
	"	8	"	.28	1782	1805	1790	1791	Rejected.
	"	"	"	.26	1866	1889	1895	1895	
	"	"	"	.20	1852	1873	1903	1901	
April 25	"	10	0.14	.41	1807	1842	1774	1787	Do.
	"	"	"	.06	1957	1981	1989	1989	
	"	"	"	.41	1964	2001	2001	2014	
June 18	"	12	0.145	.34	2026	2069	2065	2084	
	"	"	"	.18	1946	1982	1946	1958	
April 17	"	3	0.14	.85	1189	1222	1197	1216	Hay wad.
	"	"	"	25.40	1200	1247	1216	1249	"
	"	"	"	26.08	1160	1222	1185	1233	Junk wad.

DATE.	Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OF THE BALL. By ballistic pendulum. Experimental.	By ballistic pendulum. Reduced.	By gun pendulum. Experimental.	By gun pendulum. Reduced.	REMARKS.
1844.		Lbs.	In.	Lbs.	Feet.	Feet.	Feet.	Feet.	
April 17	A.	3	0.14	24.24	1203	1229	1219	1223	Cartridges
	"	"	"	.14	1214	1230	1225	1227	5 in. dia-
	"	"	"	.06	1198	1212	1217	1217	meter.
	"	6	"	.29	1616	1643	1678	1685	" "
	"	"	"	.24	1661	1693	1703	1709	" "
	"	"	"	.17	1651	1675	1696	1699	" "
23	"	"	"	.15	1567	1589	1561	1563	Cartridge 5.82
	"	"	"	.08	1570	1591	1580	1581	in. diameter
25	"	3	"	.18	1232	1248	1254	1256	Vent closed
	"	"	"	.11	1253	1271	1266	1266	" "
	"	"	"	.28	1240	1259	1254	1259	" "
	"	6	"	.36	1669	1700	1697	1707	" "
	"	"	"	.31	1709	1738	1727	1735	" "
	"	"	"	.25	1678	1705	1714	1720	" "
	"	"	"	.20	1642	1671	1671	1680	" "
June 18	"	"	0.145	.18	1667	1696	1676	1684	Vent enlar-
	"	"	"	.28	1595	1628	1609	1622*	ged by fir-
	A. 1, 2	"	"	.28	1661	1695	1690	1703	ing.
July 16	A.	"	"	.25	1654	1687	1695	1707	New vent,
	"	"	"	.09	1670	1698	1706	1713	0.175 in.
	"	"	"	.13	1678	1707	1711	1719	" "
March 22	B.	3	0.135	23.96	1223	1230	1232	1225	
	"	"	"	24.53	1205	1226	1211	1218	
	"	6	"	.10	1609	1624	1645	1640	
	"	"	"	.31	1607	1629	1638	1640	
	C.	3	"	.12	1245	1256	1249	1246	
	"	"	"	.04	1216	1225	1228	1223	
	"	6	"	.03	1622	1635	1670	1663	
	"	"	"	.32	1647	1671	1678	1680	
	D.	3	"	.20	1230	1243	1248	1247	
	"	"	"	.22	1244	1257	1250	1249	
	"	6	"	.06	1672	1686	1702	1695	
	"	"	"	.44	1628	1654	1662	1668	

* Rejected.

DATE.	Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OF THE BALL. By ballistic pendulum. Experimental.	By ballistic pendulum. Reduced.	By gun pendulum. Experimental.	By gun pendulum. Reduced.	REMARKS.
1844.		Lbs.	In.	Lbs.	Feet.	Feet.	Feet.	Feet.	
March 26	A. 1	6	0.135	24.27	1707	1729	1735	1736	
	"	"	"	.00	1678	1690	1702	1693	
	B. 1	"	"	.26	1644	1664	1677	1677	
	"	"	"	.18	1625	1641	1657	1653	
	C. 1	"	"	23.87	1625	1631	1666	1652	
	"	"	"	24.35	1652	1677	1684	1688	
	D. 1	"	"	.13	1676	1692	1724	1719	
	"	"	"	.23	1689	1709	1729	1728	
	E. 1	"	"	23.97	1531	1540	1584	1574	
	"	"	"	24.37	1515	1538	1566	1570	
	F. 1	"	0.125	.28	1533	1543	1561	1552	
	"		0.145	.41	1526	1560	1579	1594	
April 22	"	3	0.14	24.22	1198	1217	1203	1208	Fired with
	"	"	"	24.25	1173	1191	1186	1190	tubes.
	"	"	"	23.89	1204	1213	1212	1207	Do.
	"	"	"	24.32	1167	1187	1183	1189	Fired with
	"	"	"	.20	1209	1226	1214	1217	percussion
	"	"	"	.00	1198	1210	1208	1206	lock.
March 26	G. 1	6	0.135	.20	1630	1648	1657	1655	
	"	"	"	23.97	1663	1674	1684	1674	
April 23	E. 2	"	0.14	24.22	1544	1568	1589	1594	
	F. 2	"	"	.00	1520	1536	1546	1543	
	"	"	"	.39	1489	1518	1523	1533	
	A. 3	"	"	.16	1648	1672	1677	1681	
	"	"	"	.29	1619	1646	1659	1666	
	B. 3	"	"	.27	1606	1633	1641	1648	
	"	"	"	.31	1611	1639	1645	1653	
	C. 3	"	"	.10	1616	1637	1665	1666	
	"	"	"	.35	1606	1635	1651	1660	
23	D. 3	"	"	.09	1625	1646	1654	1655	
	"	"	"	.42	1617	1649	1649	1661	
	E. 3	"	"	.09	1571	1592	1621	1622	
	"	"	"	.39	1601	1632	1639	1650	

DATE.		Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OF THE BALL. By ballistic pendulum. Experimental.	Reduced.	By gun pendulum. Experimental.	Reduced.	REMARKS.
1844.			Lbs.	In.	Lbs.	Feet.	Feet.	Feet.	Feet.	
April	23	E. 5	6	0.14	24.11	1638	1661	1673	1676	
		"	"	"	.31	1646	1675	1671	1680	
	22	G. 6	"	"	.32	1722	1754	1738	1749	
		"	"	"	.34	1760	1793	1754	1765	
		"	"	"	.35	1738	1772	1745	1758	Percussion
		"	"	"	.32	1738	1771	1748	1760	lock.
		"	"	"	.27	1700	1729	1719	1727	Cartridges
		"	"	"	.35	1721	1754	1735	1747	5 in. diam.
	23	A. 0	"	"	.08	1653	1676	1699	1701	
		"	"	"	.33	1674	1705	1715	1725	
		F. 0	"	"	.23	1451	1474	1457	1462	
		"	"	"	.12	1514	1534	1512	1513	
	22	H.	3	"	.18	1211	1227	1218	1220	
		"	"	"	.40	1218	1239	1221	1228	
		"	"	"	.10	1213	1227	1220	1220	
		"	6	"	.21	1591	1615	1629	1633	
		"	"	"	.41	1600	1631	1637	1648	
		"	"	"	.13	1615	1637	1652	1654	
June	15	K. 1. r.	"	0.145	.13	1616	1652	1635	1651	
		"	"	"	.09	1608	1633	1626	1631	
		"	"	"	.34	1582	1615	1590	1603	
		"	"	"	.30	1609	1641	1617	1629	
		K. 1. g.	"	"	.04	1644	1667	1659	1662	Vent en-
		"	"	"	.15	1584	1610	1597	1603	larged by
		"	"	"	.00	1586	1609	1611	1614	firing.
		"	"	"	.28	1592	1623	1591	1602	
July	16	"	"	"	.26	1624	1654	1656	1666	New vent.
		"	"	"	.35	1612	1646	1646	1658	Do.
		"	"	"	.43	1608	1643	1641	1656	Do.
		"	"	"	.01	1650	1671	1670	1671	Vent closed
		"	"	"	.43	1621	1656	1645	1660	Do.
		"	"	"	.31	1628	1660	1659	1671	Do.

DATE.		Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OF THE BALL. By ballistic pendulum. Experimental.	By ballistic pendulum. Reduced.	By gun pendulum. Experimental.	By gun pendulum. Reduced.	REMARKS.
1844.			Lbs.	In.	Lbs.	Feet.	Feet.	Feet.	Feet.	
June	15	L. 1	6	0.145	24.18	1627	1654	1659	1666	
		"	"	"	.31	1618	1650	1637	1649	
		"	"	"	.36	1626	1659	1601	1614	
		"	"	"	.05	1610	1633	1632	1635	
		M. 1	"	"	.33	1632	1664	1655	1667	
		"	"	"	.09	1645	1670	1674	1679	
		"	"	"	.07	1612	1636	1628	1632	
		"	"	"	.26	1645	1675	1660	1670	
		N.	"	"	.25	1592	1624	1593	1605	
		"	"	"	.33	1579	1613	1585	1599	
		"	"	"	.33	1584	1618	1583	1597	
		"	"	"	.18	1615	1644	1635	1644	
July	16	"	"	"	.44	1599	1636	1617	1634	Vent closed
		"	"	"	.07	1629	1656	1659	1666	Do.
		"	"	"	.23	1558	1590	1564	1576	Do.
		"	"	"	23.88	1584	1604	1598	1598	New vent
		"	"	"	24.42	1594	1632	1627	1645	0.175 in.
		"	"	"	.27	1568	1601	1598	1611	Do.
	17	*a*	"	"	.13	1552	1580	1564	1572	
		"	"	"	.03	1573	1598	1582	1587	
		"	"	"	.25	1584	1616	1592	1604	
		W.	"	"	23.78	1591	1607	1631	1627	
		"	"	"	24.30	1591	1625	1620	1634	
		"	"	"	.25	1589	1621	1626	1638	
June	17	R. 15′	"	"	.40	1501	1535	1509	1524	
		"	"	"	.28	1473	1503	1495	1506	
		"	"	"	.40	1534	1568	1565	1580	
		R. 30′	"	"	.25	1487	1516	1492	1502	
		"	"	"	.27	1508	1538	1514	1525	
		"	"	"	.34	1525	1557	1546	1559	
		R. 60′	"	"	.25	1482	1511	1509	1519	
		"	"	"	.28	1552	1582	1565	1576	
		"	"	"	.29	1539	1569	1555	1566	

DATE.		Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OF THE BALL. By ballistic pendulum. Experimental.	Reduced.	By gun pendulum. Experimental.	Reduced.	REMARKS.
1844.			Lbs.	In.	Lbs.	Feet.	Feet.	Feet.	Feet.	
June	17	R. 90′	6	0.145	24.12	1612	1640	1633	1641	
		"	"	"	23.98	1602	1625	1643	1646	
		"	"	"	.95	1650	1672	1683	1685	
		S.	"	"	24.25	1649	1681	1665	1677	
		"	"	"	.41	1587	1624	1604	1621	
		"	"	"	.42	1636	1674	1663	1681	
		T.	"	"	.14	1321	1343	1337	1344	
		"	"	"	.07	1297	1318	1281	1287	
		"	"	"	.08	1337	1358	1356	1362	
April	4	A. 1, 2	"	0.125	.24	1571	1579	1600	1588	Mixed
		& E. 1	"	0.145	.06	1615	1640	1653	1658	powder.
	17	A. m.	"	0.14	.20	1211	1228	1233	1236	
		"	"	"	.08	1227	1241	1245	1245	
		"	3	"	23.96	982	990	1006	1004	
		"	"	"	24.23	978	992	1002	1006	
Dec'r	9	X.	6	0.145	24.26	1545	1574	1554	1564	
		"	"	"	.37	1616	1644	1637	1645	
		"	"	"	.06	1579	1602	1599	1603	
		X. p.	"	"	.16	1621	1649	1652	1660	
		"	"	"	.25	1603	1633	1611	1622	
		"	"	"	.22	1648	1678	1680	1690	
April	4	A. 1	"	0.135	18.08	1912	1944	1923		No reduction for weight or windage.
		"	"	"	"	1955	1988	1983		
		B. 1	"	"	"	1829	1860	1859		
		"	"	"	"	1838	1869	1882		
		C. 1	"	"	"	1879	1911	1911		
		"	"	"	"	1840	1871	1872		
		D. 1	"	"	"	1889	1921	1915		
		"	"	"	"	1871	1903	1903		
		E. 1	"	"	"	1687	1715	1762		
		"	"	"	"	1711	1739	1773		
		F. 1	"	"	"	1730	1760	1764		
		"	"	"	"	1697	1726	1747		

DATE.	Kind of powder.	Charge.	Windage of ball.	Weight of ball and wad.	VELOCITY OF THE BALL. By ballistic pendulum. Experi-mental.	By ballistic pendulum. Reduced.	By gun pendulum. Experi-mental.	By gun pendulum. Reduced.	REMARKS.
1844.		Lbs.	In.	Lbs.	Feet.	Feet.	Feet.	Feet.	
April 4	G. 1	6	0.135	18.08	1829	1860	1842		No reduction for weight or windage.
	"	"	"	"	1869	1900	1884		
	E. 5	"	"	"	1831	1862	1877		
	"	"	"	"	1853	1884	1883		
	G. 6.	"	"	"	1998	2031	1989		
	"	"	"	"	1965	1998	1971		
June 18	A.	4	0.19	30.88	1220	1280	1233	1282	No reduction for weight.
	"	"	"	"	1220	1280	1231	1280	
	"	"	"	"	1234	1294	1237	1286	
March 28	"	"	0.135	27.68	1325	1339	1340		
	"	"	"	"	1324	1338	1342		
	"	"	"	"	1325	1339	1345		
	"	"	"	25.88	1369	1385	1399		
	"	"	"	"	1361	1377	1388		
	"	"	"	"	1356	1372	1379		
	"	"	"	21.08	1507	1529	1543		
	"	"	"	"	1508	1530	1536		
	"	"	"	"	1542	1564	1555		
April 4	"	"	0.155	"	1504	1548	1527	1549	
	"	"	"	"	1505	1549	1521	1543	
March 28	"	"	0.135	17.68	1651	1679	1654		
	"	"	"	"	1645	1673	1666		
	"	"	"	"	1642	1670	1664		
	"	"	"	9.29	2154	2225	2195		
April 17	"	"	0.14	9.36	2160	2247	2140	2156	Reduced to weight of 9.29 lbs.
	"	"	"	9.35	2146	2233	2131	2147	
March 28	"	"	0.135	4.48	2759	2952	2742		
	"	"	"	"	–	–	2778		
April 17	"	"	"	4.50	–	–	2696		
25	A. 1,2	4	0.012	25.06	1582	1631	1587	1618*	Vent closed
March 26	"	6	0.245	23.34	1585	1575	1611	1581†	Without wads.
	"	"	"	23.35	1601	1591	1628	1598†	

*Reduced to ball of 0.007 in. windage, and 24.25 lbs. weight.

†Reduced to weight 24.25 lbs.

Summary of the experiments with the cannon pendulums.

For more convenient reference, in analysing and comparing the results of these experiments, I have prepared the following summary, showing the mean results of all the experiments of a like kind, reduced to a common standard.

Experiments with the 32-pounder gun.

No. of rounds.	POWDER.		BALL.		INITIAL VELOCITY.		REMARKS.
	Kind.	Weight.	Windage.	Weight.	By ballistic pendulum.	By gun pendulum.	
		Lbs.	In.	Lbs.	Feet.	Feet.	
6	*a*	4.	0.173	32.3	–	1221	
2	"	"	"	"	1222		
4	"	5.333	"	"	–	1386	
2	"	"	"	"	1371		
7	"	6.4	"	"	–	1466	
3	"	"	"	"	1462		
8	"	8.	"	"	–	1576	
4	"	"	"	"	1565		
4	"	10.666	"	"	–	1721	
2	"	"	"	"	1725		
3	W.	8.	"	"	1569	1586	
6	A.	4.	"	"	–	1228	
3	"	"	"	"	1244		
6	"	5.333	"	"	–	1423	
3	"	"	"	"	1433		
5	"	8.	"	"	–	1654	
2	"	"	"	"	1636		
4	"	10.666	"	"	–	1830	
1	"	"	"	"	1776		
3	B.	4.	"	"	1190	1177	
3	"	5.333	"	"	1346	1354	
2	"	8.	"	"	1539	1582	See Journal, July 20, 1843.

No. of rounds.	POWDER. Kind.	POWDER. Weight.	BALL. Windage.	BALL. Weight.	INITIAL VELOCITY. By ballistic pendulum.	INITIAL VELOCITY. By gun pendulum.	REMARKS.
		Lbs.	In.	Lbs.	Feet	Feet.	
3	C.	4.	0.173	32.3	1191	1187	
3	"	5.333	"	"	1378	1381	
2	"	8.	"	"	1581	1619	
3	D.	4.	"	"	1211	1210	
3	"	5.333	"	"	1396	1399	
2	"	8.	"	"	1599	1627	
2	E.	4.	"	"	1127	1127	
2	F.	"	"	"	1160	1163	
2	A. 1	"	"	"	1252	1256	
2	B. 1	"	"	"	1221	1208	
2	C. 1	"	"	"	1192	1186	
2	D. 1	"	"	"	1229	1230	
2	E. 1	"	"	"	1110	1121	
2	F. 1	"	"	"	1165	1166	
2	G. 1	"	"	"	1224	1213	
2	A. 2	"	"	"	1248	1247	
2	B. 2	"	"	"	1208	1201	
2	C. 2	"	"	"	1191	1192	
2	D. 2	"	"	"	1231	1228	
2	E. 2	"	"	"	1139	1137	
2	F. 2	"	"	"	1141	1140	
2	E. 5	"	"	"	1200	1194	
2	G. 6	"	"	"	1262	1252	
3	A. 0	"	"	"	1229	1230	
2	"	5.333	"	"	1413	1425	Balls without grommets,
3	F. 0	4.	"	"	1209	1209	or other wads.
2	"	5.333	"	"	1351	1360	

Experiments with the 32-pounder gun—(Continued.)

No. of rounds.	POWDER. Kind.	POWDER. Weight.	BALL. Windage.	BALL. Weight.	INITIAL VELOCITY. By ballistic pendulum.	INITIAL VELOCITY. By gun pendulum.	REMARKS.
		Lbs.	In.	Lbs.	Feet.	Feet.	
3	A.	4.	0.173	28.1	1314	1309	
3	"	5.333	"	"	1514	1515	
3	A.	4.	"	23.9	1433	1421	
3	"	5.333	"	"	1631	1620	
2	E.	4.	"	"	1295	1297	
3	"	5.333	"	"	1493	1496	
3	F.	4.	"	"	1367	1362	
3	"	5.333	"	"	1536	1536	
2	E. 1	4.	"	"	1276	1282	
2	"	5.333	"	"	1491	1499	
3	F. 1	4.	"	"	1357	1351	
3	"	5.333	"	"	1519	1519	
3	G. 1	4.	"	"	1409	1394	
3	"	5.333	"	"	1584	1591	
2	E. 5	4.	"	"	1371	1370	
2	"	5.333	"	"	1571	1578	
3	G. 6	4.	"	"	1482	1456	
2	"	5.333	"	"	1687	1660	
3	A. 1	4.	0.013	32.3	1401	1416	
3	"	"	.133	"	1300	1304	
3	"	"	.253	"	1170	1162	
2	F. 1	"	.133	"	1216	1215	
2	"	"	.253	"	1131	1111	
2	G. 1	"	.133	"	1283	1267	
2	"	"	.253	"	1149	1129	

Summary of the experiments with the 24-pdr gun.

No. of rounds.	POWDER. Kind.	POWDER. Weight.	BALL. Windage.	BALL. Weight.	INITIAL VELOCITY. By ballistic pendulum.	INITIAL VELOCITY. By gun pendulum.	REMARKS.
		Lbs.	In.	Lbs.	Feet.	Feet.	
3	A.	3	0.135	24.25	1251	1240	
"	"	"	"	"	1259	1260	Vent closed.
"	"	"	"	"	1230	1233	Hay and junk wads.
"	"	"	"	"	1224	1222	Cartridges 5 in. diameter.
6	"	4	"	"	–	1448	
3	"	"	"	"	1451		
9	"	6	"	"	–	1719	
6	"	"	"	"	1702		
4	"	"	"	"	1705	1711	Vent closed.
2	"	"	"	"	1696	1694	Vent enlarged.
3	"	"	"	"	1692	1698	Cartridges 5 in. diameter.
2	"	"	"	"	1590	1572	" 5.82 diameter.
2	"	8	"	"	1881	–	
5	"	"	"	"	–	1883	
2	"	10	"	"	1991	2002	
2	"	12	"	"	2026	2021	
2	B.	3	"	"	1228	1222	
2	"	6	"	"	1627	1640	
2	C.	3	"	"	1241	1235	
2	"	6	"	"	1653	1672	
2	D.	3	"	"	1250	1248	
2	"	6	"	"	1670	1682	
2	A. 1	"	"	"	1710	1715	
2	B. 1	"	"	"	1653	1665	
2	C. 1	"	"	"	1654	1670	
2	D. 1	"	"	"	1701	1724	

No. of rounds.	POWDER.		BALL.		INITIAL VELOCITY.		REMARKS.
	Kind.	Weight.	Windage.	Weight.	By ballistic pendulum.	By gun pendulum.	
		Lbs.	In.	Lbs.	Feet.	Feet.	
2	E. 1	6	0.135	24.25	1539	1572	
2	F. 1	"	"	"	1552	1573	
3	"	3	"	"	1207	1202	
3	"	"	"	"	1208	1204	Fired with percussion lock.
2	G. 1	6	"	"	1661	1665	
1	E. 2	"	"	"	1568	1594	
2	F. 2	"	"	"	1527	1538	
2	A. 3	"	"	"	1659	1674	
2	B. 3	"	"	"	1636	1651	
2	C. 3	"	"	"	1636	1663	
2	D. 3	"	"	"	1648	1658	
2	E. 3	"	"	"	1612	1636	
2	E. 5	"	"	"	1668	1678	
2	G. 6	"	"	"	1774	1757	
2	"	"	"	"	1772	1759	Percussion lock.
2	"	"	"	"	1742	1737	Cartridges 5 in. diameter.
2	A. 0	"	"	"	1691	1713	
2	F. 0	"	"	"	1504	1488	
3	H.	3	"	"	1231	1223	
3	"	6	"	"	1628	1645	
4	K. 1. r.	"	"	"	1635	1629	
4	K. 1. g.	"	"	"	1627	1627	Vent enlarged.
3	"	"	"	"	1648	1660	New vent.
3	"	"	"	"	1662	1667	Vent closed.
4	L. 1	"	"	"	1649	1641	
4	M. 1	"	"	"	1661	1662	

No. of rounds.	POWDER. Kind.	POWDER. Weight.	BALL. Windage.	BALL. Weight.	INITIAL VELOCITY. By ballistic pendulum.	INITIAL VELOCITY. By gun pendulum.	REMARKS.
		Lbs.	In.	Lbs.	Feet.	Feet.	
4	N.	6	0.135	24.25	1625	1611	Vent enlarged.
3	"	"	"	"	1627	1625	New vent.
3	"	"	"	"	1612	1618	Vent closed.
3	*a*	"	"	"	1598	1588	
3	W.	"	"	"	1618	1636	
3	R. 15′	"	"	"	1535	1537	
3	R. 30′	"	"	"	1537	1529	
3	R. 60′	"	"	"	1554	1554	
3	R. 90′	"	"	"	1646	1657	
3	S.	"	"	"	1660	1660	
3	T.	"	"	"	1340	1331	
2	A. 1, 2 & E. 1	"	"	"	1610	1623	Mixed powder.
2	A. m.	"	"	"	1235	1241	
2	"	3	"	"	991	1005	
3	X.	6	"	"	1607	1604	
3	X. p.	"	"	"	1653	1657	
2	A. 1	6	0.135	18.08	1966	1953	
2	B. 1	"	"	"	1865	1871	
2	C. 1	"	"	"	1891	1892	
2	D. 1	"	"	"	1912	1909	
2	E. 1	"	"	"	1727	1768	
2	F. 1	"	"	"	1743	1756	
2	G. 1	"	"	"	1880	1863	
2	E. 5	"	"	"	1873	1880	
2	G. 6	"	"	"	2015	1985	

Experiments with the 24-pounder gun—(Continued.)

No. of rounds.	POWDER.		BALL.		INITIAL VELOCITY.		REMARKS.
	Kind.	Weight.	Windage.	Weight.	By ballistic pendulum.	By gun pendulum.	
		Lbs.	In.	Lbs.	Feet.	Feet.	
3	A.	4	0.135	30.88	1285	1283	
3	"	"	"	27.68	1339	1342	
3	"	"	"	25.88	1378	1389	
5	"	"	"	21.08	1544	1545	
3	"	"	"	17.68	1674	1661	
3	"	"	"	9.29	2235	2166	
3	"	"	"	4.48	–	2739	
1	"	"	"	"	2952		
1	A. 1, 2	4	0.007	24.25	1631	1618	Vent closed.
2	"	"	"	"	1578	1603	
3	"	"	.115	"	1459	1470	
3	"	"	.245	"	1332	1327	
3	"	"	.355	"	1197	1194	
3	"	6	.115	"	1749	1755	
3	"	"	.245	"	1596	1598	
2	"	"	"	"	1583	1590	Without grommets.
3	"	"	.355	"	1465	1457	
2	F. 1, 2	"	.115	"	1556	1547	
4	"	"	.245	"	1442	1436	
3	"	"	.355	"	1333	1316	

Comparison of the initial velocities deduced from the two pendulums.

In examining the preceding summary of the experiments, we are struck with the coincidence in the results obtained by means of the two pendulums. The only exceptions, worthy of notice, occur in the experiments with high charges in the 32-pounder gun, and with very light balls in the 24-pounder; and in these instances, the discrepancies may be explained by reference to the remarks made in the discussion of the formula for the velocity of the ball by the recoil of the gun pendulum. For, all of our reasoning on the useful effect of the charge of powder rests on the supposition that the powder is entirely inflamed, or its force fully developed, before the ball leaves the gun, and this supposition will be further from the truth in proportion as the bore of the gun is shorter in comparison with its diameter, or as the charge is greater in proportion to the weight of the ball. In the case of a wooden ball fired from the 24-pounder gun, with a charge nearly equal to the weight of the ball, it is probable that the velocity of the ball at the ballistic pendulum is not accurately represented on account of the great disproportion between the weight of the pendulum and that of the ball; but even in this case, it would seem, by a comparison of the velocities and weights, that the error cannot be very great.

The general coincidence of the results obtained by the gun pendulum with those by the ballistic pendulum, in such a number and variety of cases, cannot be considered accidental, and it affords strong presumption of the correctness of the formula by which the former results are computed.

This coincidence of results is of great interest in a practical point of view, not only because it furnishes the means of verifying the accuracy of the experiments, but because, by the use of the gun pendulum alone, we may extend them much beyond the limits to which we should be restricted if it were necessary always to employ the ballistic pendulum. It is still more important, in reference to the use of this apparatus for the proof of gunpowder; as it may enable us to dispense with the service of the ballistic pendulum for that purpose, and thus render the operation much less tedious and expensive.

In discussing the relative force of various kinds of powder, reference will be generally made to the velocities obtained by the ballistic pendulum only.

RELATIVE FORCE OF VARIOUS KINDS OF CANNON POWDER.

In the following tables, the results of the experiments with different kinds of powder, under the same circumstances, are brought together, for the purpose of facilitating a comparison of their force, when fired in cannon of large calibre.

As the effect of the charge of powder is measured by the quantity of motion it imparts to the ball, the force of the powder, with balls of the same kind, is proportional to the velocity of the ball. To make the comparison more easy and obvious, the velocities communicated to the balls by the several kinds of powder are compared with those given by the powder G. 6, which has the greatest force in all cases, and the ratios are set down in the column of *relative force*. In cases where no experiments were made with the powder G. 6, I have interpolated the velocity with that powder, in order to preserve a uniform standard of comparison.

Table showing the relative force of various kinds of gunpowder, as indicated by the 32-pounder gun.

Kind of powder.	WITH SHOT—WEIGHT 32.3 LBS.						SHELLS—WEIGHT 23.9 LBS.			
	Charge 4 lbs.		5.333 lbs.		8 lbs.		4 lbs.		5.333 lbs.	
	Velocity	Relative force.	Velocity	Relative force.	Velocity	Relative force.	Velocity	Relative force.	Velocity	Relative force.
	Feet.		Feet.		Feet.		Feet.		Feet.	
a.	1222	968	1371	938	1565	921				
A.	1244	986	1433	980	1636	962	1433	967	1631	967
A. 1	1252	992								
A. 2	1248	989								
Mean	1248	989	1433	980	1636	962	1433	967	1631	967
A. 0	1216	964	1397	956						
B.	1190	943	1346	921	1539	905				
B. 1	1221	968								
B. 2	1208	957								
Mean	1206	955	1346	921	1539	905				
C.	1191	944	1378	943	1581	930				
C. 1	1192	945								
C. 2	1191	944								
Mean	1191	944	1378	943	1581	930				
D.	1211	960	1396	955	1599	941				
D. 1	1229	974								
D. 2	1231	975								
Mean	1224	970	1396	955	1599	941				
E.	1127	893	–	–	–	–	1295	874	1493	885
E. 1	1110	880	–	–	–	–	1276	861	1491	884
E. 2	1139	903								
Mean	1125	891	–	–	–	–	1286	868	1492	885
E. 5	1200	951	–	–	–	–	1371	925	1571	931
F.	1160	919	–	–	–	–	1367	922	1536	910
F. 1	1165	923	–	–	–	–	1357	916	1519	900
F. 2	1141	904								
Mean	1155	915	–	–	–	–	1362	919	1528	905
F. 0	1193	945	1336	914						
G. 1	1224	970	–	–	–	–	1409	951	1584	939
G. 6	1262	1000	1462*	1000	1700*	1000	1482	1000	1687	1000
W.	–	–	–	–	1569	923				

* Velocities interpolated by calculation.

Table showing the relative force of various kinds of gunpowder, as indicated by the 24-pounder gun.

Kind of powder.	WITH SHOT—WEIGHT 24.25 lbs. Charge 3 lbs. Velocity	Charge 3 lbs. Relative force.	Charge 6 lbs. Velocity	Charge 6 lbs. Relative force.	WITH SHELLS, Weight 18.08 lbs. Charge 6 lbs. Velocity	Charge 6 lbs. Relative force.
	Feet.		Feet.		Feet.	
a.	–	–	1598	901		
A.	1251	989	1702	959		
A. 1	–	–	1710	964	1966	976
A. 3	–	–	1659	935		
Mean	1251	989	1695	955	1966	976
A. 0	–	–	1691	953		
B.	1228	971	1627	917		
B. 1	–	–	1653	932	1865	926
B. 3	–	–	1636	922		
Mean	1228	971	1638	923	1865	926
C.	1241	981	1653	932		
C. 1	–	–	1654	932	1891	938
C. 3	–	–	1636	922		
Mean	1241	981	1648	929	1891	938
D.	1250	988	1670	941		
D. 1	–	–	1701	959	1912	949
D. 3	–	–	1648	929		
Mean	1250	988	1673	943	1912	949
E. 1	–	–	1539	868	1727	857
E. 2	–	–	1568	884		
E. 3	–	–	1612	909		
Mean	–	–	1573	887	1727	857
E. 5	–	–	1668	940	1873	930
F. 1	1207	954	1552	875	1743	865
F. 2	–	–	1527	861		
Mean	1207	954	1540	868	1743	865
F. 0	–	–	1504	848		
G. 1	–	–	1661	936	1880	933
G. 6	1265*	1000	1774	1000	2015	1000
H.	1231	973	1628	918		
A. m	991	783	1235	696		

Kind of powder.	WITH SHOT, Weight 24.25 lbs. Charge 6 lbs. Velocity	Relative force.
	Feet.	
A. 1 & E. 1	1610	908
K. 1. r.	1635	922
K. 1. g.	1637	923
L. 1	1649	930
M. 1	1661	936
N.	1626	917
R. 15′	1535	865
R. 30′	1537	866
R. 60′	1554	876
R. 90′	1646	928
S.	1660	936
T.	1340	755
W.	1618	912
X.	1607	906
X. p.	1653	932

* Interpolated.

Relative force of various kinds of gunpowder, as indicated by the gun pendulums, with blank cartridges.

Gun.	POWDER.		Moment of the gun pendulum.	Relative force.
	Kind.	Weight.		
		Lbs.		
32-pounder -	A.	8	29,977	971
" -	E. 2	"	28,410	926
" -	F. 2	"	28,355	919
" -	G. 6	"	30,860	1000
24-pounder -	A.	6	22,980	996
" -	B.	"	21,881	948
" -	C.	"	22,016	954
" -	D.	"	21,254	921
" -	E.	"	21,129	916
" -	E. 5	"	22,177	961
" -	F. 1	"	21,237	921
" -	G. 1	"	22,004	954
" -	G. 6	"	23,065	1000
" -	K. 1. g	"	22,519	976
" -	N.	"	22,422	972

REMARKS.

1. *These results agree in classing the different kinds of powder in the same order of relative force, by the 32-pounder and the 24-pounder guns, with all the charges tried, both with shot and shells.*

Any exception to this remark, that may be observed, is too slight to require notice.

The *ratio of force*, compared with that of the strongest powder, is not precisely the same in all cases, as that ratio approaches somewhat nearer to equality with the smaller charges; but even with these, the powders preserve the same *order* of force.

In comparing, therefore, the different kinds of powder, we may refer to the experiments with the 24-pounder gun, with the charge of 6 lbs.; as it is with that charge that the most numerous trials have been made.

Although the results with blank cartridges class the several kinds of powder in nearly the same order of relative force as those with balls, yet the differences in the ratio of force, by the two methods, are so great as entirely to preclude the hope of obtaining an accurate test of the strength of gunpowder by firing blank charges from a gun of any calibre.

2. *Influence of the size of grain on the force of cannon powder.*

Within the limits of the difference in the size of grain which occurs in ordinary cannon powder, the granulation appears to exercise but little influence on the force of the powder, unless the grain be exceedingly dense and hard. Thus it will be seen that, although in the cannon powders A, B, C, and D, the largest grain has a slight advantage in force over the smallest, yet the difference is generally unimportant, and the very coarse grain A. 0, which is ten times larger than the largest grain of the ordinary cannon powder, has nearly the same force as the latter. But the force of the powder E, the density and hardness of which are carried to excess, is very much affected by the size of grain, even when the difference of size is not very great, as in the cases of E. 1 and E. 3. This effect is still more remarkable, when we pass to the very fine grain of the dense powders, E. 5 and G. 6, the force of which is vastly greater than that of the large grain E. 1 and G. 1. On the other hand, the mealed power A. m (which is made by reducing mill cake to dust) is so minutely divided as to reduce its force to about three-fourths of that of similar powder in grain; the powder lying in such a compact mass that the flame penetrates it with difficulty.

On the whole, the usual mixture of grain, as in the powder A, appears to be favorable to the development of the force of powder in guns of large calibre.

The difference in the force of the several sizes of grain sifted from the same cannon powder being inconsiderable, I have, in the preceding tables, taken a mean of the whole, to represent the average force of each distinct kind of powder.

3. *Influence of different proportions of the ingredients of powder.*

A comparison of the force of the pounding mill powders K. 1. g. and M. 1, and of the rolling mill powders N and X, indicates that there is no marked superiority in either of the proportions 76, 14, 10 or 75, 12.5, 12.5; neither do the proportions of the sporting powder G. 1 appear to possess any advantage over the others, when worked into large grain. The great strength of the powder S, which is incorporated in a similar manner to N and X, but contains only 70 per cent. of nitre, would seem to show that the quantity of nitre might be reduced much below the usual proportion, without sensibly altering the mere strength of the powder when new; such powder would probably not be well preserved for any considerable time, but the fact of its strength, if confirmed by further trials, may furnish a useful hint, in case of a necessity for economizing saltpetre, in making powder for immediate use. It is probable that the force of this powder S is partly due to the great inequality in the size of grain, and to the large proportion which it contains of fine grain.

4. *Influence of different modes of manufacture.*

The highest degree of strength in the cannon is exhibited by powder made under the heavy rollers by the process now generally adopted in England and at the principal powder works in this country. But the superiority of this method of incorporation, although uniform and decided, is not so great as to give it an absolute preference over all other methods, so far as regards the strength alone of the powder; and the choice between them may be determined by their relative economy, and by an examination of the other qualities which they impart to the powder. Thus the mean velocity of the 24-pounder ball by 6 lbs. of all the rolling mill powders (*a*, A, G. 1, H, M. 1, N, R. 90′, S and X) is 1643 feet, not very different from the mean of the results obtained by other kinds of powder of *similar density*. I omit the powder C in this enumeration, because the mill charge and the time of running do not conform to the usual practice in the best mills, although the effect of that mode of working, on the strength of the powder, would seem to be nearly the same as that of the common practice.

The efficiency of the method of incorporation by means of heavy rollers is shown by a comparison of the powders R, which differ from each other only in the time of running under the rollers, the coal and sulphur having been previously pulverized. It appears that powder worked not more than 30 minutes in this way has nearly as much strength as the powder F, *made of similar materials*, by 14 hours' work in the pounding mill; but it must be remarked, that the cylinder coal used in making these powders is not considered suitable for working in the pounding mill, being too hard to admit of sufficient pulverization by the action of the pestles. In the manufacture of powder for the French military service, in which the pounding mill alone is used, the coal is therefore charred in open pits, (à l'air libre,) by which means it is more thoroughly burnt and much more friable than the cylinder coal. The difference in the use of these two kinds of coal, for pounding mill powder, is exhibited by comparing the powders F and K 1. r., which differ only in this respect. The strength of the powder K shows that the pounding mill is capable of manufacturing powder of great force; but this sample is decidedly superior to the ordinary French cannon powder, which, under the same circumstances, would give to the 24-pounder ball a velocity of about 1540 feet, instead of 1640. This superiority is due partly to the longer time of working on the powder K; (14 hours instead of 11, as in the French mills;) partly to its being free from dust; and partly to the better quality of the coal, owing to its having been prepared on a small scale, and therefore more carefully than in large pits. It would appear that 14 hours is nearly the limit of useful work under the pestles, as scarcely any additional force is gained by 24 hours' work, which was employed in making the powder L.

The results obtained with the powder G. 1 show that, for cannon powder, no advantage, in point of strength, is gained by the thorough working and great density which are favorable to the production of the greatest force in small grain powder, such as G. 6.

The force retained by the Waltham powder H, after having been kept, without especial care, for thirty-three years, furnishes strong evidence in favor of the English mode of manufacture.

I am at a loss to explain the difference between the strength of the powders *a*, N and X, and that of the powder A, otherwise than by supposing that, notwithstanding the previous pulverization of the materials, one hour's work, even under very heavy rollers, is not sufficient to ensure uniformity in the quality of the powder. But there may have been some peculiarity in the working of the powder A, such as the mixture of the dust of former working, which would account for its superior strength; it must be remarked, however, that the same

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superiority was found in all the trials of this powder, which has been taken from ten different barrels.

A comparison of the strength of the powder T with that of S, or of ordinary cannon powder, shows that there can be no real economy in the use of inferior and cheap powder for blasting rocks.

From the experiments with the powders C and D, in which the saltpetre is far from being refined to the proper standard, it appears that a notable proportion of foreign salts may exist in the nitre, without sensibly impairing the strength of the powder when it is new, or when it has been well preserved for a moderate time. Hence the great importance of using proper tests, besides the mere proof of the force of powder, for determining this point, so essential to the due preservation of the strength of powder in service.

4. *Influence of the density of powder on its strength.*

By whatever means a thorough incorporation of the ingredients of gunpowder may be effected, it is evident that a very considerable degree of density is requisite for the full development of its force in the cannon. But there is a limit beyond which an increase of density is no longer favorable to the strength—this limit is passed in the powders E and G. 1, in both of which, the density and hardness of the grain are too great for cannon powder. This will be apparent by comparing the force with the size of grain in each of these powders; for whilst in most of the other kinds, the force decreases with the size of grain, it here increases in a great ratio as the grain becomes smaller.

Thus also it will be seen, by comparing the pounding mill powders F and K, that the density of the former is much below the proper standard for strength. Of all the samples tried, the lowest density which appears consistent with great force in the cannon, is that of the rolling mill powders H and R. 90′, the gravimetric density of each of which is nearly 870. On the other hand, it does not appear necessary, on the score of strength, as it is certainly not advisable in other respects, that the gravimetric density of the coarse grain of cannon powder should exceed 920.

5. *Influence of glazing, on the strength of powder.*

As it is considered necessary that all the powder for the military service should be glazed, in order to prevent the formation of too much dust in its transportation, but few experiments were made on this subject. The only direct comparison between glazed and rough powder was with the powders K. 1. r. and K. 1. g., the former of which is rough, and the latter glazed; both being nearly free from dust, there is no appreciable influence exercised by the glazing on the strength.

No experiment was deemed necessary to prove that the greater quantity of dust formed from unglazed powder in transportation impedes the penetration of the flame through the charge, and therefore materially diminishes its force.

6. The great and uniform superiority of the fine sporting powder, G. 6, even in large charges in the cannon, evinces the combined effect of the most careful preparation of the materials, their thorough incorporation, perfect drying, and high glazing; all of which are favorable, not only to the production of the greatest inherent force of the composition, but to the quick combustion of the grains, and to the rapid transmission of the flame through the whole mass of powder.

OF THE RELATIVE INITIAL VELOCITIES OF BALLS OF DIFFERENT DENSITIES, PROPELLED BY VARIOUS CHARGES.

In the previous discussion of the relation between the weights and velocities of balls of equal diameters, for the purpose of reducing the experimental velocities to a common standard of weight, it appeared that, for small variations of weight, the common rule of the velocity being in the inverse ratio of the square root of the weight may be adopted without sensible error; although it does not represent, with accuracy, the results of the experiments when the variation of weight is very great.

This might indeed have been anticipated; for the rule in question would indicate that the force generated by the inflamation of a given quantity of powder is always the same; whereas, it is well known that the tension of the gaseous fluid increases with the resistance opposed to its expansion. Thus, Robins and others, reasoning from the effects of the charge in a gun, have estimated the force of fired gunpowder at from 1,000 to 10,000 atmospheres; whilst Count Rumford, by burning the charge in a confined space, under heavy pressure, makes the force equal to 40,000 atmospheres. It follows, therefore, that no function of the weight of the ball alone can express its relation to the velocity communicated to it by a given charge of powder.

Again, it has been usual to consider that the velocities communicated to the same ball, by different charges of powder, are proportional to the square roots of the charges. But this rule rests on a similar supposition to the preceding—that the force produced by the combustion of the charge is proportional to the quantity of powder; whereas, it is obvious, that the portion of the charge which acts with the maximum effect on the ball, (that is to say, which exerts its force before the ball has been much displaced,) will vary with the resistance, or with the density of the ball; this density must therefore enter into the expression of the relation between the velocity of the ball and the charge of powder.

It appears, therefore, that although the weight of the ball or the charge of powder should remain the same, (the other being varied,) the corresponding variations of velocity must be expressed in terms of both those quantities.

We are indebted to M. Piobert for the suggestion of an empirical formula which appears to express, with great accuracy, this compound relation of the velocity, weight, and charge. This formula I find in the report of experiments at Metz, contained in the 4th No. of the Mémorial de l'Artillerie.

Putting b for the weight of the ball, and c for that of the charge of powder, Piobert's formula makes the velocity of the ball proportional to $\sqrt{\text{Log.}\left(1+\frac{c}{b}\right)}$; the charge being such, in proportion to the weight of the ball and to the length of the gun, that the powder may be supposed to act on the ball whilst the gaseous fluid retains a high degree of tension. This he considers to be the case with any charge not exceeding half the weight of the ball, in a gun of not less than 17 calibres length of bore.

The following comparative statement of the experimental and computed velocities of balls of different weights, propelled by the same charge of powder, shows how nearly this formula agrees with the experiments:

Calibre of gun.	Kind of powder.	Charge c.	BALL'S Weight B.	BALL'S Velocity V.	BALL'S Weight b.	BALL'S VELOCITY. Experimental	BALL'S VELOCITY. Computed v.
		Lbs.	Lbs.	Feet.	Lbs.	Feet.	Feet.
32 pdr.	A.	4	32.3	1244	28.1	1314	1328
	"	"	"	"	23.9	1433	1432
	"	5.333	"	1433	28.1	1514	1528
	"	"	"	"	23.9	1631	1645
	E.	4	"	1127	"	1295	1298
	E. 1	"	"	1110	"	1276	1278
	E. 5	"	"	1200	"	1371	1382
	F.	"	"	1160	"	1367	1336
	F. 1	"	"	1165	"	1357	1341
	G. 1	"	"	1224	"	1409	1409
	G. 6	"	"	1262	"	1482	1453
24 pdr.	A. 1	6	24.25	1710	18.08	1966	1947
	B. 1	"	"	1653	"	1865	1882
	C. 1	"	"	1654	"	1891	1883
	D. 1	"	"	1701	"	1912	1937
	E. 1	"	"	1539	"	1727	1752
	E. 5	"	"	1668	"	1873	1899
	F. 1	"	"	1552	"	1743	1767
	G. 1	"	"	1661	"	1880	1878
	G. 6	"	"	1774	"	2015	2020
	A.	4	"	1451	30.88	1285	1296
	"	"	"	"	27.68	1339	1364
	"	"	"	"	25.88	1378	1408
	"	"	"	"	21.08	1544	1548
	"	"	"	"	17.68	1674	1677
	"	"	"	"	9.29	2235	2222
	"	"	"	"	4.48	2952	2966
					Means	1657	1655

The velocities v, in the last column of this table, are computed from the first velocities V, by the formula

$$v = V \frac{\sqrt{\text{Log.}\left(1+\frac{c}{b}\right)}}{\sqrt{\text{Log.}\left(1+\frac{c}{B}\right)}};$$

and the correspondence of the results of this computation with those of the experiments is, with few exceptions, remarkably close.

Denoting by M the constant ratio

$$\frac{v}{\sqrt{\text{Log.}\,(1+\frac{c}{b})}} = \frac{V}{\sqrt{\text{Log.}\,(1+\frac{c}{B})}}$$

we shall have

$$v = M\sqrt{\text{Log.}\,(1+\frac{c}{b})}$$

which is the formula given by Piobert for expressing, in general, the velocity of the ball in terms of its weight and that of the charge of powder.

In the preceding table it is shown that M may be regarded as constant in cases when the weight of the ball alone varies, all other circumstances being the same. But the author proposes to apply the formula in a much more general manner, and to consider M as constant for all values of c and b in the same gun, with the same powder and with balls of the usual windage, (if not with all balls of the same windage,) provided the length of bore and the proportion between the powder and ball be within the limits before mentioned.

To ascertain how far this supposition is consistent with facts, I have computed the values of M, from my experiments, for various charges of several kinds of powder, as expressed in the following table:

32-POUNDER GUN.			24-POUNDER GUN.			REMARKS.
Kind of powder.	Charge.	Value of coefficient *M.*	Kind of powder.	Charge.	Value of coefficient *M.*	
	Lbs.			Lbs.		
a	4.	5427	*a*	6	5157	Windage 0.135 in.
	5.333	5322				
	8.	5048	A.	3	5558	
	10.666	4900		4	5635	
				6	5519	
A.	4.	5550		8	5346	
	5.333	5562		10	5047	
	8.	5277				
	10.666	5113	B.	3	5456	
				6	5286	
B.	4.	5356				
	5.333	5237	C.	3	5514	
	8.	4964		6	5292	
C.	4.	5290	D.	3	5554	
	5.333	5349		6	5399	
	8.	5100				
			E.	6	5076	
D.	4.	5436				
	5.333	5419	F.	3	5363	
	8.	5158		6	4967	
E.	4.	4965	G. 1	6	5360	
	5.333	5045				
			G. 6	6	5722	
E. 5	4.	5329				
	5.333	5312	H.	3	5469	
				6	5254	
F.	4.	5160				
	5.333	5166	E. 5	6	5383	
G. 1	4.	5435	A.	4	6141	Windage 0.007 in.
	5.333	5356				
			A.	4	5658	Do. 0.115 in.
G. 6	4.	5604	"	6	5641	
	5.333	5704				
			"	4	5164	Do. 0.245 in.
			"	6	5146	
			"	4	4642	Do. 0.355 in.
			"	6	4722	

By this table we see that, although the value of M decreases, in most cases, as the charge increases, we may assign to that coefficient a mean value which will not lead to any great error in estimating, by the above formula, the velocity of the ball for charges not exceeding *one-third* of its weight. Beyond this limit, with the dense kinds of powder at least, the velocity increases in so small a ratio with the increase of charge, that the same coefficient no longer represents it correctly.

The variations in the value of M, for the several kinds of powder, a, A, B, C, and D, which compose the principal part of our present stock of cannon powder, are not so great as to prevent our using its mean value to express the force of these powders. We may therefore conclude, that by assigning to M the value of 5,200 for the 32-pounder gun, and 5,400 for the 24-pounder, the formula will give, with sufficient accuracy, the velocity of balls of the true windage, (0.16 in. and 0.14 in. respectively,) from those guns.

It will be remarked, that there is also a close agreement in the values of the coefficient M, obtained from the velocities of balls of other corresponding diameters, propelled by different charges of the same powder; which shows that the formula applies to all the usual cases of practice, by giving the proper value to M.

The experiment of 25th August, 1844, in which a 24-pounder ball, with very small windage, was fired, with the vent of the gun closed, gives for the coefficient M, the value of 6,334, which may be regarded as very nearly its maximum value for the 24-pounder gun, and as furnishing the means of computing the greatest velocity which can be communicated to a ball fired from that gun, with any ordinary charge of the powder A. On this principle, the maximum velocities in the following table have been computed.

Gun.	POWDER.		Weight of ball.	INITIAL VELOCITY OF BALL.			
	Kind.	Weight.		Without windage.	Windage 0.135 in.	Windage 0.245 in.	Windage 0.355 in.
		Lbs.	Lbs.	Feet.	Feet.	Feet.	Feet.
24-pounder	A.	3	24.25	1426	1255		
"	"	4	"	1631	1450	1332	1197
"	"	6	"	1963	1702	1596	1465
"	"	8	"	2229	1882		

By comparing these results, an estimate may be formed of the loss of force by the windage of the ball. Thus it will be seen that 4 lbs. of powder give to a ball without windage, nearly as great a velocity as is given by 6 lbs. to a ball having the windage of 0.14 in., which is considered the true windage of a 24-pounder ball; or, in other words, this windage causes a loss of nearly *one-third* of the force of the charge.

In my former remarks on the subject of windage, it has been stated, that the loss of velocity by the same windage is different for different kinds of powder; the light pounding mill powder F losing a smaller proportion of its force than the dense rolling mill powders A and G. This is undoubtedly favorable to the former kind of powder, but the advantage in this case is counterbalanced by the fact, that the velocity of the ball by the powder F is still inferior to that by the powder A, with the windage increased 0.11 in., as will be seen by reference to the experiments on windage with the 24-pounder gun. The result, however, affords an argument in favor of reducing the density of the rolling mill powders, and thus increasing their quickness of burning in a mass.

The following table shows the results of the experiments relative to the loss of force by the vent of the gun:

	No. of rounds.	POWDER.		Vent.	Velocity of ball.
		Kind.	Weight.		
			Lbs.	In.	Feet.
24-pounder gun.	3	A.	3	0.175	1251
	3	"	"	Closed	1259
	2	"	6	0.25	1696
	6	"	"	0.175	1702
	4	"	"	Closed	1705
	4	K. l. g.	"	0.25	1627
	3	"	"	0.175	1648
	3	"	"	Closed	1662
	4	N.	"	0.25	1625
	3	"	"	0.175	1627
	3	"	"	Closed	1612
	Mean	A, K & N.	6	0.25	1649
			"	0.175	1659
			"	Closed	1660

These experiments, although not very extensive, are deemed sufficient to show that the loss of force, by the escape of gas from the vent, is altogether inconsiderable, when compared with the whole force of the charge, or with the other unavoidable variations which affect the velocity of the ball.

This result might have been anticipated, when we reflect that the orifice for the escape of gas through a vent of 0.25 in. diameter, is equal only to the difference between the areas of the great circles of balls whose diameters are 5.68 in. and 5.6745 in.; and the orifice of a vent of 0.175 in. diameter is equivalent to a diminution of windage of only 0.0027 in. in a ball of 5.68 in. diameter.

In the preceding comparison, I have not included the experiments made with balls of 0.007 in. windage, because there was but one ball fired with the vent closed; and, in that case, the increase of velocity over that of the others is obviously too great to have been caused by the mere closing of the vent, and must be attributed to some accidental variation; probably to a slight difference of windage, which may have easily escaped observation where the whole windage was so small.

OF THE EFFECT OF USING PERCUSSION PRIMERS.

The following experiments with the 24-pounder gun show that no influence on the force of the charge in a cannon can be attributed to the use of percussion primers for igniting the powder:

No. of rounds.	POWDER.		PRIMER.	Velocity of ball.
	Kind.	Weight.		
		Lbs.		Feet.
3	F. 1	3	Tube	1207
"	"	"	Percussion	1208
2	G. 6	6	Tube	1774
2	"	"	Percussion	1772

OF THE EFFECT OF WADS.

In the experiments with the cannon pendulum the ball was habitually kept in place by means of a very light *grommet*, or ring of rope yarn; a few experiments were made in firing balls without grommets, and also in putting hay and junk wads over the balls, as will be seen by reference to the summary of the experiments.

By reducing the velocity impressed on the ball and wad, conjointly, to that of a ball of the standard weight, it is found that very little effect on the force of the charge is produced by the use of the hay or junk wads. The velocity of the ball is somewhat less than when fired with a grommet, indicating perhaps that the motion of the ball in the bore is more impeded by the friction of the wad than it is accelerated by the slight additional force which is developed in the charge by reason of the increased resistance. There can be little doubt that the wad diminishes the velocity of the ball very nearly in the proportion of the increased weight; but the great deviation caused by the wads, in the direction of the balls, obliged me to desist from continuing these experiments, for fear of injury to the ballistic pendulum.

The experiments which were afterwards tried, on the effect of wads in causing the deviation of the ball, (for the particulars of which I refer to the Journal, under date of May 28th and 29th, 1844,) show conclusively that the use of hay or junk wads is decidedly injurious to the accuracy of fire; and that when a wad is required to hold the ball in its place, it should be made as light as possible, in the form of a grommet. This conclusion is confirmed by similar experiments made with 32-pounder and 24-pounder guns at Washington Arsenal in 1844, under the direction of Major Symington. In these experiments it was found that the accuracy of fire was not affected by a sabot, or a hay wad, placed between the powder and ball; a result of great practical value, since, by this use of the wad or sabot, we are enabled to increase the durability of guns, and especially of brass guns, by changing the position of the ball, without impairing the accuracy of fire.

These facts, relative to the effect of wads, have been long known, I believe, in the naval services of France and England, and have led to the general substitution, in those services, of the grommet, for the inconvenient and costly junk wad.

OF THE EFFECT OF VARYING THE DIAMETER OF THE CARTRIDGE.

The following experiments were made with cartridges of different diameters and lengths:

	No. of rounds.	POWDER. Kind.	POWDER. Weight.	CARTRIDGE. Diameter.	CARTRIDGE. Mean length.	Velocity of ball.	Moment of the gun pendulum.
			Lbs.	In.	In.	Feet.	
24-pounder gun.	3	A.	3	5.	4.5	1224	37,585
	3	"	"	5.35	4.2	1251	38,256
	3	"	6	5.	8.3	1692	57,762
	6	"	"	5.35	7.35	1702	58,389
	2	"	"	5.82	6.85	1590	54,122
	2	G. 6	"	5.	7.4	1742	58,906
	2	"	"	5.35	6.75	1774	59,472

From this table it appears, that whilst the usual diameter of the cartridge, for the 24-pounder gun, as now established, (5.35 in.) is favorable to the development of the force of the charge, no great diminution of effect arises from reducing the diameter to 5 in.; on the other hand, the force of the charge is vastly reduced by increasing the diameter of the cartridge to the full size of the bore. The latter effect is readily understood when we consider, that, in this case, the flame is communicated to the front part of the charge only by penetrating through the mass of powder; the ball must therefore be a good deal removed from its first position before the whole of the charge becomes inflamed, and consequently the gaseous fluid, expanding in a larger space, has its tension proportionally reduced; this effect, too, will be greater in proportion as the density of the powder increases, and presents a greater obstacle to the rapid combustion of the charge.

The experiments of the Board of officers at Metz, whose Report I have mentioned in the beginning of my Journal, show that, with charges exceeding one-fourth the weight of the ball, the cartridge of diminished diameter has even the advantage in point of force, and this circumstance assumes great practical importance when taken in connection with another fact developed by numerous experiments in France, viz: *that by reducing the diameter of the cartridge, the strain on the gun may be greatly diminished.*

In order to prevent the very rapid destruction of brass siege guns, which is caused by the use of large charges, Capt. Piobert proposed, in a memoir written in 1833, to increase the space in rear of the ball, by diminishing the diameter of the cartridge, or by interposing an elastic wad between the powder and ball. Numerous experiments on the relative injury to brass guns, by using the common and the elongated cartridge, have fully realized M. Piobert's anticipations, by showing that whilst the increase of diameter in the gun is much diminished by the use of the long cartridge, the force of the charge in its action on the ball is not lessened, but in many cases increased; and to effect this object it has not been found necessary to make the cartridge of an inconvenient length.

The most full and careful experiments which have been made on this subject are those of the Board of officers just mentioned. For the particulars of these experiments I must refer to their Report, a copy of which has been so obligingly furnished to the Ordnance Department by the French Minister of War. It is sufficient to state here the general result of these experiments: that by reducing the diameter of the cartridge for the 24-pounder gun (the bore of which is 6 in. diameter) from 5.5 in. to 5.15 in., which increases the length of the cartridge about 2 in., the enlargement of the area of the section of the bore, (produced by 4 rounds with a charge of half the weight of the ball,) is reduced *four-fifths*, whilst the initial velocity of the ball, as before stated, is somewhat increased; and this result is confirmed by numerous experiments with other large charges.

This effect of increasing the length and diminishing the diameter of the cartridge, seems to admit of an explanation similar to that which I have suggested, with regard to the operation of the charge when the cartridge is of the whole size of the bore. For, in the present case, the flame produced by the combustion of the first, or hinder, part of the charge, expands rapidly in the empty space above the cartridge; its tension, and the consequent strain on the gun, before the ball is moved, are, therefore, much less than in the ordinary case of a larger and shorter cartridge. At the same time, in consequence of this rapid expansion of the flame, it is communicated more quickly to the front part of the cartridge than when it has to pass through the mass of powder; and so much the more quickly in proportion as the transmission of the flame through the powder is more difficult, or as the powder is more dense, and the charge greater. Consequently, the complete inflammation and combustion of the whole charge, producing the final velocity of the ball, take place under these circumstances in a smaller space than before, although that space is sufficiently great to reduce very much the intensity of the action of the powder on the sides of the bore.

Be the explanation as it may, the facts are considered, in the French service, to be so well established that, in the new edition of the Aide-Mémorie d'Artillerie, in 1844, the principle of reducing the diameter of the cartridge is adopted for all siege and garrison guns.

Although the range of my experiments did not allow me to verify these results, I have permitted myself to make the foregoing remarks on the French experiments, in order to call the attention of the Ordnance Department to a matter which may be of the greatest importance to us, in reference to giving increased durability to our iron guns, and diminishing the risk of accidents which have been lately of frequent occurrence from the bursting of these guns.

COMPARISON OF THE RESULTS OF EXPERIMENTS ON RANGES WITH THOSE OBTAINED BY COMPUTATION.

The position of the pendulum gun offering a facility for determining points in the trajectory of a ball fired horizontally, I was induced to make some experiments on that subject, as explained in the Journal. The initial velocities of the balls having been determined by the recoil of the gun pendulum, and afterwards by firing with similar charges at the ballistic pendulum, an opportunity was thus afforded of making the comparison now under consideration.

In computing the theoretic ordinates of the trajectory at different distances from the gun, I have used the following equation of the trajectory at low angles, which applies to ranges not exceeding 2,000 feet:

$$y = x \tan. \varphi - \frac{g\, x^2}{6\, c\, v^2}(3\, c + 2\, x)$$

in which

y, is the ordinate, or the distance of any point in the trajectory from the horizontal plane passing through the muzzle of the piece.

x, the abscissa, or the distance of the ordinate y from the muzzle of the piece.

ϕ, the angle of elevation, or, strictly speaking, the angle of departure of the ball; that is to say, the angle which the first direction of the ball makes with the horizontal plane.

v, the initial velocity of the ball.

g, the force of gravity.

$c = \frac{n}{e}$; n and e being the same terms that were used in estimating the loss of velocity by the resistance of the air: Page 229.

The axis of the gun being always horizontal in my experiments, I have, in computing the values of y by the above formula, considered tang. $\phi = 0$. This supposition is not strictly accurate, in consequence of the irregularities produced in the direction of the ball by its striking against the sides of the bore, as indicated in the Journal of experiments by the variations in the position of the point struck, at the first target, near the muzzle of the piece. But as in ordinary practice we have no means of ascertaining this anomaly, our calculations must be made on the supposition that the ball leaves the piece in the direction of the axis of the bore, and they are accordingly thus made in the present case; the errors in the results are probably unimportant, as those in opposite directions will generally balance each other.

In computing the value of the quantity c, I have used the mean values of the coefficient n, making it variable with the velocity, according to the law established by Hutton.

The results of the calculations, and their comparison with those of the experiments, are exhibited in the following table:

DATE.	POWDER.		Initial velocity of ball by gun pendulum.	CO-ORDINATES OF THE TRAJECTORY.					
				At the wharf target.			At the water level.		
				Abscissæ.	Ordinates.		Abscissæ.	Ordinates.	
	Kind.	Weight.			Experimental.	Computed.		Experimental.	Computed.
1843.		Lbs.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
April 7 & 17th	*a.*	4.	1225	1098	17.00	15.02	1212	22.31	
	"	"	1235	"	13.14	14.75	1350	22.15	
	"	"	1179	"	14.56	16.18	1270	20.61	
	"	"	1233	"	10.96	14.79	1412	20.77	
	Mean	4.	1218	1098	13.92	15.18	1311	21.46	21.63
	a.	5.333	1404	"	11.23	11.45	1437	21.83	
	"	"	1387	"	10.56	11.74	1467	21.67	
	Mean	5.333	1396	1098	10.9	11.60	1452	21.75	21.31
	a.	6.4	1462	"	9.12	10.60	1555	21.64	
	"	"	1484	"	11.06	10.29	1479	21.60	
	"	"	1430	"	6.26	11.08	1640	20.93	
	"	"	1470	"	9.36	10.49	1530	21.09	
	Mean	6.4	1462	1098	8.95	10.62	1551	21.32	22.31
	a.	8.	1579	"	8.40	9.13	1615	21.52	
32-pounder gun.	"	"	1578	"	8.14	9.13	1646	21.48	
	"	"	1580	"	10.66	9.13	1503*	21.25	* Rejected.
	"	"	1552	"	8.51	9.45	1620	21.41	
	Mean	8.	1570	1098	8.35	9.24	1627	21.49	21.46
	a.	10.666	1634	"	8.40	8.10	1665	21.48	20 78
	"	"	1698	"	7.64	7.96	1712	21.44	20.38
	Mean	10.666	1691	1098	8.02	8.03	1689	21.46	20.58
Nov. 1st	A.	4.	1200	"	16.76	15.62	1200	23.95	
	"	"	1212	"	12.58	15.31	1412	23.81	
	"	"	1226	"	15.66	15.04	1315	23.70	
	Mean	4.	1213	1098	15.	15.33	1310	23.81	21.81
	A.	5.333	1414	"	9.41	11.29	1598	23.60	
	"	"	1408	"	13.36	11.39	1387	23.53	
	"	"	1407	"	13.46	11.41	1384	23.43	
	Mean	5.333	1410	1098	12.08	11.36	1456	23.52	20.89

DATE.		POWDER.		Initial velocity of ball by gun pendulum.	CO-ORDINATES OF THE TRAJECTORY.					
					At the wharf target.			At the water level.		
						Ordinates.			Ordinates.	
		Kind.	Weight.		Abscissæ.	Experimental.	Computed.	Abscissæ.	Experimental.	Computed.
			Lbs.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1843. Nov'r 1	32-pounder gun.	A.	8.	1660	1098	9.06	8.26	1597	22.54	
		"	"	1668	"	7.76	8.18	1659	22.48	
		"	"	1627	"	10.31	8.60	1567	22.36	
		Mean	8.	1652	1098	9.04	8.35	1608	22.46	19.11
		A.	10.666	1868	"	7.31	6.58	1752	22.23	
		"	"	1811	"	6.06	7.	1778	22.13	
		"	"	1823	"	6.82	6.91	1723	22.05	
		Mean	10.666	1834	1098	6.73	6.83	1751	22.14	18.94
1844. Feb'y 2	24-pounder gun.	A.	4.	1437	1098	10.56	11.09	1557	23.56	
		"	"	1451	"	15.56	10.88	1336	23.47	
		"	"	1475	"	9.06	10.53	1685	23.40	
		Mean	4.	1454	1098	11.73	10.83	1526	23.47	22.30
		A.	6.	1712	"	7.71	7.91	1790	23.30	
		"	"	1742	"	8.01	7.64	Lost	23.24	
		"	"	1740	"	8.36	7.66	1845	23.17	
		Mean	6.	1731	1098	8.03	7.74	1818	23.24	23.64
		A.	8.	1902	"	5.61	6.44	2060	23.10	
		"	"	1864	"	8.21	6.71	Lost	23.03	
		"	"	1868	"	6.66	6.68	1964	22.96	
		Mean	8.	1885	1098	6.83	6.61	2012	23.03	25.10
May 29		W.	6.	–	1004	3.32		Angle φ, computed by Lombard's method, $= 5' 53''$.		
		"	"	–	"	5.52				
		"	"	–	"	5.07	5.85			
		"	"	–	"	4.62				
		"	"	–	"	4.37				
		"	"	–	"	6.92	7.25	$\varphi = 0$.		
		Mean	6.	1620	1004	4.97	7.25			

The close agreement here found between the results of calculation and those of experiment must be regarded as a confirmation of Hutton's conclusions respecting the law of resistance of the air to balls moving with great velocities; or, at least, it shows that this law is applicable to practice within the limits of elevation and distance in which the above form of the equation of the trajectory can be applied, including most of the cases of ricochet firing.

The greater disparity between the experimental and computed ordinates of the trajectory, in the practice with the powder W, in the 24-pounder gun, may be attributed to a want of precision in leveling the bore of the gun, which, in that case, was mounted on a barbette carriage. It will be seen that a much nearer coincidence in the results is produced by making the correction for the term x tang. ϕ, computing the angle of departure by Lombard's method. A similar coincidence of the experimental and theoretic ordinates is found in the last round of these experiments, where the ball passed (as will be seen in the Journal) through the centre of the target, at 50 feet from the gun; thus showing that it must have left the piece very nearly in a horizontal direction.

VI. SUMMARY OF THE EXPERIMENTS WITH THE MUSKET PENDULUM.

DATE.	No. of rounds.	POWDER. Kind.	POWDER. Weight.	BALL. Windage.	BALL. Weight.	BALL. Initial velocity.	Relative force of powder.	Moment of the musket pendulum.	REMARKS.
1844.			Grs.		Grs.	Feet			
June 6	5	A.	120.	0.05	397.5	1260	679	110.11	Usual weight of wad 11 grs.
" 7	5	A. 1	"	"	"	1256	677	110.55	
" "	5	A. 3	"	"	"	1336	720	116.86	
May 27 to June 1	10	A. 4	154.33	"	"	1758	–	153.80	
May 24	5	"	140.	"	"	1585	–	141.20	
June 5	5	"	120.	"	"	1499	808	124.64	
July 5	5	"	120.	0.037	416.45	1554	–	132.29	Wad 11.6 grs.
" 17	5	"	110.	0.04	411.5	1508	–	123.95	Do. 13.25 grs.
" "	5	"	110.	0.05	397.5	1437	–	117.88	
" "	5	"	100.	0.04	411.5	1429	–	115.50	Ditto.
" 9	5	"	100.	0.05	397.5	1368	–	109.50	
" 5 & 8	10	A. 5	120.	"	"	1684	907	134.84	
" 5	5	"	"	0.037	416.46	1758	–	142.09	
June 10	5	A. 0	"	0.05	397.5	1348	726	116.34	
" 6	"	B.	"	"	"	1376	741	117.58	
" 7	"	B. 1	"	"	"	1269	684	111.35	
" 10	"	B. 3	"	"	"	1443	778	122.77	
" 6	"	C.	"	"	"	1394	751	118.47	
" 7	"	C. 1	"	"	"	1279	689	111.19	
" 10	"	C. 3	"	"	"	1463	788	123.77	
" 12	"	C. 5	"	"	"	1522	820	125.83	
" "	"	C. 6	"	"	"	1648	888	133.49	
" 6	"	D.	"	"	"	1229	662	108.56	
" 7	"	D. 1	"	"	"	1187	640	106.09	
" 10	"	D. 3	"	"	"	1373	740	119.06	
" 7	"	E. 1	"	"	"	1098	592	100.15	
" 10	"	E. 3	"	"	"	1187	640	106.94	
" 7	"	E. 5	"	"	"	1351	728	117.37	
" 6	"	F.	"	"	"	1463	788	123.03	
" 7	"	F. 1	"	"	"	1404	756	120.03	
" 10	"	F. 2	"	"	"	1426	768	122.60	
" "	"	F. 0	"	"	"	1373	740	117.56	

Experiments with the musket pendulum.—Continued.

DATE.		No. of rounds.	POWDER.		BALL.			Relative force of powder.	Moment of the musket pendulum.	REMARKS.
			Kind.	Weight.	Windage.	Weight.	Initial velocity.			
1844.				Grs.	In.	Grs.	Feet			
June	7	5	G. 1	120	0.05	397.5	1270	684	108.23	
"	5	4	G. 6	"	"	"	1856	1000	145.37	
May 24 to June 1		10	"	77.17	"	"	1308	–	99.91	
June	10	5	H	120	"	"	1318	710	115.20	
"	11	"	K. 1. r	"	"	"	1265	682	111.89	
"	"	"	K. 1. g	"	"	"	1207	650	108.92	
"	"	"	L. 1	"	"	"	1229	662	109.22	
"	"	"	M. 1	"	"	"	1287	693	113.65	
"	"	"	N	"	"	"	1425	768	122.12	
"	"	"	R. 15′	"	"	"	1376	741	118.63	
"	"	"	R. 30′	"	"	"	1471	793	124.88	
"	"	"	R. 60′	"	"	"	1434	772	123.14	
"	"	"	R. 90′	"	"	"	1387	747	119.25	
"	12	"	English. Cannon	"	"	"	1357	731	116.02	
"	"	"	English. Musket	"	"	"	1561	841	129.82	
"	"	"	English. Rifle	"	"	"	1606	865	132.73	
"	"	4	English. Sporting	"	"	"	1818	980	144.61	
"	"	5	French. Cannon	"	"	"	1550	835	126.27	
"	"	"	French. Musket	"	"	"	1478	796	122.94	
May	27	2	French. "	154.33	"	"	1673	–	149.92	
June	12	5	French. Sporting	120	"	"	1735	935	138.00	
"	"	"	Swedish musket	"	"	"	1377	742	117.30	
"	"	"	Old cartridges	"	"	"	1332	718	114.24	
Dec'r	10	"	X. p. 4	"	"	"	1548	834	126.79	
"	"	"	"	"	"	"	1371	–	119.76	Ball next to powder.
"	"	"	X. p. 5	"	"	"	1750	943	137.79	
"	12	"	X. p. 4	110	"	"	1432	–	117.30	
"	"	"	"	100	"	"	1316	–	106.47	
"	"	"	"	120	0.04	410.2	1507	–	126.79	
"	"	"	"	110	"	"	1430	–	119.20	
"	"	"	"	100	"	"	1324	–	109.70	

REMARKS.

1. *Influence of the density and size of grain on the force of powder for small arms.*

From the foregoing table, we find that in the musket, as in other arms in which small charges are used, the highest velocities are produced, generally, by powder of low density, if the grains be large, and by the finest grain of dense powders. The influence of the size of grain on the force of dense powder is strikingly shown by a comparison of the velocities given by powders A. 1 and A. 4, G. 1 and G. 6, which differ in scarcely any thing but the size of grain. On the other hand, by comparing the velocities given by the different sizes of grain of powder F, we see that very little effect on its force is produced by variations in the size of grain, if the powder is of low density. It is remarkable indeed that, in this case, the large grain may give the ball a greater velocity than the small grain; thus the French cannon powder, (which resembles the sample F,) gives a greater velocity than the musket powder, which differs from it only in the size of grain; and the same circumstance is remarked in the proof of these samples by the musket pendulum in France, as inscribed on the original packages.

The influence of the density of grain on the force of powder, in the musket charge, is strikingly exemplified by comparing the several samples of powder R, from which it appears that the advantage of the more thorough incorporation, produced by additional working, is more than counterbalanced, in large grained powder, by the increase of density, which diminishes the quickness of burning.

Although our best musket and rifle powders, A. 4 and A. 5, leave little to desire in point of strength, the proper proportion between the density and size of grain, in the musket powder at least, appears to be better observed in the English powders, which are finer grained than ours. There will be an advantage, independently of the increase of force, in reducing the size of grain of musket powder for use in percussion arms, as that will cause the powder to enter more readily into the cone, and thus increase the certainty of ignition.

In accordance with this view, the powders X. p. 4 and X. p. 5 were prepared; but having been made of the dust of cannon powder re-worked, and again pressed, the density of the powder is rather too great for the musket grain, which was also in this case too much equalized in size to produce the greatest effect.

2. *Effect of wads in small arms.*

We have before seen that no appreciable increase in the inherent force of the charge in a heavy gun is produced by the use of wads; but the numerous experiments on the different modes of wadding the musket, show that, in small arms, the wad has a very great influence on the development of the force of the charge. By increasing the resistance to the motion of the ball, the wad causes the perfect combustion of the powder to take place in a smaller compass than it would otherwise do, and the intensity of the force is thus increased in a greater ratio than the resistance.

It is satisfactory to find that the most advantageous wad is the paper of the musket cartridge, as it is used in ordinary service.

The effect of increasing the resistance to the motion of the ball, and diminishing the space occupied by the charge, is shown by the experiment on the 13th December, where, by repeated ramming, the height of the charge in the barrel was reduced from about 1.9 in. to 1.6 in., and the velocity increased more than 100 feet, or $\frac{1}{15}$th part.

3. *Influence of a diminution of windage.*

This subject is akin to the preceding, as the effect of the wad is no doubt due, in a great measure, to its tendency to reduce the windage and lessen the escape of the inflamed fluid.

The influence of this cause is, however, more clearly exemplified by comparing the velocities impressed, by different charges of powder A. 4, on balls of different windage. From this it appears that a reduction of 0.01 in. in the windage is nearly equivalent in effect to an increase of 10 grs. in the charge, notwithstanding the increased weight of the larger ball. That this result was not obtained in the experiments with the powder X. p. 4 is attributable to the fact that, in this case, the balls although stated to be of 0.04 in. windage, were sensibly smaller than those of a similar kind used with the powder A. 4.; so that the difference of windage was only sufficient to compensate for the difference of weight, by giving to the heavier ball nearly the same velocity as to the lighter. But the influence of the diminution of windage, on the force of a charge of this powder, appears by comparing the velocities obtained in the experiments of December 13th and 19th, 1844, with the same charge of powder and ball, in muskets of different sized bores, as exhibited in the table under the succeeding head.

4. *Effect of using percussion primers.*

The following is a summary of the comparative experiments made by firing a musket, alternately, with quick match and with percussion primers :

DATE.	No. of rounds.	POWDER.		BALL.		INITIAL VELOCITY.		REMARKS.
		Kind.	Weight.	Windage.	Weight.	With match.	With percussion.	
1844.			Grs.	In.	Grs.	Feet.	Feet.	
June 5	5	A. 4	120	0.05	397.5	1470	1484	*Mean of 4 rounds. Caps not varnished.
Dec. 13	5	X. p.4	110	0.04	410.2	1474*	1519	
" 19	5	"	"	0.046	"	1407	1425	
	Mean	–	–	–	–	1450	1476	
June 5	5	G. 6	120	0.05	397.5	1864	1888	

These experiments appear to me sufficient to show that, although the increase of force by the use of the percussion primer, which nearly closes the vent, is constant and appreciable in amount, yet it is not of sufficient value to authorize a reduction of the charge on this account alone. They are, therefore, far from confirming the conclusions drawn by Mr. Lovell, of the Royal Manufactory of arms at Enfield, England, from his experiments, as stated in Ure's Dictionary, (art. Fulminate,) viz: that 8.84 parts of gunpowder fired with percussion are equal to 10 parts fired with flint.

I am not acquainted with the construction of the "recoiling target" used by Mr. Lovell, nor with the other details of his experiments; but we have seen, in the present course of experiments, that great irregularities may be produced in the force of the musket charge by slight variations in the windage of the ball, or in the manner of loading and ramming the charge, and that great care is, therefore, requisite to confine these variations within narrow limits, in order to estimate accurately the change which is due to any other special cause of variation.

5. *Of the proper charge for the percussion musket.*

The cartridge for the flint musket contains 130 grains weight of powder, from which, deducting about 10 grs. for priming, we have 120 grs. for the charge which is put into the musket. This charge has always been considered ample in service, and when composed of the best powder, it is quite as much as can be used with comfort to the soldier, in firing the present ball of 18 to the pound.

The sufficiency of this charge may also be deduced, by analogy, from that of the French flint lock musket, which is the model of ours. When the charge was established at the present standard of 146.5 grs., it was found, by numerous experiments, that the effect of this charge, with the ball of 18 to the pound, was equal to that of the former charge of 189 grs., with the old powder, and the ball of 19 to the pound; and this latter charge, having been used in all the wars of the Revolution, was thought to have been proved sufficient, by long experience. Now, by the experiments with powders from a large number of the French powder works, which led to the adoption of the present standard of proof by means of the musket pendulum, it was found that the mean velocity of the ball, with a charge of 154 grs., (10 grammes,) was 1477 feet, which was therefore adopted as the minimum velocity for the proof of musket powder. The proportional velocity with a charge of 146.5 grs., would be 1440 ft., considerably below that of 1500 ft., which we have obtained for the same ball, with the charge of 120 grs. of the powder A. 4. It may be remarked, here, that some of the French musket powder, although made in the pounding mill, is of not very inferior force to this powder A. 4, as will be seen by the experiments with the sample of powder made at Bouchet, which gives a velocity of 1478 ft. with a charge of 120 grs., and would therefore give about 1630 ft. with the charge of 146.5 grs. But we see that, by reducing the size of grain of our musket powder and making it conform more nearly to the English powder, we may obtain, with a charge of 120 grs., a force nearly equal to that of this Bouchet powder, with a charge of 146.5 grs. We may, therefore, regard this charge of 120 grs. as sufficient for the musket, with a ball of 18 to the pound, having 0.05 in. windage.

But we find, from the table of experiments, that by reducing the windage of the ball to 0.04 in., and increasing its weight to $\frac{1}{17}$th of a pound, we may obtain, with the percussion musket, as great a velocity for this heavier ball with a charge of 110 grs., as for the smaller and lighter ball with 120 grs., and this without any increase of the force of recoil. Having satisfied myself, by the trials mentioned in the Journal, that this increase in the diameter of the ball will not impede the service of the arm, if the balls are smooth, I propose that the changes above indicated, in the kind of powder, the charge and the size of the ball, should be adopted in service, and that in order to ensure the uniformity and smoothness of the balls, they should be made by compression, as is now practised in the British service, and in some others.

In this manner we may obtain, with the charge of 110 grs., in the percussion musket, an initial velocity of about 1550 ft., which is greater than requisite for a musket ball, and leaves sufficient room to allow for deterioration of the powder, or for accidental loss of a small portion in loading, &c., as well as for variations of windage, consequent on the differences permitted in the bores of muskets.

As a further evidence of the sufficiency of this charge, we may compare the experiments on the range of the musket, (or the ordinates of the trajectory, at different distances from the muzzle,) with those made in France, with the same ball of 17 to 1 lb., and the old charge of 189 grs., as stated in the Aide Mémoire d'Artillerie:

FRENCH POWDER; Charge 189 grs.		POWDER X. p. 4; Charge 110 grs.	
Abscissa.	Ordinate.	Abscissa.	Ordinate.
Yds.	In.	Yds.	In.
76.6	6.38	80	7.7
120.3	17.	120	23.
153.	28.83	150	32.

According to the same authority, an elevation of 33 min. is required for a range of 219 yds. with the charge of 146.5 grs. and the ball of $\frac{1}{18}$th lb.; and I find nearly the same result with the ball of $\frac{1}{17}$th lb. and the charge of 110 grs., viz: that an elevation of about 36 min. is required for a range of 200 yds. The range of 500 yds. requires, with this charge, an elevation of less than $3\frac{1}{2}°$, and at that distance the ball retains sufficient force to pass through a pine board 1 in. thick, showing that it would inflict a serious wound at a still greater distance.

I may add, also, that the charge for the British percussion musket is reduced to $4\frac{1}{2}$ drachms, or 123 grs., whilst the ball is $14\frac{1}{2}$ to the pound, or 480 grs. This charge is therefore smaller, in proportion to the weight of the ball, than that here proposed, in the ratio of 3.73 to 3.93.

By the new edition of the Aide Mémorie d'Artillerie, I find that a change similar to that which I propose has been adopted in establishing the charge of powder and ball for the new percussion musket in the French service. The windage of the ball has been reduced to 0.04 in.; and although the bore of the musket is enlarged, so as to receive a ball of $\frac{1}{15}$th lb., or

467 grs., the charge is reduced to 123.5 grs. This charge bears almost exactly the same proportion to the weight of the ball as that which I propose; but the use of pounding mill powder is continued for the military service in France, notwithstanding its inferior force in most cases.

6. *Comparison of the force of the charge in various arms.*

SUMMARY OF THE EXPERIMENTS MADE WITH DIFFERENT SMALL ARMS, OF RIFLE CALIBRE.

DATE.	No. of rounds.	Kind of arm.	Kind of lock.	POWDER.		BALL'S		
				Kind.	Weight.	Windage.	Weight.	Velocity.
1844.					Grs.	In.	Grs.	Feet.
July 8	4	Common rifle	Percussion.	A. 5	100	0.015	219.	2018
Dec. 19	5	Do	Do.	X. p. 5	80	"	220.3	1826
July 8	"	Do	Do.	A. 5	70	"	219.	1755
	"	Hall's rifle*	Flint.	"	"	0.0	"	1490
	"	Hall's carbine*	Percussion.	"	"	"	"	1240
	"	Jenks' carbine*	Do.	"	"	"	"	1687
	"	Cadet's musket	Flint.	"	"	0.045	"	1690
Dec. 13	"	Pistol	Percussion.	"	35	0.015	218.5	947

* Loading at the breech.

For the description of these arms, and for other particulars of the experiments, reference is made to the Journal.

The great accession of force obtained by *slugging* the ball is shown by the experiment with Jenks's carbine, in which nearly the whole force of the charge is exerted on the ball, giving it a velocity equal to that of the ball from the Cadet's musket, notwithstanding the great difference in the length of bore of the two arms.

In Hall's arms, the loss of force, by the opening between the chamber and the barrel, is more than sufficient to neutralize the advantage of destroying the windage of the ball; so that a given charge impresses on the ball from Hall's rifle, a much smaller velocity than from the common rifle loaded with a patched ball.

The force of the charge of 35 grs. in the pistol, is greater than necessary for that arm, and the experiments made on the 19th Dec'r, 1844, show, that with 30 grains of good powder, the pistol ball is propelled with sufficient velocity to inflict a severe wound even at more than 80 yards; but as this charge can be fired without inconvenience to the hand, I should not propose less than 30 grs. as the charge for the pistol.

Numerous experiments on ranges, made at Washington Arsenal, have shown, that with good powder, the charge of 70 grs. is sufficient for the percussion rifle, even at the distance of 300 to 350 yards, and we might draw the same inference from the velocity which this charge communicates to the ball; but as the charge of 75 grs. can be fired with perfect ease, and without *stripping* the ball, it would be perhaps safer to adopt that charge, in order to provide for accidental loss, deterioration of powder, &c. This charge is considerably greater, in proportion to the weight of the ball, than those lately adopted for the English and French service rifles; but it is properly so, because the ball of our rifle, being of less than half the weight of either of those, will be more affected by the resistance of the air, and should, therefore, have a greater initial velocity.

In order that Hall's rifle may be effective at long distances, its charge should hardly be less than 100 grs., and the chamber of the rifle ought to be enlarged, to admit that charge, if the arm should be again put in service.

VII.—TRIAL OF VARIOUS KINDS OF GUNPOWDER WITH AN 8-INCH GOMER MORTAR.

Charge of powder 12 *oz.*; *weight of ball* 48 *lbs.*

Kind of powder.	Range of ball.	Time of flight.	Relative force.	Kind of powder.	Range of ball.	Time of flight.	Relative force.
	Yards.	Seconds.			Yards.	Seconds.	
A. 1	421	9.75	789	F. 1	695	12.53	1013
A. 3	355	8.71	724	F. 2	722	12.93	1033
A. 0	540	11.02	893	F. 0	525	10.50	881
B. 1	536	11.02	890	G. 1	587	11.57	931
B. 3	577	11.40	923	G. 6	677	12.27	1000
				H.	583	11.42	927
C. 1	518	10.72	875	K. 1. r.	488	10.40	849
C. 3	597	11.75	939	K. 1. g.	443	9.92	809
D. 1	458	10.07	823	L. 1	451	10.07	816
D. 3	587	11.57	931	M. 1	497	10.77	857
				N.	543	10.97	896
E. 1	455	10.18	820	R. 15′	558	11.08	908
E. 5	225	7.05	577	R. 90′	580	11.35	925

The ranges and relative force of powders tried by this mortar, with the above mentioned charge, follow nearly the order of the quickness of inflammation of the several kinds of powder, and the inverse order of their densities, whatever may be the mode of manufacture, or the degree of incorporation of the components of the powder; thus showing, that the qualities required for developing the greatest force of powder, in very short pieces of ordnance, are materially different from those requisite for the same purpose in long guns. But the high rank occupied in this respect by the powder H, in practice both with the gun and with the mortar, proves that it is not impossible to combine these qualities in such a manner as to produce gunpowder which shall be well adapted for the service of long guns, and still possess a considerable force in the mortar.

VIII. PROOF OF VARIOUS KINDS OF GUNPOWDER WITH THE UNITED STATES MORTAR EPROUVETTE.

Charge of powder 1 *oz.—Ball* 24 *lbs.*

Kind of powder.	Range.	Relative force.	Kind of powder.	Range.	Relative force.
	Yards.			Yards.	
A.	290	958	F. 1	304	981
A. 1	277	936	F. 2	312	994
A. 2	294	965	F. 0	296	968
A. 3	312	994	G. 1	260	907
A. 4	316	1000	G. 6	316	1000
A. 0	293	963	H.	290	958
B.	303	979	K. l. r.	288	955
B. 1	292	961	K. l. g.	276	935
B. 2	297	970	L. 1	242	875
B. 3	312	994	M. 1	281	943
C.	274	931	N.	300	974
C. 1	240	872	R. 15′	309	989
C. 2	278	938	R. 30′	317	1002
C. 3	296	968	R. 60′	314	997
C. 5	313	995	R. 90′	300	974
D.	268	921	S.	300	974
D. 1	261	909	T.	56	421
D. 2	289	956	English. Cannon.	267	919
D. 3	303	979	English. Musket.	327	1017
E.	212	819	English. Rifle.	319	1005
E. 1	194	784	French. Cannon.	311	992
E. 2	201	798	French. Musket.	308	987
E. 3	221	836	French. Sporting.	323	1011
E. 5	237	866	Swedish musket.	273	930
F.	300	974	From old cartridges.	287	953

IX. PROOF OF VARIOUS KINDS OF GUNPOWDER WITH THE FRENCH MORTAR EPROUVETTE.

Charge of powder 1420 *grs. Troy, or* $3\frac{1}{4}$ *oz. nearly.*
Weight of ball $64\frac{1}{2}$ *lbs.*

Kind of powder.	Range.	Relative force.	Kind of powder.	Range.	Relative force.
	Yards.			Yards.	
A.	222	933	E. 5	238	966
A. 1	237	953	F.	268	1025
A. 2	240	970	F. 1	264	1018
A. 3	268	1025	F. 2	257	1004
A. 4	266	1021	F. 0	259	1008
A. 0	256	1002	G. 1	216	920
B.	255	1000	G. 6	255	1000
B. 1	240	970	H.	236	962
B. 2	252	994	K. 1. r.	240	970
B. 3	265	1019	K. 1. g.	214	916
C.	228	946	L. 1	213	914
C. 1	192	868	M. 1	231	952
C. 2	238	966	N.	239	968
C. 3	264	1018	R. 15′	260	1010
D.	233	956	R. 90′	237	953
D. 1	234	958	S.	243	976
D. 2	262	1014	T.	59	481
D. 3	260	1010	English. Cannon	227	944
E.	173	824	English. Musket	270	1029
E. 1	163	800	English. Rifle	263	1016
E. 2	171	819	French Cannon	267	1023
E. 3	200	886	French Musket	258	1006

X. PROOF OF VARIOUS KINDS OF GUNPOWDER WITH THE ENGLISH HALF-POUNDER PENDULUM EPROUVETTE.

Charge 2 oz. of powder, without ball or wad.

Kind of powder.	Vibration of eprouvette.	Relative force.	Kind of powder.	Vibration of eprouvette.	Relative force.
	Degrees.			Degrees.	
A.	19.	691	F. 1	22.04	808
A. 1	18.25	669	F. 2	23.78	872
A. 2	19.20	612	F. 0	17.07	626
A. 3	21.05	772	G. 1	20.87	765
A. 4	22.	807	G. 6	27.27	1000
A. 0	14.5	532	H.	22.13	811
B.	21.52	789	K. 1. r.	18.75	687
B. 1	19.75	724	K. 1. g.	19.23	705
B. 2	20.60	755	L. 1	19.05	699
B. 3	22.67	831	M. 1	20.23	742
C.	21.17	776	N.	20.02	734
C. 1	18.37	674	R. 15′	20.30	744
C. 2	19.88	729	R. 30′	20.57	754
C. 3	22.27	817	R. 60′	21.	770
C. 5	22.23	816	R. 90′	20.33	745
D.	20.49	751	S.	19.82	726
D. 1	18.83	690	T.	11.47	421
D. 2	21.20	777	English. Cannon	21.97	806
D. 3	22.77	835	English. Musket	26.03	955
E.	20.83	764	English. Rifle	27.93	1024
E. 1	20.09	737	French. Cannon	23.13	848
E. 2	20.72	760	French. Musket	24.67	904
E. 3	21.68	795	French. Sporting	26.35	966
E. 5	21.85	801	Swedish musket	22.75	831
F.	22.83	837	Old cartridges	21.18	776

Remarks on the proof of powder by the eprouvettes.

By comparing the results of the proofs by the eprouvettes with those furnished by the cannon pendulum, it will appear that the eprouvettes are entirely useless as instruments for testing the relative projectile force of different kinds of powder, when employed in large charges in a cannon. Powders of little density or of fine grain, which burn most rapidly, give the highest proof with the eprouvettes, whilst the reverse is nearly true with the cannon. Thus all the eprouvettes concur in assigning the first rank among the cannon powders to the powder F, which is the lowest on the scale by the cannon; whilst the powder A, which is the strongest in the gun, is one of the weakest by the eprouvettes. Nor do these instruments assign any superiority to powder, which is well incorporated, over powder of the same kind, in other respects, which has been very imperfectly worked; on the contrary, they all give results with the powder incorporated by 15 minutes work under the rollers, equal or superior to those furnished by the same powder worked 90 minutes.

The only real use of these eprouvettes is to check and verify the uniformity of a current manufacture of powder, where a certain course of operations is intended to be regularly pursued, and where the strength, tested by means of any instrument, should therefore be uniform; but as a means of proving gunpowder received, as it is in our service, from manufactories pursuing entirely different processes, these eprouvettes may be pronounced worse than useless, since they may lead to erroneous results. By the French mortar eprouvette, scarcely any of the powders which we have found to be the strongest in the cannon, could be received as having given the required proof range of 246 yards.

The results by these eprouvettes correspond generally with those given by the 8 in. mortar, with a charge of 12 oz., by the 1-pounder gun pendulum, and by the musket pendulum, in which, as in all cases where small quantities of powder are used, rapidity of inflammation is the most influential element of strength.

Comparison of the observed time of flight of a ball from a mortar, with the time computed by regarding the trajectory as a parabola.

Kind of mortar.	No. of rounds.	Mean range.	Initial velocity.	TIME OF FLIGHT. Observed.		TIME OF FLIGHT. Computed.	
		Yards.	Feet.	Sec.	Thirds.	Sec.	Thirds.
8-inch - -	36	561	233	11	06	10	24
Do. - -	15	446	207	10		9	07
U. S. eprouvette -	18	306	172	8	14	7	33
French do. -	18	238	152	7	14	6	40
U. S. do. -	1	56	74	3	17	3	14
French do. -	2	49	69	3	14	3	01

In estimating the relative force of the powders, as indicated by these mortars, the trajectory is regarded as a parabola, and the velocity is, therefore, supposed to be proportional to the square root of the range.

XI. EXPERIMENTS WITH THE 1-POUNDER GUN PENDULUM.

Having ascertained that there is no correspondence between the indications of the force of cannon powder, which are furnished by the gun itself, and those given by the eprouvettes in common use, and also that no accurate indication of the relative force of different kinds of powder can be expected from the use of blank charges, even with large quantities of powder, I determined to try whether such an indication would be furnished by firing with balls from a gun of so small a calibre that its use would be attended with little difficulty or expense, and that the apparatus might even be susceptible of removal, if necessary, from place to place. For this purpose, I constructed a pendulum apparatus for a 1-pounder gun, to be fired with balls, with a charge of $\frac{1}{4}$ lb.; the velocity of the ball to be computed from the recoil of the gun pendulum alone, in order to dispense with the costly and slow process of using the ballistic pendulum.

The results of the experiments with this pendulum are exhibited in the following table :

Summary of experiments with 1-*pounder gun pendulum. Charge of powder* $\frac{1}{4}$ *lb.; windage of ball* 0.0475 *in.*

Kind of powder.	Initial velocity of ball.	Relative force of powder.	Kind of powder.	Initial velocity of ball.	Relative force of powder.
	Feet.			Feet.	
A.	1407	843	F.	1490	890
A. 1	1370	821	F. 1	1459	875
A. 3	1467	880	F. 0	1476	885
A. 0	1463	877	G. 1	1406	843
A. 4	1574	944	G. 6	1668	1000
B.	1446	866			
B. 1	1381	828	K. l. r.	1392	835
B. 3	1481	888	K. l. g.	1366	819
C.	1452	870	R. 15′	1460	875
D.	1376	825	R. 90′	1502	900
E.	1161	692	X. p.	1489	893
E. 1	1110	665	X. p. 4.	1534	919
E. 3	1263	757	X. p. 5.	1635	980
E. 5	1429	857			

From these results, it appears that the indications given by the 1-pounder gun, with respect to the relative force of different kinds of powder, conform much more nearly to those of the eprouvettes and the musket, in which small charges are used, than to those of the cannon with large charges. Thus, again, the powder F, which is among the weakest of the cannon powders in the 24-pounder gun, occupies nearly the highest rank in the 1-pounder gun; and the powder A, which is the strongest of all the cannon powders in the former gun, stands almost at the foot of the list in point of strength when tried by the latter; a similar remark may be made with respect to the powders D and K. In short, it appears that low density and fineness of grain, which are the qualities most favorable to the quickness of powder, exercise, in general, the greatest influence on the force of small charges; whilst in large charges, (unless the powder is *excessively* dense, as the sample E,) the slower development of force, which would be caused by the less rapid combustion of the coarse grains of dense powder, seems to be more than compensated by the greater intensity of the flame produced by such powder. So that, in the combustion of large charges, the whole force of the powder is actually developed in a smaller compass, and therefore with greater effect, when the powder is dense.

This remark may be illustrated by a comparison of the initial velocities of balls fired with similar charges from a large and a small gun, of nearly the same relative length of bore. Thus, with a charge of $\frac{1}{4}$th the weight of the ball, we have:

With powder A.

In the 24-pounder gun, a velocity of	- -	1702 feet.
In the 1-pounder gun	- - - -	1407 "
Difference	-	295

With powder F.

In the 24-pounder gun, a velocity of	- -	1552 feet.
In the 1-pounder gun	- - - -	1470 "
Difference	-	82

XII. GENERAL VIEW OF THE RESULTS OF THE EXPERIMENTS.

The following tabular statement exhibits a comprehensive general view of the principal results of the comparative trials of the different kinds of powder which have been subjected to these experiments:

(*See next page.*)

No.	Designation.	Kind of grain.	COMPOSITION Saltpetre.	Charcoal.	Sulphur.	Kind of coal.	Mode of incorporation, &c.	Glazing.
1	*a.*	Cannon	76	14	10	Cylinder;	3 hrs. dust barrel, & 1 hour	Glazed
2	A.	"	"	"	"	brown.	heavy rollers; not pres'd.	"
3	A. 1	"	"	"	"	"	" "	"
4	A. 2	"	"	"	"	"	" "	"
5	A. 3	"	"	"	"	"	" "	"
6	A. 4	Musket	"	"	"	"	" "	"
7	A. 5	Rifle	"	"	"	"	" "	"
8	A. 0	Coarse	"	"	"	"	" "	"
9	A. m.	Mealed	"	"	"	"	" "	–
10	B.	Cannon	76	13.7	10.3	Cylinder;	Dust barrels and light	Glazed
11	B. 1	"	"	"	"	black.	rollers; pressed.	
12	B. 2	"	"	"	"	"	" "	"
13	B. 3	"	"	"	"	"	" "	"
14	C.	"	76	15	9	Cylinder;	Heavy rollers; part of	"
15	C. 1	"	"	"	"	brownish	cake pressed; saltpe-	"
16	C. 2	"	"	"	"	black.	tre not pure.	"
17	C. 3	"	"	"	"	"	" "	"
18	C. 5	Rifle	"	"	"	"	" "	"
19	C. 6	Sporting	"	"	"	"	" "	"
20	D.	Cannon	75	15	10	Cylinder;	Dust barrels; pressed;	"
21	D. 1	"	"	"	"	jet black.	saltpetre not pure.	"
22	D. 2	"	"	"	"	"	" "	"
23	D. 3	"	"	"	"	"	" "	"
24	E.	"	76	14	10	Cylinder;	Dust barrels; heavy rol-	"
25	E. 1	"	"	"	"	brown.	lers, and pounding mill;	"
26	E. 2	"	"	"	"	"	pressed very hard.	"
27	E. 3	"	"	"	"	"	" "	"
28	E. 5	Rifle	"	"	"	"	" "	"
29	F.	Cannon	75	12.5	12.5	"	14 hrs. pounding mill;	Rough
30	F. 1	"	"	"	"	"	not pressed.	"
31	F. 2	"	"	"	"	"	" "	"
32	F. 0	Coarse	"	"	"	"	" "	"

Weight of 1 cubic foot.	Number of grains of powder in 10 grs. troy.	Relative quickness of burning.	Water absorbed (per ct.) by exposure to air.	Velocity of 24-pdr. ball. Charge 6 lbs.	RELATIVE FORCE, COMPARED WITH THAT OF POWDER G. 6 DENOTED BY 1000. 24-pdr. Gun. With shot	With blank cartridges.	Musket pendulum.	1-pdr. pendulum eprouvette.	8-inch mortar.	U. S. mortar eprouvette.	French mortar eprouvette.	English pendulum eprouvette.	No.
Oz.				Feet									
911	–	–	–	1598	901	–	–	–	–	–	–	–	1
929	141	275	3.64	1702	959	–	679	847	–	958	933	691	2
916	77	275	2.77	1710	964	–	677	821	789	936	953	669	3
914	151	270	2.87	–	–	996	–	–	–	965	970	612	4
927	569	314	3.35	1659	935	–	720	880	724	994	1025	772	5
896	1134	214	–	–	–	–	808	944	–	1000	1021	807	6
–	6174	142	–	–	–	–	907	–	–	–	–	–	7
821	7.4	169	–	1691	953	–	726	877	893	963	1002	532	8
–	–	–	–	1235	696	–	–	–	–	–	–	–	9
906	426	219	2.82	1627	917	948	741	870	–	979	1000	789	10
882	105	193	2.15	1653	932	–	684	828	890	961	970	724	11
879	191	216	2.69	–	–	–	–	–	–	970	994	755	12
904	769	212	2.75	1636	922	–	778	888	923	994	1019	831	13
944	291	178	6.58	1653	932	954	751	870	–	931	946	776	14
915	113	180	6.27	1654	932	–	689	–	875	872	868	674	15
896	192	185	6.67	–	–	–	–	–	–	938	966	729	16
940	1420	193	6.66	1636	922	–	788	–	939	968	1018	817	17
934	2378	204	–	–	–	–	820	–	–	995	–	816	18
–	–	–	–	–	–	–	888	–	–	–	–	–	19
968	205	169	5.23	1670	941	921	662	827	–	921	956	751	20
932	89	179	4.73	1701	959	–	640	–	823	909	958	690	21
922	166	178	5.46	–	–	–	–	–	–	956	1014	777	22
933	809	173	5.18	1648	929	–	740	–	931	979	1010	835	23
957	152	–	2.47	–	–	916	–	692	–	819	824	764	24
937	111	205	2.58	1539	868	–	592	665	820	784	800	737	25
948	163	209	3.61	1568	884	–	–	–	–	798	819	760	26
996	275	203	2.37	1612	909	–	640	757	–	836	886	795	27
1044	5344	282	3.55	1668	940	961	728	857	577	866	966	801	28
780	166	183	2.09	–	–	–	788	890	–	974	1025	837	29
775	103	182	1.91	1552	875	921	756	875	1013	981	1018	808	30
751	163	186	2.95	1527	861	–	768	–	1033	994	1004	872	31
762	11	200	–	1504	848	–	740	885	881	968	1008	626	32

No.	Designation.	Kind of grain.	COMPOSITION Saltpetre.	Charcoal.	Sulphur.	Kind of coal.	Mode of incorporation, &c.	Glazing.
33	G. 1	Cannon	77	13	10	Cylinder; reddish brown.	5 hrs. dust barrels and 4 hrs. heavy rollers; not pressed.	Highly glazed.
34	G. 6	Sporting	"	"	"			
35	H.	Cannon	75	15	10	Cylinder.	Heavy rollers; pressed.	Glazed
36	K.1.r.	"	75	12.5	12.5	Pit; black.	14 hrs. pounding mill; not pressed.	Rough
37	K.1.g.	"	"	"	"	"		Glazed
38	L. 1	"	"	"	"	"	24 hrs. do. do.	"
39	M. 1	"	76	14	10	"	14 hrs. do. do.	"
40	N.	"	75	12.5	12.5	Cylinder.	Like A. - -	"
41	R. 15′	"	76	14	10	"	15 min. heavy rollers, not pres'd.	"
42	R. 30′	"	"	"	"	"	30 " "	"
43	R. 60′	"	"	"	"	"	60 " "	"
44	R. 90′	"	"	"	"	"	90 " "	"
45	S.	Blasting	70	15	15	"	2 hrs. dust barrels and ¾ hr. heavy rollers.	"
46	T.	"	–	–	–	Kiln.	Crude saltpetre - -	"
47	W.	Cannon	–	–	–	–	Pounding mill; pressed.	"
48	X.	"	76	14	10	Cylinder.	Like A, not pressed; -	"
49	X. p.	"	"	"	"	"	Do. pressed. -	"
50	X.p.4	Musket	"	"	"	"	Dust of X, reworked and pressed.	"
51	X.p.5	Rifle	"	"	"	"		"
52	English	Cannon	75	15	10	"	Heavy rollers; pressed.	"
53	English	Musket	"	"	"	"	" " "	"
54	English	Rifle	"	"	"	"	" " "	"
55	English	Sporting	-	–	–	"	- - -	"
56	French	Cannon	75	12.5	12.5	Pit.	11 hrs. pounding mill; not pressed.	Rough
57	French	Musket	"	"	"	"		"
58	French	Sporting	76	14	10	Cylinder.	Heavy rollers - -	Glazed
59	Swedish	Musket	–	–	–	–	Pressed very hard. -	"
60	Old cartridges	"	–	–	–	–	Pounding mill; not pres'd	Rough

Weight of 1 cubic foot.	Number of grains of powder in 10 grs. troy.	Relative quickness of burning.	Water absorbed (per ct.) by exposure to air.	Velocity of 24-pdr. ball. Charge 6 lbs.	RELATIVE FORCE COMPARED WITH THAT OF POWDER G. 6, DENOTED BY 1000.								No.
					24-pdr. Gun.		Musket pendulum.	1-pdr. pendulum eprouvette.	8-inch mortar.	U. S. mortar eprouvette.	French mortar eprouvette.	English pendulum eprouvette.	
					With shot	With blank cartridges.							
Oz.				Feet									
958	92	162	2.96	1661	936	954	684	843	931	907	920	765	33
1047	72,808	100	4.42	1774	1000	1000	1000	1000	1000	1000	1000	1000	34
874	269	148	–	1628	918	–	710	–	927	958	962	811	35
896	90	170	–	1635	922	–	682	835	849	955	970	687	36
916	91	206	–	1637	923	976	650	819	809	935	916	705	37
954	95	208	–	1649	930	972	662	–	816	875	914	699	38
925	88	214	–	1661	936	–	693	–	857	943	952	742	39
898	172	227	–	1626	917	–	768	–	896	974	968	734	40
793	97	213	–	1535	865	–	741	875	908	989	1010	744	41
842	92	186	–	1537	866	–	793	–	–	1002	–	754	42
844	91	171	–	1554	876	–	772	–	–	997	–	770	43
868	96	198	–	1646	928	–	747	900	825	974	953	745	44
917	295	212	–	1660	936	–	–	–	–	974	976	726	45
914	100	281	–	1340	755	–	–	–	–	421	481	421	46
970	–	–	–	1618	912	–	–	–	–	–	–	–	47
904	125	–	–	1607	906	–	–	–	–	–	–	–	48
930	82	–	–	1653	932	–	–	893	–	–	–	–	49
937	1642	–	–	–	–	–	834	919	–	–	–	–	50
955	13,152	–	–	–	–	–	943	980	–	–	–	–	51
872	174	–	–	–	–	–	731	–	–	919	944	806	52
844	2832	–	–	–	–	–	841	–	–	1017	1029	955	53
820	11,600	–	–	–	–	–	865	–	–	1005	1016	1024	54
–	–	–	–	–	–	–	980	–	–	–	–	–	55
804	316	–	–	–	–	–	835	–	–	992	1023	848	56
830	2410	–	–	–	–	–	796	–	–	987	1006	904	57
–	–	–	–	–	–	–	935	–	–	1011	–	966	58
–	–	–	–	–	–	–	742	–	–	930	–	831	59
–	–	–	–	–	–	–	718	–	–	953	–	776	60

XIII. CONCLUSIONS.

The following are some of the practical conclusions which have been suggested to me by the results of these experiments.

1. *With regard to the proof of gunpowder.*

The only reliable mode of proving the strength of gunpowder is to test it, with service charges, in the arms for which it is designed; for which purpose the ballistic pendulums are perfectly adapted.

Although the present tendency to the use of cannon of very large calibre would make the proof by means of a 32-pounder or 24-pounder gun more satisfactory than by using a piece of smaller calibre, it does not seem to be necessary to resort to those heavy guns for obtaining a correct indication of the relative force of different kinds of powder. We have seen, indeed, that such an indication is not given by a 1-pounder gun; but the experiments at Metz have shown that the 12-pounder gun classes the powders in the same order of strength as the 24-pounder, and further experiments may, perhaps, prove that a long gun of yet smaller calibre, a 9-pounder or a 6-pounder, will give corresponding results. As the use of the large ballistic pendulum is difficult, slow, and expensive, and as the indications furnished by the recoil of the cannon pendulum correspond with those given by the ballistic pendulum, I should propose, for the usual proof of gunpowder, to make use of the cannon pendulum alone; employing a gun of the smallest calibre which will give correct results, and firing the balls into a bank of earth, which would not make them unfit for ordinary service.

An apparatus of this kind would not be costly, and might, therefore, be erected at several of the Arsenals, where powder may be conveniently received for inspection; the 24-pounder pendulum at Washington Arsenal being used occasionally, for verification.

In the 24-pounder gun, new cannon powder should give, with a charge of $\frac{1}{4}$th, an initial velocity of not less than 1600 feet, to a ball of medium weight and windage.

For the proof of powder for small arms, the small ballistic pendulum is a simple, convenient, and accurate instrument. The cost of the apparatus might be very much reduced, without impairing the accuracy of the results, by dispensing, in most cases, with the musket pendulum, which is the most costly part of it, and simply firing the ball into the ballistic pendulum block, from a barrel set in a permanent frame.

The initial velocity of the musket ball, of 0.05 in. windage, with a charge of 120 grains, should be:

With new musket powder, not less than 1500 feet;

With new rifle powder, not less than 1600 feet;

With fine sporting powder, not less than 1800 feet.

The common eprouvettes are of no value as instruments for determining the relative force of different kinds of gunpowder.

2. *Of the hygrometric test of gunpowder.*

Although the projectile force of gunpowder is the most important quality to be attended to in the proof and inspection, its capability of being long preserved without much deterioration, and of resisting the effects of such exposure as it is subject to in service, must be regarded as of little less importance. This quality should, therefore, be tested either by comparing the quantity of moisture absorbed, under similar circumstances, by the powder which may be under trial, and by other powder of approved good quality; or by the application of a simple chemical test of the purity of the saltpetre, as it is on this circumstance chiefly that the capacity of the powder to resist the action of a moderate degree of moisture depends.

3. *Of the proportions of the ingredients of gunpowder.*

The proportions used in making our best powder, 76—14—10, and the English proportions, 75—15—10, appear to be favorable to the strength of powder, and not sensibly disadvantageous in other respects; but the ordinary variations in the proportions of cannon powder are scarcely appreciable by their effects on its force.

4. *Of the mode of manufacture.*

The powder of greatest force, whether for cannon or small arms, is produced by incorporation in the "cylinder mills," under heavy rollers, and this process alone is now considered capable of making sporting powder of the best quality. This is the mode of incorporation which has been practised for more than 50 years in England, and the superior quality universally attributed to the English powders is attested by the results of my experiments with them. I would, therefore, propose the Waltham powder as the type or standard to which our powder for military service should conform in nearly all respects. In this manufacture, the essential operations are the separate pulverization of the materials, their incorporation by the cylinder mills alone, and the formation into cake by moderate pressure, on thick cakes. The time of running the mills on a given charge must depend partly on the weight of the rollers; but the diminution of this time by means of previous mixture of the ingredients for several hours, in the dust barrels, appears to impart to the powder a degree of density which, although attended, perhaps, with somewhat increased force in the cannon, is injurious to other valuable qualities of the powder, and especially to its capability of resisting the effects of exposure to moisture.

I have mentioned in this Report, the well-known fact that, after all the experiments with gunpowder in France, the use of the pounding mill is still continued in making all powder for the military service. This decision results principally from three advantages claimed for the pounding mill powder over that made by other processes: 1st, that it is better adapted to the promiscuous service of all arms; 2d, that it is less injured by exposure to moisture; 3d, that it is less destructive to the gun. The first of these advantages has no value in our service, because we shall, undoubtedly, continue to use, as we have always done, different kinds of powder for cannon and for small arms. As for mortar service, we have seen that the rolling mill powder, if not made of undue density, is but little inferior to the other, even with small charges. In mortars, also, we have always the faculty of varying the charge and elevation according to the range required, and the use of mortars will probably be so much diminished by the introduction of long howitzers of all calibres, that no sacrifice of the strength of powder in long guns should be made for the sake of adapting it to mortar service.

With regard to the second advantage claimed for pounding mill powder, we see that it may also be possessed in a high degree by rolling mill powder, such as the English Government powder.

The French experiments themselves indicate a simple method of neutralizing, in a great degree, the destructive quality of dense powder without diminishing its projectile effect, and this may be still further accomplished by the reduction which the greater force of the latter kind of powder enables us to make in the charge.

The strength of the barrels of small arms is so great that the destructive effect of the small charges used in them constitutes no objection to the use of powder even more violent in its operation than the strongest rifle powder proposed to be made.

I have before said that the pounding mill is capable of producing powder of nearly equal force to the cylinder mill powder, but for that purpose it must be worked not less than 14 or 16 hours, and even then, unless it is pressed, the grain is hardly sufficiently firm to bear, without injury, the jolting of ammunition wagons.

5. *Of the density of gunpowder.*

Here, again, I propose to refer to the English standard, according to which the mean gravimetric density of the coarse grains of cannon powder is about 875. That density should not be *less* than 850; it is not easy, and perhaps not necessary, to establish an absolute *maximum* of density, on account of the differences caused by accidental variations in the size and form of the grains; but it does not appear necessary or advisable that the gravimetric density should exceed 920.

6. *Of the sizes of grain for gunpowder.*

For *cannon powder*, no change appears to be required in the present regulation with respect to the size of grain.

If it should not be deemed incompatible with the convenience of service to multiply the varieties of powder for special purposes, there would probably be an advantage in using very large grained powder, (such as that designated by A. 0,) for 13 in. mortars and for the heavy sea coast howitzers, in which enormous charges of powder are used. By this means the strain on the gun would be diminished, and the velocity of the ball perhaps increased; and we have seen that, even in the 32 and 24-pounder guns, with moderate charges, the velocity of the ball is not diminished, in an important degree, by the use of such powder.

For *musket powder*, I would recommend a reduction of the size of grain, to be regulated by the present standard gauges as follows:

All the grains should pass through No. 4.

About one-half, through No. 5.

Nearly one-fourth, through No. 6.

This would give about 2000 or 2500 grains of powder in 10 grs. troy.

For *rifle powder*, a small reduction may also be made in the size of grain, by requiring that all the grains shall pass through No. 6, the other gauges being used according to the present regulation. There would then be about 12,000 or 15,000 grains of powder in 10 grs. troy.

7. *Of the charges for cannon and small arms.*

For *cannon*, the charge of $\frac{1}{4}$th the weight of the ball, with powder of the standard strength proposed, impresses on the ball a sufficient velocity for all the ordinary purposes of service. For any purpose, even for a breaching battery, the advantage gained by using a charge greater than $\frac{1}{3}$d the weight of the ball is unimportant, and by no means compensates for the inconvenient recoil, and the destructive strain on the gun and carriage, &c.

In illustration of these conclusions, it might suffice to refer to the tables of experiments; but as the habitual charge in the French and other services is $\frac{1}{3}$, and the battering charge $\frac{1}{2}$ the weight of the ball, it may be well to compare the effects of these charges of French powder with that of the charges which I propose to substitute for them. For this comparison, a glance at the following table will suffice.

The French 30-pounder corresponds, very nearly, in diameter and length of bore, with our 32-pounder. The windage of the balls used in the French experiments is somewhat greater than that of the balls used in my experiments, but the difference is not very important.

Place of experiment.	Calibre of gun.	Kind of powder.	Charge.	Velocity of ball at the pendulum.	REMARKS.
				Feet.	
Esquerdes	30-pdr.	French pounding mill	$\frac{1}{3}$	1513	Mean with 4 kinds of powder.
Washington Arsenal	32-pdr.	a. Cylinder mill	$\frac{1}{4}$	1535	
		A. Cylinder mill	$\frac{1}{4}$	1611	
Esquerdes	24-pdr.	French pounding mill, 11 hours.	$\frac{1}{3}$	1677	Mean of 40 rounds, with 2 kinds powder.
Metz	"	French pounding mill, 11 hours.	$\frac{1}{3}$	1575	Powder made at Metz, 1836.
Washington Arsenal	"	a.	$\frac{1}{4}$	1570	
		A.	$\frac{1}{4}$	1687	
Metz	24-pdr.	French pounding mill	$\frac{1}{2}$	1772	Ditto.
Washington	"	A.	$\frac{1}{3}$	1833	

For small arms, the following charges are proposed:

For *the percussion musket*, with the proposed musket powder, 110 grains.

For *the percussion rifle*, 75 grs.

For *the percussion pistol*, 30 grs. of rifle powder.

8. *Of cartridges for cannon.*

For the purpose of diminishing the strain on the gun, I propose that the principle of increasing the length of the cartridge, by reducing its diameter, should be adopted for heavy guns. The diameters of the cartridge formers may be established as follows:

Calibre - - - -	42	32	24	18
Diameter of cartridge former - Inches	6.	5.5	5.	4.6

9. *Of the windage of balls for cannon and small arms.*

In view of the great diminution of velocity, which may be caused even by such a difference of windage as may occur from the variations now allowed in the diameter of the bore and that of the ball, I recommend that the limits of those variations should be restricted. In the present state of the mechanic arts, the manufacturers can, without difficulty, execute their work with greater uniformity than is required by the existing regulations on this subject; and I believe that, in fact, the limits of variation allowed are seldom reached. It is therefore only necessary to make obligatory on all, the present practice of the best workmen.

With regard to cannon balls, I have found no difficulty in restricting the variations of diameter to *one-half* of what is now allowed, and although I should not propose to confine the founders to this narrow limit, yet I think it would be useful to require that a certain proportion of the balls should come between the high gauge and an intermediate gauge between the high and low gauge; this would cause the moulders to work as nearly as possible to the high gauge.

For small arms also, especially for the musket, the variation now allowed in the diameter of the bore is, I believe, unnecessarily great. But for these arms, a much more important change is that of reducing the windage, by increasing the diameter of the ball, and to effect this object, with certainty and uniformity, I propose that balls for small arms shall be made by compression, instead of being cast.

10. *Of the loss of force by the vent of the gun.*

The loss of velocity in consequence of the escape of gas through the vent of a cannon is inappreciable, in comparison with the unavoidable variations produced by other causes, and, so far as this effect is concerned, it would be nearly useless to close the vent in firing the gun.

11. *Of the effect of wads.*

In the service of *cannon*, heavy wads over the ball are, in all respects, injurious. For the purpose of retaining the ball in its place, light *grommets* should be substituted for junk or hay wads, and the latter should be used only for proving guns, for firing hot shot, or for saving the bore of the gun from injury by placing them between the powder and ball, in order to change the seat of the ball, from time to time, and prevent the formation of a *lodgement*.

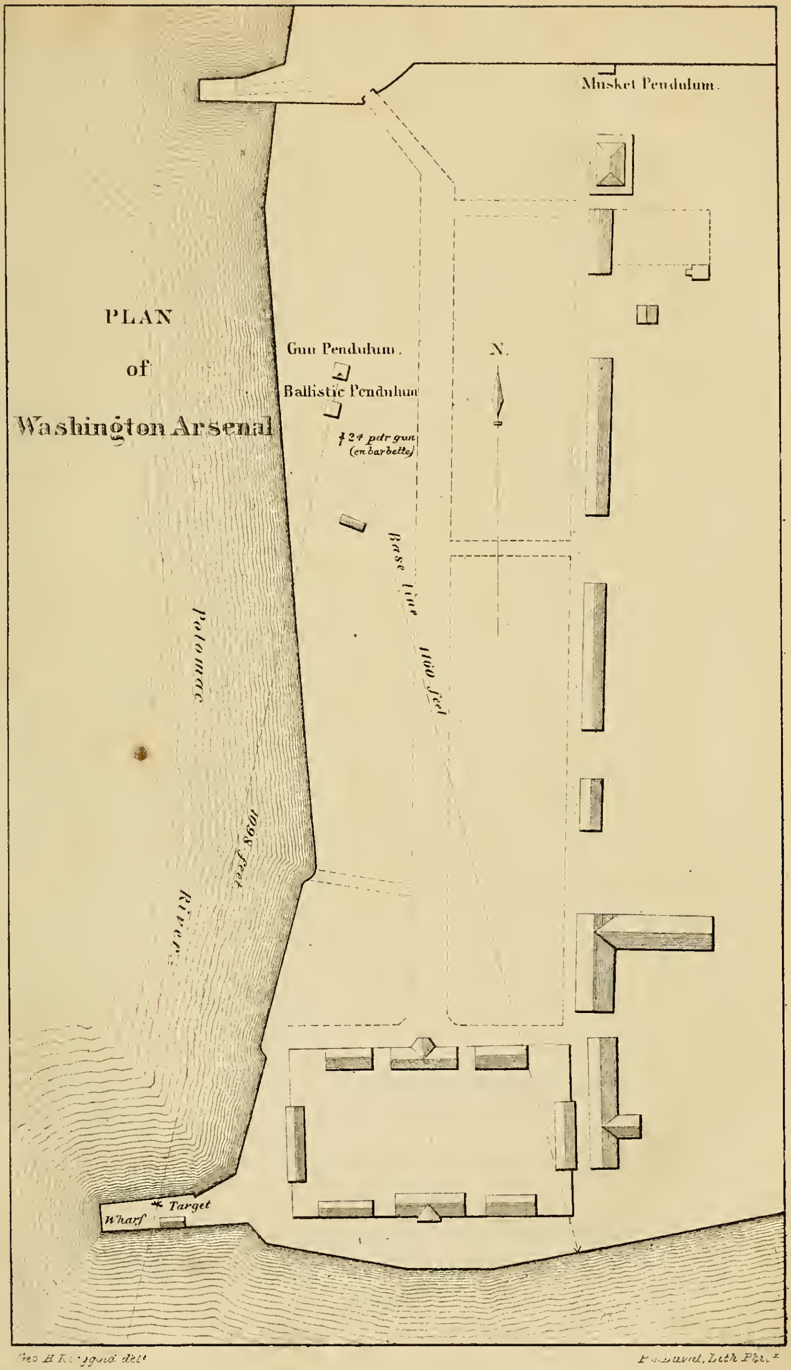
In *small arms*, on the other hand, it is of great importance, for developing the full force of the charge, that there should be a good wad over the powder, unless the ball has but very little windage, as in the rifle.

12. The great differences observed in the strength and solidity of cannon balls, made at different foundries, indicate the propriety of greater care, in the manufacture and proof of balls, than is now bestowed on them.

13. The stock of powder in store, of the kinds designated by the letters C and D, in this Report, should be used in current service before the other kinds.

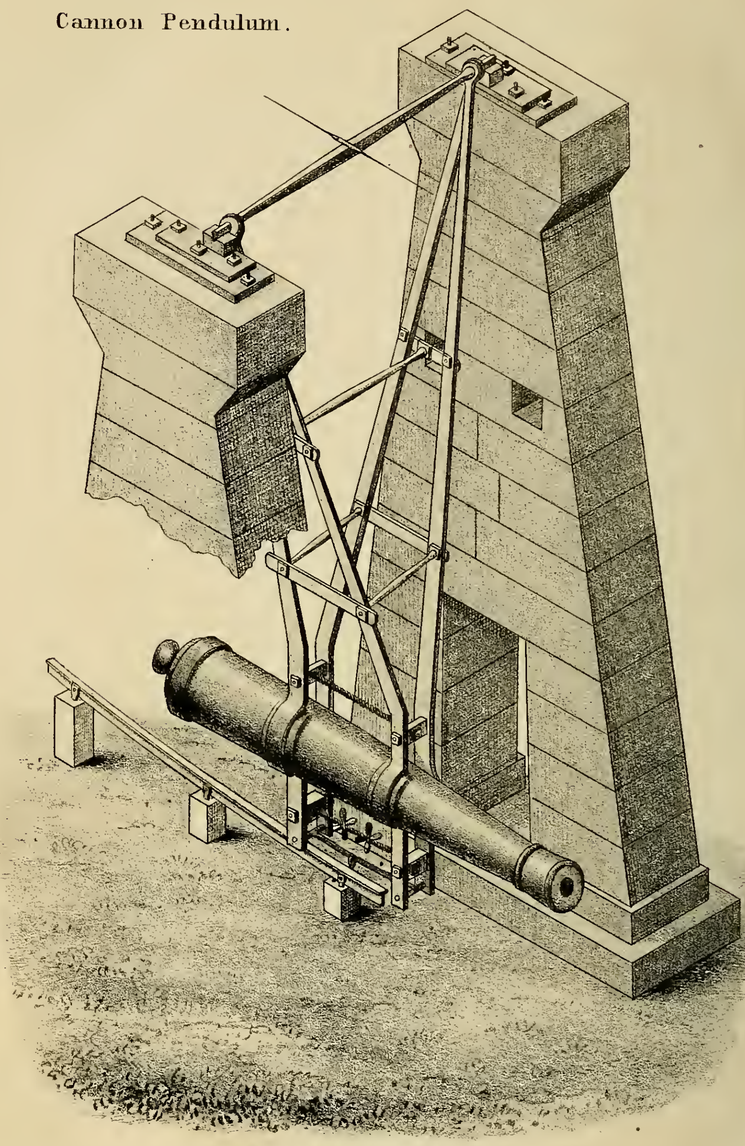
A. MORDECAI,
Capt. Ordn. Dept.

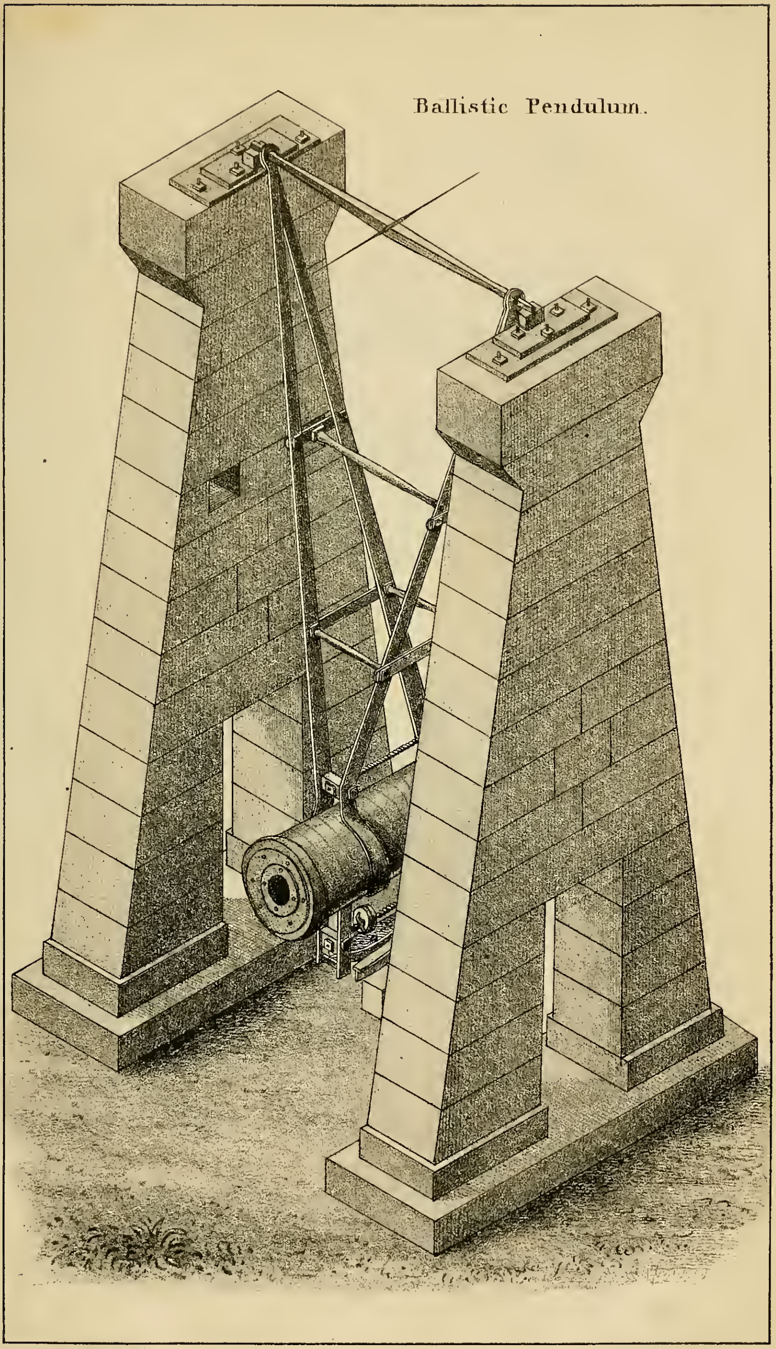
WASHINGTON ARSENAL,
February 11*th*, 1845.



Geo H K...good del.   P. S. Duval, Lith Phil.

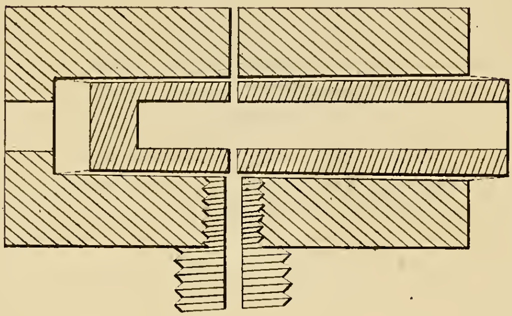
Cannon Pendulum.




Ballistic Pendulum.

Apparatus for closing the vent.

Scale 1/2



Section.

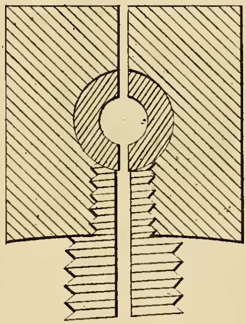
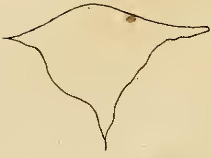


Fig. A.

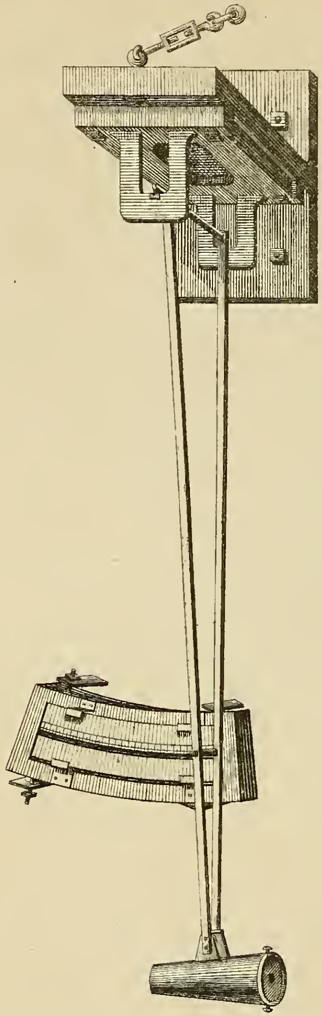
Fig. B.



Geo H Ringgold delt

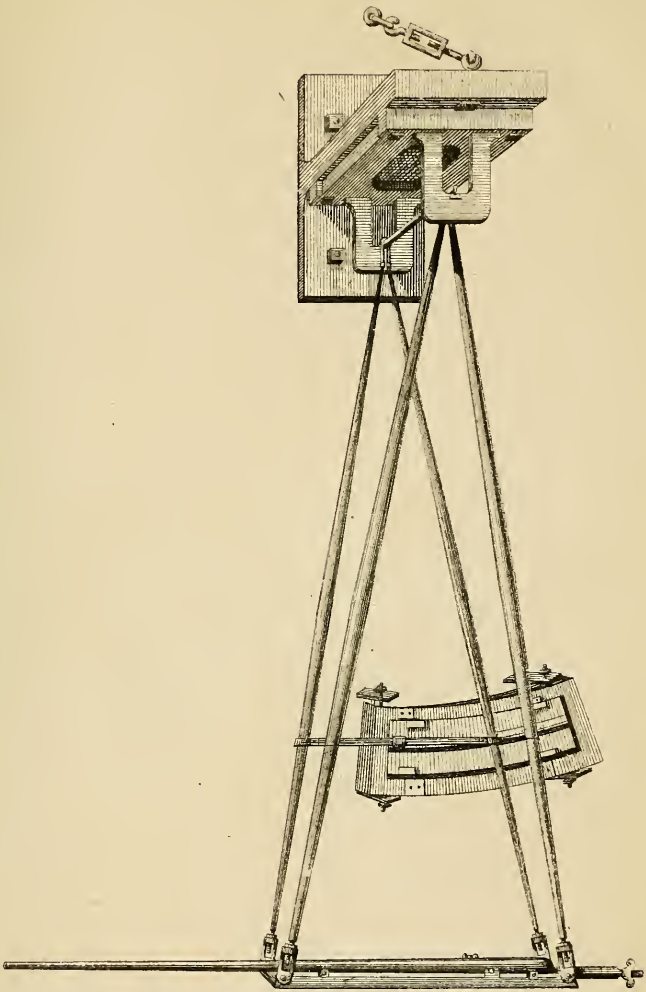
P S Duval, Lith Phila

Plate IV.



Ballistic Pendulum.

Geo. H Ringgold, delt   *P. S. Duval, Lith. Philada.*



Musket Pendulum.

Geo. H. Ringgold, del.t   P. S. Du.al, Lith. Phil.a