ENGINEER DEPARTMENT, U. S. ARMY.

REPORT

UPON

THE RESULTS OF FIRINGS

TO DETERMINE

THE PRESSURE OF THE BLAST

FROM

15-INCH SMOOTH-BORE GUNS,

MADE AT

STATEN ISLAND, NEW YORK HARBOR, IN 1872 AND 1873,

BY

JOHN NEWTON,

LIEUT. COL. ENGINEERS, BVT. MAJOR GENERAL, U. S. A.,

AND

Q. A. GILLMORE,

MAJ. ENGINEERS, BVT. MAJOR GENERAL, U. S. A.

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HEADQUARTERS CORPS OF ENGINEERS,
Washington, D. C., October 30, 1871.

SIRS: The open barbette-batteries for 15-inch guns, or equivalent rifles, projected by the board of engineers and adopted for our sea-coast defenses, consist generally of guns in pairs, separated by traverses. The two guns in each "bay," or division, of the battery are placed twenty-five feet distant from each other, pintle from pintle; and it is desired to determine by some experiments the force of the blast of any one gun (fired at various angles to the line of the crest) at varying distances and positions from the muzzle, but more particularly at those distances and positions that would be occupied by the cannoneers while loading the piece adjacent to the one being fired.

The Chief of Engineers requests that you will combine these experiments with the experiments you are now making upon wooden platforms, and will take advantage of the shots you fire from the piece mounted on that platform to determine the effects of the blast at the positions above indicated.

Very respectfully, your obedient servant,

By command of Brig. Gen. Humphreys:

THOS. LINCOLN CASEY,
Maj. Engineers.

Lieut. Col. J. NEWTON and
Maj. Q. A. GILLMORE, *Corps of Engineers, New York City.*

REPORT.

NEW YORK, *January* 24, 1874.

GENERAL: We have the honor to transmit herewith our report, with tabular statements, of the results obtained by our experiments for determining the pressure of the blast of a 15-inch smooth-bore gun; also five diagrams showing the positions of the anemometers relative to the gun fired.

The same kind of instrument was used for recording all the pressures. A drawing of it, with details, was forwarded with our report dated September 25, 1872.

The tabular records of firing are shown, for convenience of reference, in four series, corresponding to the periods during which the experiments were made.

Where the pressure is given in this report, it always means the pressure on one square foot.

The first series (six shots, see diagram I) extends from April 30 to June 13, 1872.

Shot No. 1 was a blank cartridge, with a charge of 50 pounds of powder; it was used chiefly as a preliminary test of the anemometers.

Shot No. 2 was fired with a ball and 50 pounds of powder; its effects upon the instruments indicated what parts of them required strengthening, as did also the following four shots, each of which were fired with a ball and 75 pounds of powder.

The second series (six shots, see diagram I) extends from August 23 to September 9, 1872.

Each shot was fired with ball and 75 pounds of powder.

The experiments of the second series, and, to some extent, also those of the first, were made with a view to demonstrate the effect of the blast in the vicinity of the nearest gun not separated by a traverse or any other species of shield or cover from the gun fired.

The more important results obtained from the records in the above series are indicated in a diagram sent with our report of September 25, 1872; but a more complete sketch, marked diagram I, accompanies this report.

The amount of pressure found at the places where the men serving the neighboring gun would be likely to stand seems to show that it would be impossible to maneuver and load one of a pair of XV-inch guns while the other was being fired, especially as the pressure would have been proportionally greater if a full charge of 100 pounds of powder had been used instead of 75 pounds, as stated.

A pair of these guns would, therefore, have to be loaded and fired together.

We would here remark that the tables of the first and second series, having been already referred to in our previous report, are inserted chiefly for the sake of completeness.

The third series (ten shots) extends from October 1 to December 13, 1872.

Excepting shot No. 2, which consisted of a blank cartridge with a charge of 100 pounds of powder, every shot was fired with a 460-pound ball and 100 pounds of powder.

This series, which is represented in dotted lines on plan, (diagram II,) and in sections on diagram III, develops some remarkable facts.

Comparing the effects of shots Nos. 1 and 2, the first fired with 100 pounds of powder and ball at 8° elevation, the second with the same charge of powder, but no ball, and at 3° elevation, an anemometer in each case being placed 62 feet from pintle at "c" in diagrams II and III, it will be seen that the first shot produced a pressure of 29 pounds, the second only 13 pounds, showing that the tension of the gas created in the bore of the gun when a blank cartridge is fired is greatly increased by loading it with a 460-pound ball.

Shot No. 5, 0° elevation, caused the third board-screen, on the top of which the anemometer was placed, to heel over about 22 degrees from its original vertical position; the anemometer, whose center of disk was 8 feet 4 inches below the line of fire, recording a pressure of 128 pounds.

The screen, a frame-work of inch-boards, 5 feet in height and 15 feet wide, resting on the ground, its top edge being 10 feet below the line of fire and 62 feet from the pintle, or about 54 feet from the muzzle, was struck and penetrated from one-fourth inch to one-half inch by 46 grains of unburned powder, which, from their size, would have weighed in the aggregate about one pound; one of these grains striking a man would disable and possibly kill him.

According to this, a square target placed in the same plane as the screen, and having all its sides the same distance from the line of fire as the lower edge of the said screen, and therefore its center in the axis of the cone of blast, would have received about 11 pounds of unburned powder, taking the quantity which struck the screen as an average.

The amount of powder actually lost is probably greater than this estimate, as the base of the cone through which the unburned grains are disposed, circumscribe, and is therefore somewhat larger than the assumed target, and because the stream of grains following in the wake of the ball is most probably of a greater density than at points at some distance from the trajectory.

That the third screen was forced from its vertical position was, no doubt, due to the powerful impact of the blast, aided by the exposed position of the screen on the crest of the ridge.

It will further be seen, by referring to the notes, section PX, diagram

III, that the fifth shot produced no pressure, and the sixth shot 2 pounds of pressure upon an anemometer placed at *j′* on top of the fourth screen; and yet the instrument was moved, in both cases, about 4 inches forward.

At *p*, or 208 feet from pintle, the anemometer on the top of the fifth screen indicated no pressure from the fifth shot, and yet it fell off its support.

It is, therefore, quite probable that the blast had still some force left when arriving at the last-mentioned point.

The anemometer, being adjusted to indicate pounds, only failed to mark pressure below one pound.

If the remnants of the blast were possessed of only a portion of a pound pressure per square foot, it would amount in the aggregate to quite a considerable pressure when exerted upon a perpendicular surface of 75 square feet, the area of either the fourth or fifth screen.

The vibratory motion thus imparted to the screens would then be the cause of the behavior of the anemometer just mentioned.

Trial-shots Nos. 7, 8, 9, and 10, fired on the line PS′, (diagram II,) were chiefly made with a view to ascertain the effect of the blast of the 100-pound charge of powder with ball on points in the vicinity of the nearest gun separated by a traverse from the gun fired.

The points tested were selected with reference to a line of fire emanating from a gun traversed to the extreme limit of its sector of fire, (in this case 65°,) that being the position from which the blast of the gun would be most felt by the men serving a gun placed at the usual distance on the other side of an intervening traverse.

The pressures were found to range from 0 to 10 pounds per square foot.

Taking into consideration that the maximum pressure was found at a point where a gunner's head would scarcely be liable to be exposed, and that the forward part of the traverse experimented on was in an unfinished condition, it would seem probable that a gun so placed may be served without injurious effects to the men while the gun beyond the traverse is being fired, provided the head of the traverse be specially proportioned to this object, and terminated by slopes carried close to the trajectory at the extreme traverse.

A few more observations concerning this series will be made in discussing the fourth series.

The fourth series (18 shots, see diagrams II and IV) extends from September 17 to October 13, 1873.

Each of these shots was fired with a 460-pound ball and 100 pounds of powder, their elevation varying from 0° to 15°. All of them were fired in the same vertical plane.

The intersection of this plane with the ground is shown on diagram II by a black line commencing at pintle C. (See also sections A and B, diagram IV.)

This line was marked by stakes driven into the ground at regular intervals of 10 feet, measured horizontally.

The stakes were numbered from 0 to 13, which numbers are shown in black on the diagram, stake 0 being 17½ feet from the pintle horizontally; stake 1, 27½ feet; and so on.

The parapet over which the fire was delivered was in an unfinished condition, requiring additional thickening, besides shaping and trimming.

The exterior slope immediately underneath the line of fire was of irregular profile, with a marked and well-pronounced depression of the ground at stake 10, 117½ feet from the pintle, which to some extent sheltered the anemometer placed there.

Other stakes were set out to the right of the line of fire, which were marked with letters *a*, *b*, *c*, &c., and are shown in black on diagram 2.

Three board-screens were also erected across and underneath the line of fire.

An examination of the behavior of the anemometers at the various stations, 4, 5, 6, &c., as recorded in the tables of the fourth series, affords an opportunity to draw conclusions approximately correct as to what distance in front of a 15-inch gun, and how far below its trajectory, the blast ceases to be sensibly felt.

This point, being determined, would indicate the nearest position where a barbette-battery might be located and served simultaneously with the one in rear of it without any other precaution than what would be necessary to intercept grains of unburned powder, or fragments of sabots, in the possible event of the 15-inch gun being fired with shell or case-shot.

The greatest distance in advance of the pintle at which, in this series, the pressure was ascertained, was at stake 13, or 147½ feet from pintle horizontally; the center of disk being 56½ feet below the horizontal trajectory of shot No. 17. The indicated pressure was 6 pounds.

The mean of two observations (shots Nos. 1 and 17) at stake 12, 137½ feet from pintle horizontally and 54 feet below horizontal trajectory, was 9 pounds; while shot No. 18, fired at 5° elevation, produced only 7 pounds.

Here an opportunity offers to compare the effects of shots fired over different profiles of ground, elevations being equal.

Anemometers were placed at *j′* for the fifth and sixth shots, (third series, see diagram III, section on line PX,) or 140 feet from pintle horizontally, and 36 feet below trajectory; while for the first and seventeenth shots, (fourth series, see diagram IV, section A,) the anemometers were placed at stake 12, or 137½ feet from pintle horizontally, and 54 feet below trajectory.

The distances from pintle were, therefore, nearly alike.

The fifth shot (third series) produced no pressure. A straight line from the disk to the muzzle of the gun was intercepted by the third screen on the crest of the big slope.

The sixth shot (third series) caused 2 pounds pressure. The screen spoken of had been removed. A straight line from disk to muzzle just passed the crest of the big slope.

The first and seventeenth shots (fourth series) produced an average pressure of 9 pounds, although the disks were 18 feet more distant from the trajectory than in the case of the fifth and sixth shots of the third series; but a direct line from the disks to the muzzle passed clear of all obstructions, though only just about clearing the irregular exterior crest of the unfinished parapet, about 9 feet from the muzzle, a point at which the blast had lost but little of its initial force.

This fact shows the fitness of a screen, when located like the third of the third series, to cause a considerable reduction of the blast-pressure at a given point, even in case of the latter being at a comparatively great distance from said screen.

Close by stake 11, or 127½ feet from pintle, a board-screen had been erected similar to those used for the third series, its top edge being 50½ feet below the horizontal trajectory.

For shots No. 2 (0° elevation) and No. 11 (10° elevation) anemometers placed on top of this screen indicated in each case a pressure of 10 pounds; the third shot (0° elevation) and eleventh shot (10° elevation) made *no* impression on anemometers placed immediately behind and protected by this screen, but the eighteenth shot (5° elevation) produced 5 pounds pressure at the same point.

These results, notwithstanding their discrepancy, seem to indicate that a screen about 5 feet high, resting on the ground, has a powerful effect in diminishing the force of the blast.

If made of 2-inch yellow-pine planks, it would doubtless arrest all grains of unburned powder and fragments of sabots.

At stake 10, or 117½ feet from pintle, on depressed ground, only one pound pressure was produced by shot No. 1, the center of disk being 50 feet directly below the horizontal trajectory, and no pressure was indicated at the eleventh shot, (10° elevation.)

In this instance a straight line from the center of disk to muzzle of gun passed tangent to the upper edge of screen at stake 8 (20 feet nearer the gun) and also tangent to the exterior crest of parapet, so that the muzzle of the gun was in fact seen from the disk.

Comparing this result with that obtained at stake 11, (anemometers on top of screen,) it is found that while in the latter case the pressure was 10 pounds for a horizontal distance of 127½ feet from pintle, and 49 feet below the trajectory, that at a point 10 feet nearer to the gun, and but one foot lower, protected by an irregular bank of 4 or 5 feet in height, (upon which stakes 7, 8, and 9 were located,) the force of the blast was practically eliminated.

As the disk could be seen from the gun over the screen and parapet, this protection was doubtless afforded by the lower portions of the cone of blast being deflected upward from the ridge in rear of screen at stake 8, so as to disturb the direct wave of blast between the muzzle and disk.

The screen alone would cause eddies materially affecting the force of the blast in advance of it.

At stake 9, or 107½ feet from the pintle, the center of disk being 45 feet below horizontal trajectory, and upon a ridge of ground with a decided depression of the surface in both front and rear, the average pressure by shots Nos. 1, 9, and 10 amounted to about 12 pounds.

Near and in front of stake 8, or 97½ feet from pintle, another screen was erected upon the same ridge, having its upper edge 41 feet below the horizontal trajectory.

An anemometer placed behind the screen and protected by it, with the center of its disk 2 feet below the top edge of the screen, indicated *no* pressure by the blast of the second shot, (0° elevation,) but 6 pounds for the eighteenth shot, (5° elevation.)

For the third, ninth, and tenth shots, (0° elevation,) and for the eleventh shot (10° elevation,) the anemometers were placed on the top of the screen, with the centers of disk 39 feet below the trajectory.

The pressure indicated was 12 pounds, except the third shot, which produced 14 pounds.

At stake 7, or 87½ feet from pintle, and 40½ feet below trajectory, shots Nos. 6, 7, 9, and 10 (0° elevation) caused an average pressure of 17 pounds.

A straight line from disk to muzzle would just pierce the exterior crest of the unfinished parapet.

There can be no doubt that if the parapet were finished to the necessary thickness of 20 to 25 feet, as shown in dotted lines on diagrams III and IV, the pressure would be less.

This remark, of course, applies with more or less force to all other points of observation.

Near and in front of stake 6, or 77½ feet from pintle, a screen was erected similar to the others, with its top edge 36 feet below horizontal trajectory.

For the sixth shot (0° elevation) the anemometer was placed on top of the screen, disk 34 feet below trajectory.

The instrument was thrown down by the force of the blast; it indicated a pressure (doubtful, however) of 62 pounds.

For the second, third, ninth, tenth, and seventeenth shots (0° elevation) the anemometer was behind and protected by the screen, disk about 2 feet lower than edge of screen; the screen intercepting a straight line from the disk to the muzzle.

The effect of the third shot was somewhat anomalous, the indicated pressure being only 4 pounds, which is difficult to account for, considering that the mean pressure by the other four shots was 18½ pounds.

Adopting the latter figure as correct, another chance is afforded to compare the effects of shot fired over different profiles of ground.

The fourth shot, (third series, see diagram III, section PX,) with 5° elevation, caused 20 pounds pressure upon an anemometer placed at *f*, or 76 feet from pintle, and 35 feet shortest distance below trajectory.

The instrument was protected by a bank, preventing its being seen from the muzzle of the gun.

Comparing this fact with those in the case of the four shots of the fourth series above mentioned, it is found that, at equal distances from muzzle and trajectory, a vertical screen resting on the ground and projecting but a few feet above a given point, *near* to, and protected by it, is about as effective as a bank with a moderately steep slope but several times higher than the top edge of the screen.

In this way, as the points of observation approach the gun and the line of fire, the pressures steadily increase, as might be naturally inferred, and as is proved by examining the tabular statements of the fourth series.

From the data on hand it would appear that—

1. Augmenting the thickness of the parapet so as to intercept the view of the ground in front from the muzzle of the gun, tends to reduce the pressure at every point in advance of the muzzle and below the trajectory.

Other things being equal, it follows that upon such points a shot fired at right angles to the line of parapet produces the greatest effect as for blast, and the least effect when fired at the extreme traverse of the gun to the right or left, because a greater segment of the cone of blast is intercepted in the latter than in the former case.

If in the latter case the line of fire is compelled to pass close by the head of a traverse, resting well to the front on the superior slope of the parapet, the influence of the blast will doubtless be still more diminished, the waves of concussion getting more broken and disturbed.

2. If the exterior crest of parapet were to form the coping of a scarp-wall of sufficient height, a lower battery may be located at the foot of such wall, exempt from the effects of the blast from the upper battery.

Such a position would be at the minimum distance possible, both from muzzle and trajectory of the gun above, the high scarp-wall performing the functions of a tall screen.

Additional trials would be necessary to determine how far below the trajectories from the upper guns it would be necessary to locate the terreplein of the advance battery.

3. If instead of a steep wall the exterior slope is formed by a uniform and gently inclined plane, the lower battery will have to be at a more advanced position and lower reference, to be safe from the effect of the blast, than in the case 2; and these distances must be increased as the angle of slope is reduced.

4. If, however, such an inclined plane is furnished with one row or

more of strong screens, sufficiently high to project several feet over a direct line drawn from a gunner's head, in his most exposed position, to the muzzle of gun when fired at its maximum depression, the lower battery can be located nearer to the upper one than in the previous case Such screens should be made stronger the nearer they are to the gun fired, to withstand the impact of the blast and to arrest grains of unburned powder.

5. An exterior slope formed of alternating elevation and depression, irregular in shape, seems to tend to disarrange the waves of blast, and may, in connection with screens mentioned above, still more favor a reduction of distance between the batteries.

6. In reference to the profiles of ground mentioned in this report, it is believed that a battery, located as shown in dotted lines in section PX, diagram III, will be beyond the range of unburned grains of powder, and will require no other protection from the blast, except finishing the parapet of the upper battery to its proper thickness, or perhaps making this thickness slightly in excess; provided, also, that only solid shot be fired from that battery.

7. It is thought advisable that whenever two batteries are to be built, one in rear and above the other, a few experimental shots should first be fired, in order to test the force of the blast at points of the intended site.

A few observations were made at points *a*, *c*, *q*, and *x*, (fourth series,) to detect the force of the counter-blast.

The ball, projected from the gun with a great velocity, acts as a plunger, creating a vacuum in its track; the surrounding air, after sustaining the shock of the suddenly-developed gas, and rebounding as it were, rushes in to fill the vacuum, thus producing the counter-blast.

The results obtained were not as satisfactory as desirable; they showed, however, that the pressure occasioned by the counter-blast was in every case less than that obtained at the same point by the direct blast.

An attempt has been made to construct curves of equal pressure, as shown on diagram V.

Where no modifying influences exist, due to the shape of the ground, it may be assumed that, in a plane at right angles to the trajectory,* all points of a circle having for its center the point where the trajectory passes the plane will be points of equal pressure.

If, therefore, the shortest distances of a number of points of observation from a trajectory be known as well as the pressure at such points, they may be represented in a diagram, considering all trajectories experimented on, no matter of what elevation, as horizontal.

A curve drawn through points of equal pressure, revolved around

* The trajectory and axis of cone of blast must nearly coincide for the short distances in question.

the trajectory as an axis, would create a curved surface, in which every point would have the same pressure.

The observations of pressures at the stations sideways from the line of fire (fourth series) were chiefly made with that object in view.

The results showed, however, that, in order to arrive at anything satisfactory in this regard, a greatly-increased number of trials would be required.

The greater number of the observations of pressure employed to form the curves of diagram were made at points but little elevated above the ground; and it is scarcely to be doubted that this proximity to some extent vitiates the results.

A suitable arrangement for determining pressures at points of sufficient altitude above the ground, where the waves of blast are less disturbed, would certainly be preferable.

A somewhat reliable set of curves of equal pressure would be of advantage in so far as they would show the maximum pressure at any point within the range of the action of the blast; and by interposing any sort of obstructions between this point and the muzzle of the gun, it may be reasonably inferred that the pressure at such point would be reduced.

Very respectfully, your obedient servants,

JOHN NEWTON,
Lieut. Col. Engineers, Bvt. Maj. Gen.
Q. A. GILLMORE,
Maj. Engineers, Bvt. Maj. Gen.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. A., Washington, D. C.

FIRST SERIES—DIAGRAM I.

Date.	No. of fire.	Charge of powder.	Weight of shot.	Elevation.	No. of anemometer.	Position of disk, referred to point of gun's axis, directly over the pintle; gun being "in battery." In front.	In rear.	To left.	Below.	Shortest distance from center of disk to line of fire.	Position of anemometer on diagram.	Indicated pressure on disk.	Pressure on one square foot.	Area of disk.	Remarks.
1872.		*Lbs.*	*Lbs.*	°		*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*		*Lbs.*	*Lbs.*	*Sq. ft.*	
April 30	1	50	......	0	1	14	......	4	8.2	9	*a*	10	20	½	Blank cartridge.
					2	14.8	......	6	8.7	10.5	*b*	5	10	½	
" "	2	50	460	5	1	12	......	4	7	7.8	*c*	33	66	½	Top carriage struck counter-hurter; disks bent and broken by the force of the blast.
					2	14	......	6	8.7	10.5	*d*	14¾	29½	½	
June 12	3	75	460	5	1	34	......	16.7	2	17.6	I	20⅓	40⅔	½	Top carriage struck counter-hurter; all the anemometers at the same place and worked well; average of the four indications, 43⅓ pounds.
					2	34	......	16.7	2	17.6	I	21⅓	42⅔	½	
					3	34	......	16.7	2	17.6	I	21	42	½	
					4	34	......	16.7	2	17.6	I	24	48	½	
" "	4	75	460	5	1	23.7	......	16.7	2	17.3	II	32⅓	64⅔	½	Pressure too great for correct measure; top carriage struck counter-hurter.
					2	23.7	......	16.7	2	17.3	II	16⅓	65⅓	¼	Limit of spring not reached; good result.
					3	23.7	......	16.7	2	17.3	II	34	68	½	Pressure too great for spring.
					4	23.7	......	16.7	2	17.3	II	34	68	½	Do.
" "	5	75	460	5	1	34	......	8	2	9.5	IV	35⅓	70⅔	½	Pressure too great for spring; its coils brought in contact, and disk blown off.
					2	34	......	8	2	9.5	IV	20⅓	81⅓	¼	Limit of spring not reached; good result.
					3	34	......	8	2	9.5	IV	42	84	½	Pressure too great; coils of spring overlapped in spring-case, and disk blown off.
					4	34	......	8	2	9.5	IV	34½	69	½	Pressure too great for correct measure.
June 13	6	75	460	5	1	13.5	......	16.7	2	17.2	III	14⅓	28⅔	½	Average of the two indications, 34⅔ pounds; the two lower plates of the compressor drawn out of front fastening and doubled up against second front transom, arresting recoil of gun in 2 feet.
					2	13.5	......	16.7	2	17.2	III	20⅓	40⅔	½	

SECOND SERIES—DIAGRAM I.

Date.	No. of fire.	Charge of powder.	Weight of shot.	Elevation.	No. of anemometer.	In front.	In rear.	To left.	Below.	Shortest distance from center of disk to line of fire.	Position of anemometer on diagram.	Indicated pressure on disk.	Pressure on one square foot.	Area of disk.	Remarks.
August 23	1	75	460	5	1	83	......	16.3	3.6	19.5	*a*	6	24	¼	Recoil, 6 feet 8 inches.
					2	34	......	16.7	2	17.5	*b* or I	10	40	¼	
					3	46	......	26.7	3.8	27.8	*f*	18	36	½	
					4	74.5	......	0	4.6	11.1	*h*	10	40	¼	Directly under line of fire.
" "	2	75	460	5	1	64.5	......	7	5.6	13.3	*e*	13½	54	¼	Recoil, 7 feet 10¾ inches.
					2	34	......	16.7	2	17.5	*b* or I	8	32	¼	
					3	47	......	38.7	1.8	39.3	*g*	9	18	½	
					4	74.5	......	0	4.6	11.1	*h*	16	64	¼	

August 24	3	75	460	5	1	13.5	......	8	2	8.8	*i* or VI	15	60	¼	Pressure exceeded limit of spring; bent and badly broken; recoil, 9 feet 1¼ inches.
					2	23.7	......	8	2	9.1	*j* or V	35	140	¼	Coils of spring in forcible contact with pressure of 34 pounds, (not reliable.)
					3	16.5	......	29.1	1.6	29.2	*k*	10	20	½	
					4	2.3	......	18.6	4.8	19.3	*l*	8	16	½	In rear of muzzle.
" "	4	75	460	5	1	....	......	......	......	....	....	......	......	......	Recoil, 8 feet 5 inches, rails being sanded; anemometer No. 1 not used, being damaged in No. 3.
					2	13.5	......	8	2	8.8	*i* or VI	34	136	¼	Coils of spring in forcible contact with pressure of 34 pounds, (not reliable.)
					3	23.7	......	24.2	1.6	24.4	*n*	20	40	½	
					4	2.3	......	18.6	4.8	19.3	*l*	6	12	½	In rear of muzzle.
September 9......	5	75	460	5	1	77.6	......	54	4.2	55.2	*p*	4	8	½	Recoil, 9 feet 2 inches.
					2	115.6	......	0	17.7	27.8	*q*	3	6	½	
					3	115.6	......	18.7	20	35.4	*r*	2½	5	½	
					4	115.6	......	53.7	24.4	63.7	*s*	2	4	½	
" "	6	75	460	5	1	101.6	......	0	16	24.8	*t*	3	6	½	Recoil, 8 feet 6 inches, rails being sanded.
					2	115.6	......	0	17.7	27.8	*q*	2½	5	½	
					3	115.6	......	0	17.7	27.8	*q*	3	6	½	
					4	115.6	......	0	17.7	27.8	*q*	3	6	½	Average of three indications at *q*, 5⅔ pounds.

THIRD SERIES—DIAGRAMS II AND III.

Date.	No. of fire.	Charge of powder.	Weight of shot.	Elevation.	No. of anemometer.	Position of disk, referred to point of gun's axis, directly over the pintle; gun being "in battery." In front.	In rear.	To right.	Below.	Shortest distance from center of disk to line of fire.	Position of anemometer on diagram.	Indicated pressure on disk.	Pressure on one square foot.	Area of disk.	Remarks.
1872.		*Lbs.*	*Lbs.*	°		*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*		*Lbs.*	*Lbs.*	*Sq. ft.*	
October 1.........	1	100	460	8	1	62	......	0	13	22	*c*	7¼	29	¼	Fired on line P Y; protected by board-screen No. 1, which was 4 feet in front of, and 4 feet above center of, disk.
					2	101	......	0	32	46	*e*	0	0	......	On line P Y.
					3	156	......	0	54	75	*g*	0	0	......	Do.
" "	2	100	0	3	1	62	......	0	13	16	*c*	3¼	13	¼	Fired on line P Y; protected as in shot No. 1; screen No. 1 perforated by numerous grains of unburnt powder; blank cartridge.
					2	101	......	0	32	37	*e*	0	0	......	
					3	156	......	0	54	62	*g*	0	0	......	Screen No. 2, between *c* and *e*, struck by numerous grains of unburnt powder; some went through.
" "	3	100	460	12	1	62	......	0	13	26	*c*	24	96	¼	First screen blown down; instrument broken; pressure probably greater than that indicated; fired on line P Y.
					2	101	......	0	32	52	*e*	0	0	......	
					3	156	......	0	54	85	*g*	0	0	......	
" "	4	100	460	5	1	76	......	0	28	35	*f*	5	20	¼	Fired on line P X; protected by bank; third screen removed.
					2	140	......	0	52	65	*j*	0¼	3	¼	Third screen was removed.
October 6.........	5	100	460	0	1	63	......	0	8½	8½	*d*	32	128	¼	On top of first screen and blown down; screen forced over so as to make an angle of 22° with the vertical; perforated by 46 pieces of unburnt powder; fired on line P X.
					2	140	......	0	36	36	*j′*	0	0	......	On top of fourth screen; top edge of screen about 18 inches below center of disk; no powder-marks on screen.
					3	209	......	0	56	56	*p*	0	0	......	On top of fifth screen; top edge of screen about 18 inches below center of disk; no powder-marks on screen.
October 17........	6	100	460	0	1	140	......	0	36	36	*j′*	0¼	2	¼	On top of fourth sceeen, (third screen removed;) no powder-marks on screen; fired on line P X.
					2	198	......	0	60	60	*q*	0	0	......	
December 9	7	100	460	5	1	72	......	32	0½	32½	....	......	10	......	Shots Nos. 7, 8, 9, and 10 here fired on line P S′; they were fired to ascertain the effect of the blast in the vicinity of a neighboring gun separated by a traverse from the gun fired; the location of the anemometers for each shot is indicated on the plan; the number of the shot and amount of pressure being shown in red.
					2	80	......	59	1	59½	....	......	0	......	
December 13	8	100	460	5	1	85	......	29	1	29	....	......	8	......	
					2	85	......	39	0	39	....	......	0	......	
" "	9	100	460	5	1	75	......	29	0	29	....	......	8	......	
					2	95	......	39	0¼	39	....	......	0	......	
" "	10	100	460	5	1	75	......	29	0	29	....	......	7	......	
					2	95	......	29	0	29	....	......	0	......	

FOURTH SERIES—DIAGRAMS II, IV, AND V.

September 17.....	1	100	460	0	1	137½	......	0	54	54	12	5	10	½	Recoil, 8 feet 1 inch.
					2	117½	......	0	50	50	10	0½	1	½	Under a bank.
					3	107½	......	0	45	45	9	7½	15	½	
					4	67½	......	0	33	33	5	7½	30	¼	
" "	2	100	460	0	1	127½	......	0	49	49	11	5	10	½	Recoil, 8 feet; on top of screen.
					2	57½	......	0	29½	29½	4	4	16	¼	
					3	97½	......	0	43	43	8	0	0	½	Behind screen.
					4	77½	......	0	38	38	6	4	16	¼	Do.
" "	3	100	460	0	1	57½	......	0	29½	29½	4	7½	30	¼	Recoil, 8 feet 1 inch.
					2	77½	......	0	38	38	6	1	4	¼	Behind screen.
					3	97½	......	0	39	39	8	7	14	½	On top of screen.
					4	127½	......	0	52	52	11	0	0	½	Behind screen.
" "	4	100	460	0	1	17½	......	20	2.6	20.17	*a*	13	52	¼	Recoil, 8 feet.
					2	17½	......	30	2.9	30.18	*b*	15½	31	½	
					3	7½	......	20	0.8	20	*c*	3½	14	¼	In rear of muzzle.
					4	7½	......	30	0.9	30	*d*	8½	17	½	Do.
" "	5	100	460	0	1	7½	......	20	0.8	20	*c*	12½	25	½	In rear of muzzle; recoil, 8 feet.
					2	7½	......	30	0.9	30	*d*	4	8	½	In rear of muzzle.
					3	17½	......	30	2.9	30.18	*b*	17½	35	½	
					4	17½	......	20	2.6	20.17	*a*	12	48	¼	
September 20.....	6	100	460	0	1	77½	......	0	38	34	6	31	62(?)	½	Thrown down; recoil, 8 feet.
					2	87½	......	0	40½	40½	7	9	18	½	
					3	....	2½	30	0	30	*e*	0	0	½	In rear of muzzle.
					4	....	2½	40	0½	40	*f*	2	4	½	Do.
" "	7	100	460	0	1	77½	......	0	38	38	6	......	......	......	Broken; recoil, 8 feet.
					2	....	2½	30	0	30	*e*	2	4	½	In rear of muzzle.
					3	87½	......	0	40½	40½	7	9	18	½	
					4	7½	......	40	1.3	40	*g*	......	......	......	Too much damaged by previous shot to record.
" "	8	100	460	5	1	27½	......	30	5	31	*x*	23	46	½	Recoil, 8 feet.
					2	27½	......	40	5.3	40.8	*i*	4	8	½	
October 4.........	9	100	460	0	1	67½	......	0	33	33	5	8	16	½	Recoil, 8 feet.
					2	77½	......	0	38	38	6	10	20	½	Behind screen.
					3	87½	......	0	40½	40½	7	8	16	½	
					4	97½	......	0	39	39	8	6	12	½	On top of screen.
					5	107½	......	0	45	45	9	5	10	½	
" "	10	100	460	0	1	67½	......	0	33	33	5	9	18	½	Recoil, 8.05 feet.
					2	77½	......	0	38.	38	6	10	20	½	Behind screen.
					3	87½	......	0	40½	40½	7	8	16	½	
					4	97½	......	0	39	39	8	6	12	½	On top of screen.
					5	107½	......	0	45	45	9	5	10	½	
" "	11	100	460	10	1	97½	......	0	43	62	8	6	12	½	On top of screen; recoil, 8.05 feet.
					2	117½	......	0	50	67	10	0	0	½	Sheltered by bank.
					3	127½	......	0	49	70	11	5	10	½	On top of wooden screen.
					4	127½	......	0	52	73	11	0	0	½	Behind screen.
					5	67½	......	0	33	44	5	14	28	½	
" "	12	100	460	10	1	17½	......	20	2.6	20.7	*a*	39	78	½	Recoil, 8.05 feet.
					2	17½	......	30	2.9	30.6	*b*	16	32	½	
					3	7½	......	20	0.8	20.1	*c*	23	46	½	In rear of muzzle.
					4	7½	......	30	0.9	30	*d*	10	20	½	Do.

FOURTH SERIES—DIAGRAMS II, IV, AND V—Continued.

Date.	No. of fire.	Charge of powder.	Weight of shot.	Elevation.	No. of anemometer.	Position of disk, referred to point of gun's axis, directly over the pintle; gun being "in battery."				Shortest distance from center of disk to line of fire.	Position of anemometer on diagram.	Indicated pressure on disk.	Pressure on one square foot.	Area of disk.	Remarks.
						In front.	In rear.	To right.	Below.						
1873.		Lbs.	Lbs.	°		Ft.	Ft.	Ft.	Ft.	Ft.	No. stake	Lbs.	Lbs.	Sq. ft.	
					5	....	2½	30	0	30	*e*	5	10	½	In rear of muzzle.
October 4........	13	100	460	15	1	27½	......	30	5	32	*x*	12	24	½	Recoil, 8.1 feet.
					2	....	2½	40	0.5	40	*f*	3	6	½	In rear of muzzle.
					3	7½	......	40	1.3	40	*g*	4	8	½	Do.
					4	17½	......	40	3.5	40.8	*h*	8	16	½	
					5	27½	......	40	5.3	42	*i*	8	16	½	
October 10........	14	100	460	0	1	7½	......	20	0.8	20	*c*	9	18(?)	½	Wire bent; pressure doubtful; recoil, 7½ feet.
					2	17½	......	20	2.6	20.2	*a*	36	72	½	
					3	....	2½	30	0	30	*e*	5	10	½	In rear of muzzle.
					4	27½	......	30	5	30.4	*x*	18	36	½	
					5	37½	......	40	6.3	40.5	*j*	9½	19	½	
					6	17½	......	50	4	50.2	*m*	5½	11	½	
					7	7½	......	50	2.7	50	*n*	3	6	½	In rear of muzzle.
					8	....	2½	50	0.1	50	*o*	3	6	½	Do.
					9	37½	......	50	7.8	50.6	*k*	6½	13	½	
" "	15	100	460	5	1	27½	......	50	6.6	50.8	*l*	7	14	½	Recoil, 7 feet 9 inches.
					2	37½	......	60	7.7	61	*p*	5	10	½	
					3	27½	......	60	6.4	60.6	*q*	5	10	½	
					4	17½	......	60	5.7	60	*r*	3	6	½	
					5	7½	......	60	3	60	*s*	2.5	5	½	In rear of muzzle.
					6	....	2½	60	1.7	60	*t*	1	2	½	Do.
					7	7½	......	20	0.8	20	*c*	30	60	½	Do.
					8	17½	......	20	2.6	20.17	*a*	46	92	½	
" "	16	100	460	5	1	27½	......	60	6.4	60.6	*q*	0	0	½	Reversed to detect counter-blast; recoil, 7 feet 9 inches.
					2	37½	......	60	7.7	61	*p*	5	10	½	
					3	17½	......	60	5.7	60	*r*	2½	5	½	
					4	7½	......	60	3	60	*s*	2	4	½	In rear of muzzle.
					5	....	2½	60	1.7	60	*t*	0	0	½	Do.
					6	....	12½	60	0	60	*u*	0	0	½	In rear of muzzle; sheltered by traverse 3.7 feet above point of reference.
					7	7½	......	20	0.8	20	*c*	4	8	½	In rear of muzzle ... } Reversed to detect counter-blast; disks bent and broken.
					8	17½	......	20	2.6	20.17	*a*	......	......	½	
October 13........	17	100	460	0	1	137½	......	0	54	54	12	4	8	½	Recoil, 7 feet 6 inches.
					2	147½	......	0	56.5	56.5	13	3	6	½	
					3	77½	......	0	38	38	6	9	18	½	
					4	27½	......	30	5	31	*x*	10	20(?)	½	Pressure doubtful.

						5	27½	......	30	5	31	*x*	4½	9	½	Reversed to detect counter-blast.
						6	37½	......	50	7.8	50	*k*	5	10	½	
						7	37½	....	60	7.7	60	*p*	6	12	½	
"	"	17	100	460	0	8	27½	......	60	6.4	60	*q*	4½	9	½	
"	"	18	100	460	5	1	137½	.....	0	54	65	12	3.5	7	½	Recoil, 8 feet.
						2	127½	.....	0	49	59	11	2.5	5	½	Protected by screen.
						3	97½	......	0	43	51	8	3	6	½	Do.
						4	27½	......	30	5	31	*x*	10	20	½	Reversed to detect counter-blast.
						5	27½	......	30	5	31	*x*	13	26	½	
						6	37½	.....	50	7.8	50	*k*	7	14	½	
						7	37½	.....	60	7.7	61	*p*	5.5	11	½	
						8	27½	......	60	6.4	60.6	*q*	4	8	½	