31

SECOND REPORT

OF THE

Board of Artillery Officers,

ASSEMBLED AT AUGUSTA, GEORGIA,

By Special Orders No. 278, Head Quarters Dep't S. C., Ga. & Fla., dated December 19th, 1863, for the purpose of determining the proper Charges for Heavy Guns, the highest allowable angles of Elevation, and other matters connected with the service of Artillery in general.

Presented to Col. Chas. C. Jones C. S. Artillery
From Maj. G. Girardey C. S. Arty & Ord:

The first or partial Report of the Board, referred directly to the proper forms and weights of projectiles, and their service charges, as deduced from existing facts and the practice of service; but many points intimately related with the above were left undetermined, on account of the want of experimental data. Artillery of very large calibre being brought into the service of war for the first time during the present revolution, and heavy rifle artillery being previously unknown in military operations, several important points, relating to their proper use in service, have heretofore necessarily been left undetermined. For the investigation of these matters, a series of experiments were instituted at the *Augusta Arsenal*, with the approbation of the Chief of Ordnance, and the Board was reassembled by its President to witness and assist in these experimental researches:

Some of the results attained from the above have been omitted in this Report as, although useful and interesting to the service in general, they have only a partial relation to the subject matter of the service of artillery.

The several propositions are placed under the head of questions, and the deductions from the series of experiments instituted in each case follow as their answers. After these, a few miscellaneous general facts, interesting to the artillery service, are appended as deductions from the series of experiments.

The Board reassembled at the *Augusta Arsenal, March 22d*, 1864, and were about four weeks, more or less, engaged in daily experiments.

The guns made use of in the trials were: *First*, a 3 inch rifle and banded iron gun, carrying a shell of 7½ lbs. weight; *Second*, a bronze 6 pounder; *Third*, a 12 pounder Napoleon; and *Fourth*, a 7 inch Columbiad, carrying a bolt of one calibre in length, with a windage of .05 inch and weighing 65 lbs.

This bolt, at its end nearest the charge, had a recess about 1½ inches broad, which was wrapped with lubricated cloth, and thus the bolt fitted the bore of the gun practically without windage, and corresponded more nearly to a rifle gun.

In connection with the above, and for the purpose of obtaining the initial velocities and corresponding pressures on the bores of the guns at each discharge, the following instruments were employed: *First*, an electro ballistic machine of two pendulums, on the principle of Capt. Benton's, but somewhat modified and improved; *Second*, a pressure piston, arranged after the plan of Capt. Rodman, but using a composition of type metal and lead, in place of copper disks. This change is regarded as decidedly more reliable and convenient.

The dimensions of this instrument coincide in all respects with that used by Capt. Rodman in his experiments. The method of determining the pressure was to remove the block of composition metal from the piston housing, carefully lifting it from the steel cutter after the discharge, and reversing the same block so as to bring its back on the cutter, and then subjecting it to pressure by means of a heavy iron lever, until a cut was made of the same length as that produced by the force of the charge. The dimensions of the lever, and weights added, afforded the data for a near approximation to the true pressures experienced on each square inch of the bore at the moment of inflammation of the charge.

The wire targets of the electro ballistic machine were placed 70 feet apart in all the experiments, with one exception, which will be referred to at the proper time. The muzzles of the smaller guns were 20 feet from the first target, and of the 7 inch Columbiad 30 feet, to avoid the force of the blast. It will be seen, from the table of firings, that the initial velocities given by the above instrument coincide with those given by the rifle and ballistic pendulums for the same charges.

The charges of powder were accurately weighed, by means of a delicate balance, and proper care taken in each case that the conditions should be alike in comparative trials.

The experiments were divided into series—each set for the determination of some point connected with the service of artillery, and the trials were continued in each case until the Board was satisfied as to the results. The series will be taken up in the same order as they occurred, and each discussed on its own merits, and at the end of the report a condensed table of the more important data of the firings will be appended.

First Question.—*What size of grain corresponding to a given density should be given to Gunpowder for Artillery purposes?*

To determine the above, Gunpowder made at Raleigh, and at Columbia for the Navy were employed, as well as different kinds received from Europe, and those manufactured at the Government

Powder Works near Augusta. The average gravimetric densities of the Cannon Powders were as follows:

Navy	1025
Raleigh	1026
Foreign	875
Power Works	914
*Dupont's, U. S.	919
*Hazard's, U. S.	924
*Waltham Abbey, (English Government Powder)	872
*French War Department Powder	804

*These Powders were not experimented with—none to be had. Taken from Mordecai's Report on Gunpowder.

The specific gravity of each description of Gunpowder would have been a more accurate representation of their comparative densities, but such was not attainable; and the gravimetric densities given in the table, are sufficiently near approximations for the purpose proposed. It will be seen from it that the Navy and Raleigh Powders are very dense, and hence afforded good opportunity to compare such kinds of Powder with those of a less density. The results of such trials will be found in the tables annexed to this Report, as also those relating to the comparison of "Mill Cake" and "pressed" Powders, and the comparative strengths of grained and mealed powders, and of their mixtures.

From the above series of experiments the following facts were deduced, viz:

First.—The density of Gunpowder, resulting from more or less complete pulverization of its ingredients, the time consumed in their incorporation, and the subsequent pressure of the damp mass, should not exceed 950 ounces to the cubic foot for Cannon Powders. An increase of this density cannot be fully compensated by fineness of grain, even when carried to an extreme.

Second.—The most perfect intermixture of the ingredients appears to be in the "Mill Cake," which if broken up cannot afterwards be restored by pressure, since the former operation has a tendency to disturb the intimate association of the lighter and heavier particles, and thus cause a partial separation which simple pressure cannot restore. Hence that the requisite density should be obtained by working the mass of ingredients together, and not by means of pressure. In other words, all Cannon Powder should be made directly from "Mill Cake" of the required density, and not from cake formed by pressing Meal Powder or Powder Dust. Steaming the mixed ingredients of Gunpowder before incorporation appears to make a superior Powder in much less time.

Third.—The dust formed in the manufacture of powder has about $\frac{3}{4}$ of the strength of the powder from which it is derived, when used for artillery charges, hence it may be used for such purpose when grain powder cannot be had. The dry dust formed by the mixture of the ingredients of Gunpowder in the rolling barrels which has never been subjected to moisture, is not a true Gunpowder composition, since the pores of the charcoal have not been filled with the saltpetre, which can only be done by a more or less partial solution of that salt.

Fourth.—A mixture of as large a proportion as one-half of dust seems not materially to affect the strength of Gunpowder, hence a dusty powder is no sign of its inferior strength.

Fifth.—The size of grain of Gunpowder has an important bearing in the service of heavy artillery; if the grains be too small the strain on the gun is greatly increased, with no corresponding increase of initial velocity or range to the projectile.

Sixth.—A mixture of large and small grain powder appears to burn up in the large charges for heavy artillery as if composed entirely of the smaller size of grain, hence such mixtures are hazardous for service charges. Thus a mixture of one-half large cannon and one-half small cannon in a cartridge weighing 8 pounds, packed and fitting the bore of the 7 inch gun, with a 65 pounds bolt, without windage, gave the enormous pressure of 126,000 pounds to the square inch at the moment of discharge. The same charge, under precisely the same circumstances, of large cannon powder alone, (grains .4 inch) gave a mean pressure of 80,000 pounds.

Seventh.—A Gunpowder made of proper proportions of nitre and charcoal, without sulphur, is but little inferior to good powder of the usual composition. Thus 65 grains of Gunpowder incorporated three hours gave 1057 feet initial velocity, whilst the same weight of the nitre and charcoal powder, under the same circumstances, gave 990 feet.

Eighth.—A charge of eight pounds large cannon powder, grains .6 inch in diameter, made from "mill cake," and having a gravimetric density of about 920, with a bolt weighing 65 pounds, without windage, was entirely consumed in the seven inch gun, none of the grains being thrown out unburned.

Ninth.—A similar charge in all respects, except that the powder had been subjected to hydraulic pressure, with a gravimetric density of about 1000, on being fired, several of the grains were thrown against the screen of boards in front of the gun, apparently without having taken fire at all by the discharge.

Tenth.—The air space, in connection with a charge of powder, enables us to use a much larger grain. Thus an air space of one-half calibre, in the 7 inch gun, with the 65 pounds bolt, enables a charge of 10 pounds of powder to be entirely consumed within the gun, whose grains were from .75 to .90 in diameter, and 35 of which weighed one pound. Gravimetric density about 930.

Second Question.—*What advantage, if any, results from the employment of Air Spaces for the partial expansion of the inflamed gases of the charge, and if advantageous, what should be their dimensions, and where located?*

To determine the above over one hundred trials were made, with the guns named, but mainly with the 7 inch Columbiad, with air spaces of different dimensions, from 1-16 part of a calibre to 13 calibres in extent. In each case the initial velocities and pressures were carefully taken, the mean results of which—in the more important cases—will be found in the appended tabular statements.

In making these experiments the charges were packed into paper cartridges, fitting the bore, or with a certain less diameter, so that the influence of the actual amount of air space might be certainly made in each case. It being plain to see that the intervals between the grains of powder—the latter being in a more or less compact condition—would in themselves constitute an element to be taken into consideration; thus a service charge for a heavy gun may be settled in the cartridge so as to occupy from ½ inch to 1 inch less space in length than when loosely poured in, hence in the trials the powder was closely packed in each cartridge.

The following facts were deduced from the trials, viz:

First.—Air spaces, properly proportioned to the charge of powder, greatly diminish the strain on guns, without loss of initial velocity or range, and hence are of great importance in the service of heavy artillery especially.

Thus 8 pounds of large cannon powder (grains .4 inch diameter) packed into a cartridge fitting the bore of the 7 inch gun, with a bolt of 65 pounds, without windage, gave a mean pressure of 80,000 pounds to the square inch, whilst a similar charge in all respects of 10 pounds of the same powder, with an air space of ½ calibre, gave a mean pres- of 49,434 pounds; the addition of one pound weight of charge, (11 pounds of powder) whose grains were from .75 to .90 inch, with same air space, gave a mean pressure of 24,717 pounds, the same initial velocity being had in each case.

Second.—Retaining the service pressure on the bore of the gun, increased velocity can be given to the projectile by the addition of a proper quantity of powder to the charge, by the use of the principle of the air space.

Third.—Air spaces of about one-half the calibre of the gun appear the most advantageous, with an addition to the service charge of about one-fourth of the weight of powder. Larger air spaces give the same results of pressure, but require larger charges of powder to maintain the velocity, hence no advantage appears to be gained beyond the limit specified.

The service charge is understood to mean a given amount of the proper size of grain powder placed in a cartridge fitting the bore of the gun, and closely packed, with a square end to the cartridge next to the projectile, and the latter, if of the rifle kind, rammed well home, to cause the cup to pass over the end of the charge, so as to avoid a partial air space; or, if a round shot be used, that it shall have a proper sabot attached to it.

The above charge, when fired as above arranged, to give a mean pressure not exceeding that which in service is regarded as safe for the description of gun under trial. To ascertain this pressure in any required calibre or gun, let it be loaded as usual, and by means of the pressure piston ascertain the mean pressure of several fires. Having thus ascertained the service charge as above defined—which it will readily be seen will be in general less than that usually employed—add one-fourth of its weight for an air space of ½ calibre. By this means the strain on the gun will be reduced to less than one-half of that due to the service charge, without loss of velocity or range.

The Board have thus indicated the proper method to be pursued in arriving at the proper charges for all descriptions of heavy artillery.

The want of a gun of each calibre to experiment with, is the reason why the charges themselves have not been determined, and such data would then have formed a part of this Report, which would have, in such case, been final.

As the foregoing determination requires the use only of the pressure piston, which can be attached without injury to the gun or guns at any convenient battery, it is respectfully recommended that authority be given to the Board to make use of such guns as may be selected for the above purpose, and thus enable the Board to complete its labors in a satisfactory manner.

Fourth.—The air space would be most convenient as an air chamber in rear of the charge, or, in other words, like the chambers of Howitzers; but in the guns now in service the same end may be arrived at by diminishing the diameters of the cartridges, by passing sticks through their centres with projecting ends, or by means of the devise of the hollow cartridge, or by using a cross of light boards, joined at right angles and edgewise at their centres, to insert between the charge and projectile.

Fifth.—As all cartridges of less diameters than the corresponding bores of guns have equivalent air spaces, such must be allowed for in practice. Also the spherical form of balls without sabots, when not rammed so as to embed themselves in the charge, have a certain amount of air space in each case, which must be taken into consideration.

Sixth.—The usual custom of making cartridges of less diameters than the bores of their respective guns, is an acknowledgement of the principle of the air space; but it has not been carried sufficiently far, neither has any relation been heretofore established between the weight of the charge and air space employed.

Seventh.—The pressures at each extremity of an air space, however long in the bore of the gun, are equal; in other words, all parts of the bore, between the breech and projectile, experience like pressures on equal areas at the moment of inflammation of the charge.

THIRD QUESTION.—*What are the causes of variation in Artillery Practice, and by what means can a greater uniformity in the results be obtained?*

In the investigation of this subject the Board has no hesitation in saying, that the main cause of varied results in artillery practice arises from overlooking these important facts, that variations in the diameters of the cartridges, although apparently slight, and of the more or less loose state of the powder charges, have great influence on the initial velocities and ranges of projectiles, as well as on the strains sustained on the guns employed.

First.—Hence uniformity in the compactness of cartridges, and in their diameters, are of the first importance in the service of artillery. Thus one pound of small cannon powder, packed into a cartridge fitting the bore of the 3 inch rifle gun, gave an initial velocity of 1250 feet to a shell of 7½ pounds weight, whilst the same amount of the same powder placed loosely in the cartridge bag gave but 1042 feet; the shells in each case not being rammed, but simply pressed to its position on the charge.

Again, 8 pounds large cannon powder, in the 7 inch gun, packed in a cartridge fitting the bore, with a bolt of 65 pounds, without windage, gave an initial velocity of 1265 feet, whilst the same charge in all respects, loosely put into the cartridge bag, so as to diminish its diameter about one inch, gave only 1104 feet.

Other experiments with the other calibres gave analagous results, clearly showing the fact that very considerable variations of ranges in artillery practice will be experienced, unless great care be taken in the diameters of cartridges, and the packing of the powder.

A cartridge fitting the bore, with its powder packed, cannot be essentially disturbed by variations in the force or manner of ramming, whilst a cartridge of less diameter would either be burst by hard ramming, and thus fill the bore, or would be crowded up so as to occupy less space in a more or less degree, thus materially influencing the range of the projectile and pressure on the gun.

Again, a loosely packed cartridge will admit of the ball being cushioned in it by ramming, thus decreasing more or less the air space due to its form, and consequently affecting the range.

Second.—A second cause of variation of range in smooth bore artillery arises from the windage, and consequent ballotting of the ball, which thus does not leave the muzzle of the gun in the true line of direction. Variations of range also takes place from the different degrees of quickness of burning in the charge, hence a larger amount of its force escapes around the ball before it fairly gets into motion within the gun, at one time than at others, as no two charges burn exactly in the same time.

These two causes of variations may to a great extent be removed by wrapping the ball with cloth and driving it to its position. Thus with the 12 pounder Napoleon, with equal charges, packed into cartridges fitting the bore, the following results were obtained:

1st discharge, initial velocity ....1288 feet.
2d " " " ....1288 "

With a different charge.

1st discharge, initial velocity ....1208 feet.
2d " " " ....1208 "

With a still different charge.

1st discharge, initial velocity ....1220 feet.
2d " " " ....1220 "

6 *Pounder Bronze.*

1st discharge, initial velocity ....1296 feet.
2d " " " ....1296 "

The loss of velocity by windage is sometimes very great, amounting in some cases to the $\frac{1}{8}$ part, thus in the 12 pounder Napoleon:

1st discharge, ball of large windage, without sabot, velocity 1126 feet.
2d " ball wrapped with cloth, velocity...........1288 "

Third.—The employment of sabots, or blocks of wood, between the cartridge and ball, also affects the velocity and pressure.

If the sabots be made like those for field service, that is covering the larger portion of that part of the ball next to the charge, and thus filling up to a considerable extent the vacant or air space due to the form of the ball, the initial velocity is increased by its use. But if a simple block of wood be employed, not hollowed out, there will result a loss of range from two causes, viz: From the unoccupied air space above mentioned—no powder being added to compensate for it—and from the fact that the wood at the moment of discharge is powerfully compressed, and thus partially acts as an air space itself. All air spaces to be advantageous must have a corresponding increase of the charge, as has been seen, to prevent a loss of force.

Thus, with the 12 pounder Napoleon, a given charge gave 1288 feet initial velocity to the shot; with the same charge, but using the usual sabot, the velocity was 1296 feet. With the same charge as in the two foregoing cases, but interposing a block of poplar wood 2¼ inches thick, (cannister sabot) the velocity was 1208 feet.

Fourth.—A variation of range occurs from using powders of different degrees of strength.

This cause of variation can be easily remedied, by having the different descriptions of powder in each battery tested and classified according to strength. This can be done very accurately at Augusta.

Powder of the same classification of strength should then be used only at any one time until it is expended. In passing to another powder of different classified strength, a slight variation of elevation will in general be sufficient to maintain the former range. Those powders which by the classification shall be declared too weak or damaged for service, should be sent to the Powder Works to be renewed.

Fifth.—Rifle guns have additional sources of variation of range and accuracy.

1st. From an insufficient rotary velocity.

2d. From a defective cup or saucer.

3d. From the imperfect casting, causing the shell to crack by the discharge, and thus communicate fire to its bursting charge—which failure is in general erroneously attributed to a faulty fuse.

4th. From a defective form or model, whence arises the defects of the projectile, being too weak, too heavy, or too long for the charge of powder and twist of the gun.

An insufficient rotary velocity, resulting in the turning over of the projectile, sometimes within a few feet from the muzzle of the gun, may arise either from too small a charge of powder, or from the projectile being too long and heavy. There are two ways of obtaining a higher angular velocity; either by increasing the twist of the gun, or by increasing the initial velocity. The former cannot be done except in new guns, and in these there are practical limits which cannot safely be exceeded; the increase of velocity also has its safe limits, beyond which it would create a hazardous strain on the gun, by the necessary propelling force employed.

Hence those projectiles whose defective models cannot be safely compensated by the above, and hence must remain variable in their results, should be rejected. This applies particularly to those heavy bolts, and sometimes shells, which in many cases considerably exceed the limits within which a safe charge could communicate the necessary initial velocity to produce the required angular rotation. The above is mainly the reason why the Board, in their first Report, recommended projectiles of less weight and length than many which had been and are still employed in service.

The cups or saucers at the base of rifle projectiles are frequently defective in having their edges too thick, whence they do not expand sufficiently quick, and thus allow a considerable portion of the force of the charge to escape around them. A certain amount of force is required in each case to expand the cup and cause it to take the grooves, and if any of the charge be lost from the above cause, what remains may be insufficient for the purpose.

Hence the edges of the cups should be quite thin, or they should be sawed into several segments, to the distance of about $\frac{1}{8}$ of an inch from the edge downwards, so as to permit the latter to readily yield to the first pressure, and thus prevent the escape of a portion of the inflamed gases.

The lubricating ring between the base of the projectile and cup acts mainly in assisting to close the windage at the first moment of inflammation, and thus more certainly insures the expansion of the base. As far as the lubrication of the gun is concerned, it can more certainly and effectually be accomplished by pouring a sufficient amount of the material melted into the bottom of the cup, which at the time of the discharge will be dispersed throughout the bore of the gun. The lubricating material in this case should not be hard, but rather of a soft consistency.

Fourth Question.—*The use of the Air Space in Artillery involves the necessity of placing the projectile farther towards the muzzle, or of allowing an interval between it and the charge. What is the maximum interval that can be safely allowed, or is there any danger to the gun by thus displacing the projectile from its usual position, resting against the charge?*

In the series of experiments, undertaken to elucidate this subject, with the different guns at the disposal of the Board, the fact was clearly established that the common opinion, as to the danger incurred in the displacement of the projectile from the charge, is without sufficient foundation. That the maximum strain on the gun is experienced when the projectile is closely rammed home on the charge, the latter being packed and fitting the bore. That in proportion as the projectile is removed from the charge towards the muzzle the strain decreases, and is at its lowest point when it is at or near the muzzle itself.

Thus 2 lbs. of small cannon powder has been repeatedly fired with three balls placed within 2 calibres of the muzzle of the 6 pounder; also several charges of the same weight of powder, and the ball wrapped with cloth, and driven tightly to the same distance from the muzzle. In all these cases no injury whatever was experienced by the gun.

Again in the 7 inch gun, with 8 lbs. large cannon powder, with the bolt of 65 lbs. tightly fitting the bore, the average pressure, as has been seen, was 80,000 lbs. to the square inch. When the bolt was placed at 30 inches distance from the charge, all other conditions remaining the same, the pressure was only 6253 lbs., and at 2 calibres from the muzzle the pressure fell to an average of 2617 lbs.

Thus no danger whatever arises from leaving a single projectile in any part of the bore, but on the contrary the strain on the gun is greatly decreased by removing the projectile to some distance from the charge of powder.

Fifth Question.—*Is there any danger to the Rifle Gun should the projectile fit so tightly as to require to be driven to its position on the charge, and should it get jammed in the act of loading, would there be hazard in firing off the gun in such condition!*

Experiments conclusively demonstrate that in all cylindrical projectiles which have been turned in a lathe, no amount of force that can be generally employed to drive them home on the charge, affects in the slightest degree the pressure or strain on the gun at the time of the discharge. This might be reasonably inferred without experiment; for as such projectiles cannot by any movement increase their diameters, the additional strain on the gun would be simply that due to the additional force required to overcome the friction. This has for its measure the force which was expended in driving the projectile home; but such an amount of force is inappreciable when compared to the immense force exerted by the charge in overcoming the inertia of its mass.

The preceding discussions plainly show that no danger can be incurred in firing off a gun, with a turned cylindrical projectile, which shall become jammed in the bore. The case would be very diﬀerent with spherical projectiles, for as these are never turned off to a true form, it might happen that a larger diameter would be brought into action by the rolling movement, and thus operate upon the principal of the eccentric press, wedging the gun asunder: thus a tight fitting naked shot would be too hazardous for service.

Sixth Question.—*Is there any fixed relation between different amounts of Gunpowder and the corresponding initial velocities; that is will successive additions of equal weights of powder produce an equal increase in the corresponding initial velocities!*

Experiments show that in those charges which are entirely consumed within the gun, and not too small in quantity, equal increments of powder correspond to nearly equal increments of velocity. Thus in the 3 inch gun 1 lb. of small cannon powder gave 1250 feet initial velocity; $\frac{3}{4}$ lb. gave 1040 feet; $\frac{1}{2}$ lb. gave 800 feet; each quarter of a pound, starting from the half pound charge, giving about 240 feet increase of velocity.

This also holds good of small arms, between certain limits: thus 45 grains of rifle musket powder, with an expanding projectile of 535 grains, in the Enfield rifle, gave 829 feet initial velocity; 55 grains gave 952 feet; 65 grains gave 1078 feet; or about 125 feet velocity for each 10 grains of powder. Below 40 grains of powder, there is not sufficient force to properly expand the base of the ball, and above 65 grains a portion of the powder is not consumed. A similar observation applies to artillery practice, for below a certain initial velocity the cup of the rifle projectile does not expand and take the grooves, and above a certain weight of charge the powder is not wholly burned.

SEVENTH QUESTION.—*Does a high angle of firing in the practice of Artillery increase the strain on the gun?*

Experiments were conclusive on this point, showing that firing at angles of elevation does not affect the pressure on the bore of the gun due to the same charge fired horizontally. Thus the mean of three charges of 8 lbs. large cannon powder, packed into a cartridge ⅝ of an inch less in diameter than the bore of the 7 inch gun, with a bolt of 65 lbs. without windage, gave a mean pressure of 64,000 lbs. to the square inch, when fired with the bore in the horizontal plane. The same charge in all respects, when the gun was fired at an angle of 40° elevation, gave a mean pressure of three discharges somewhat less than the above.

MISCELLANEOUS DATA.

1st. The projectile being placed inside of the bore and near the muzzle, with the charge of powder next to it, if the latter be fired in its extremity next to the breech, the pressure will be found exceedingly small, scarcely sufficient to throw the projectile ten feet from the muzzle of the gun, as the cartridge and ball are thrown out together before time has been given for but a small portion of the powder to be consumed within the gun. If the charge be fired at its end next to the projectile the pressure and explosion will be greater, though still much inferior to what it would have been with the cartridge at the bottom of the bore.

2d. The force of the charge, in small rifle guns, must be able to impart an initial velocity of not less than 1000 feet to the projectile, to insure the expansion of the cup into the grooves of the gun. Similar data in relation to large rifle guns remains to be determined.

3d. There appears no necessity for turned bolts having a greater windage than .05 inch for smooth bore guns; and if they be made with a recess of 1½ inches broad and about 3-16 inch deep, in that extremity next to the charge, and this be filled up with lubricated strips of cloth, all windage will be prevented, and additional force and accuracy given to this species of projectile.

4th. A few heavy charges is not proof that a gun will be able to continuously sustain them. Thus a 12 pounder gun was finally burst at a considerable less pressure than what it had previously, at several times, sustained without apparent injury.

5th. The pressures in the use of service charges in field artillery are about half those of smooth bore heavy guns.

6th. Half the charge of powder with a double weight of projectile, gives the same pressure in heavy artillery as a full charge and a single projectile.

7th. A charge of powder fired in a space of twice the capacity of the charge reduces the strain on a large gun to one-fourth. The above two results are in confirmation of Capt. Rodman's experiment; they do not hold good for small pieces.

8th. A bolt of one calibre in length, without windage, with a given charge, causes nearly twice the strain on the gun to that produced by a round shot without sabot. A part of this diminished pressure is due to the less weight of the ball, and a part to the air space due to its spherical form.

RECAPITULATION.

GUNPOWDER FOR ARTILLERY.

First.—It is not advantageous for cannon powder to exceed a gravimetric density of 950.

Second.—All cannon powder should be made from Mill Cake of the proper density, and not from pressed cake, or cake formed by pressing dust.

Third.—Powder for large cannon, if made from Mill Cake of a gravimetric density of not exceeding 930, should not have a less size of grain than from ½ to ¾ inch in diameter. If air spaces be employed, the grains should not be less than from .75 to .90 inch diameter for all calibers above 7 inches. For very large guns with air spaces, as the Great Blakely guns, the grains should be over one cubic in capacity, or each grain should weigh about one ounce.

Fourth.—Unless the powder be of excessive density, any mixture of small cannon or fine grain powder with large cannon powder should be most carefully avoided as very hazardous in the service of heavy guns, without any corresponding increase of force or range to projectile.

AIR SPACES.

First.—Air spaces properly proportioned to the charge of powder greatly diminishes the strain on guns without loss of initial velocity or range, and hence are of great importance in the service of heavy Artillery; they may be in front, rear, inside or outside of the Cartridge.

Second.—Air spaces of about one half caliber of the gun appear the most advantageous as far as tried, with an increase to the service charge of one fourth the weight of large grain powder.

Third.—The most convenient form for the air space would be a chamber to the gun, but the usual service Artillery may be used with air spaces by making the Cartridge hollow, and thus containing the necessary space in itself; or the cartridge being compact, with a square or flat end, two pieces of board fixed together at right angles edgewise, forming a cross, might be inserted in the bore of the gun, so as to keep the projectile a proper distance from the charge. These wood crosses could readily be made, and easily used like wads.

Fourth.—Cartridges of less diameter than the bore of the guns to which they belong have equivalent air spaces; spherical projectiles also leave spaces due to their form, next to the charge. Such air spaces however are variable in dimensions, and hence objectionable.

CAUSES OF VARIATION IN ARTILLERY PRACTICE.

First.—Uniformity in compactness of cartridges and in their diameters are of the first importance in the service of Artillery, and the want of which is the main cause of variation of range in Artillery practice.

Second.—Cartridges for Artillery should be made to fit the bore of the gun, the powder well packed, with the end next to the projectile flat. Such cartridges can be made by first making a cylindrical bag to fit the bore, and placing within this a thin paste board cylinder without ends of nearly the diameter of the bore. Into this pack the charge well, and insert at the open end a circle of wood about $\frac{8}{4}$ of an inch thick, with a deep groove cut into its edge; the paper cylinder being cut just the height of the charge, the open end of the bag is drawn up tightly around this circle of wood, which is pressed down on the powder, and then firmy tied in the groove. Hollow cartridges can be made in the same manner, first inserting a hollow cylinder or paste board, or tin, with closed ends, having the required capacity of air space.

Third.—Spherical projectiles for smooth bore heavy artillery should have sabots attached to them separate from the cartridge. Such sabots should be hollowed out in the end of the fibres of the wood, so as to cover as much as practicable the part of the ball next to the charge. Such sabots will answer a double purpose of filling up the empty space—the air space being otherwise obtained—and also preventing the rolling forward of the ball in the bore in firing on a level, or at an angle of depression; the wood cross before alluded to could be used for this last purpose. At the instant of firing the sabot is forced forward on the ball thus filling up the windage and preventing to a considerable degree the balloting of the projectile.

Fourth.—Powders at the different batteries should be tested and classified not less than every six months, if put up in cartridges; if in the original boxes or barrels, once each year would be sufficient. In the practice of Artillery the powder of the samé classification should alone be used until expended; a slight change of elevation would then maintain the same range with another class of powder.

Fifth.—Cartridges as usually made by tieing up the open end of the bag after being filled with powder, are liable to give with the same charge different results, on account of want of compactness and the more or less space between the charge and the projectile, resulting from the neck of the cartridge.

Respectfully submitted,

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Table of a portion of the results obtained from Experiments made at Augusta Arsenal.

No. of Fives	Kind of Powder.	Nature of Cartridge.	Diameter of Cartridge.	Powder Loose or Packed.	Weight of Charge.	Weight of Projectile.	Diameter of Projectile.	Caliber of Gun.	Angle of Electric Pendulum.	Initial Velocity.	Pressure per Square Inch.	Extent of Air Space.	REMARKS.
			COMPARATIVE STRENGTH OF POWDERS.							Feet.	Lbs.	Inches.	S. C. for Small Cannon.
3	Raleigh, S. C.	Flannel	Service	Service	1 lb.	$7\frac{1}{2}$ lbs.	Service	3 inch	20°.2	1021	34,602	Service	L. C. for Large Cannon.
3	Navy, S. C.	"	"	"	"	"	"	"	19°.6	1112	35,083	"	
4	Foreign, S. C.	"	"	"	"	"	"	"	19°	1149	45,962	"	No L. C., Foreign, on hand
8	Powder Works, S. C.	"	"	"	"	"	"	"	18°	1211	51,345	"	
3	Raleigh, L. C.	"	"	"	8 lbs.	65 lbs.	6. 95	7 inch.	26°	839	14,671	"	
4	Navy, L. C.	"	"	"	"	"	"	"	22°.7	931	17,589	"	
4	Powder Works, L. C.	"	"	"	"	"	"	"	19°.6	1110	34,686	"	
				MIXTURES OF POWDERS.									
1	$\frac{1}{2}$ S. C. & $\frac{1}{2}$ L. C.	Flannel	Service	Service	1 lb.	$7\frac{1}{2}$ lbs.	Service	3 inch.	23°.9	910	40,030	"	
1	$\frac{1}{2}$ R. M. & $\frac{1}{2}$ S. C....	"	"	"	"	"	"	"	17°.8	1225	67,506	"	
2	$\frac{1}{2}$ Meal & $\frac{1}{2}$ S. C.....	"	"	"	"	"	"	"	18°.1	1207	34,341	"	
3	Meal Powder.......	"	"	"	"	"	"	"	22°	1024	13,153	"	
2	$\frac{1}{2}$ L. C. & $\frac{1}{2}$ S. C....	Paper	6. 9 in.	Packed	8 lbs.	65 lbs.	6. 95	7 inch.	17°.1	1280	126,997	"	
						AIR SPACES.							
			Inches.										
2	L. C...............	Paper	6. 95	Packed	8 lbs.	65 lbs.	6. 95	7 inch.	17°.4	1265	80,079	"	
3	L. C...............	"	6. 5	Loose	"	"	"	"	17°.5	1251	67,249	1	
3	L. C...............	"	6. 0	"	"	"	"	"	19°.5	1120	46,000	2	
3	L. C...............	"	6. 9	Packed	"	"	"	"	18°.6	1176	35,182	$3\frac{1}{2}$	

5	L. C...........	Paper	6. 9	Packed	8 lbs.	65 lbs.	6. 95	7 inch.	20°.4	1071	22,165	5	
2	L. C...............	"	6. 9	"	"	"	"	"	21°.4	1020	14,000	8	
1	L. C...............	"	6. 9	"	"	"	"	"	27°.9	775	6,253	30	
2	L. C...............	"	6. 9	"	"	"	"	"	36°.8	579	4,903	52	
3	L. C...............	"	6. 9	"	"	"	"	"	60°.6		2,414		Bolt 2 calibres from muzzle.
2	S. C...... (Powder Works, made from Mill Cake)	"	6. 95	"	"	"	"	"	16°.3	1344	69,619	3½	Grains .12 inches in diameter.
3	L. C. No. 4	"	"	"	12 lbs.	"	"	"	16°.5	1328	43,361	7	" .4 " " "
3	L. C. No. 4	"	"	"	12 "	"	"	"	16°.7	1312	38,274	9	" .4 " " "
4	L. C. No. 4	"	"	"	10 "	"	"	"	17°	1288	49,434	3½	" .4 " " "
5	L. C. No. 3	"	"	"	11 "	"	"	"	17°.2	1272	37,896	3½	" .6 " " "
3	L. C. No. 2	"	"	"	11 "	"	"	"	17°.2	1272	24,717	3½	" .87 " " "

MILL CAKE AND PRESSED POWDERS.

3	L. C. No. 3.........	Paper	6. 95	Packed	10 lbs.	65 lbs.	6. 95	7 inch.	17°.2	1272	38,171	3½	Mill Cake, not pressed.
3	L. C. No. 3.........	"	"	"	"	"	"	"	18°.1	1206	42,409	3½	Pressed Dust.

STEAMED AND COMMON POWDERS.

2	S. C. Powder Works,	Flannel	Service	Service	1 lb.	7½ lbs.	Service	3 inch.	18°.5	1182	65,054		Service powder, incor. 4 hours
2	S. C. " ..	"	"	"	"	"	"	"	17°.1	1280	53,470		Steamed and incorp'd 1 "

PRESSURE AT EACH EXTREMITY OF A LONG AIR SPACE.

5	S. C. " .	Flannel	Service	Service	1¼ lbs.	6.25 lbs	Service	6 pdr.			11,993	55	Piston at charge at breech } ball tightly driven in.
5	S. C. " ..	"	"	"	"	"	"	"			12,107	55	Piston at ball near muzzle } ball tightly driven in.
2	L. C. " ..	Paper	6. 95	Packed	8 lbs.	65 lbs.	6. 95	7 inch.	36°.8	579	4,903	52	Piston at charge at breech.
1	L. C. " ..	"	"	"	"	"	"	"	31°.4	685	5,151	52	Piston at projectile.

COMPARISON BETWEEN ELECTRIC & BALLISTIC PENDULUMS.

7	Rifle Musket " ..	......	......	.....	65 g'ns	540 g's	......	......	6°.49	1123	Initial Velocity by Ballistic Pendulum, at 6ft.		
8	" " " ..	......	......	......	"	"	......	......	19° .5	1120	Initial Velocity by Electric Pendulum, at 38ft.		