HEAVY RIFLED ORDNANCE,

CAST IRON AND WROUGHT IRON.

REVIEW OF THE REPORT

OF THE

LATE ORDNANCE SELECT COMMITTEE,

ON THE TRIAL OF

UNSTRENGTHENED

RIFLED CAST-IRON SERVICE GUNS,

Under the altered circumstances now arising from the adoption of Pebble Powder.

The principle of the Modern Construction of heavy Guns considered in reference to economy of labor and material, and the means of obtaining supplies,

WITH TABLES OF RESULTS,

And an Analysis of the forces developed in various Guns now used.

BY BASHLEY BRITTEN.

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SYLLABUS.

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REVIEW OF

THE REPORT

OF

LATE ORDNANCE SELECT COMMITTEE,

On the subject of *Rifling the Cast Iron Service Guns* without resorting to any plan for strengthening them.

THE above Report, printed by the War Office in 1863, is an official document of considerable length, and is drawn up with much care. It carries with it also such strong internal evidence that the distinguished officers, whose names appear on the title page, had every desire to perform their duties with strict impartiality to all whose interests were concerned, and, at the same time to promote the interests of their profession, that the Report could not fail to command the official respect which it received from the War Office, and be treated as authoritative and conclusive.

In taking upon myself therefore the task of calling in question the soundness of the views the Committee adopted, I am fully sensible that I lay myself open to the imputation of presumption. Nevertheless, I may observe that having been called upon by the War Office under the administration of the late Lord Herbert to demonstrate my views fully in reference to the plan I had submitted for rifling our cast-iron guns, which plan he had referred in a special manner to the consideration of the select Committee, a duty devolved upon me which remains unfulfilled so long as the subject continues unsettled and unexhausted.

For the ultimate decision of the authorities was a peculiar one. It admitted fully and fairly that my invention had succeeded, and accomplished all that I ever claimed in favor of it; yet, while the credit was awarded to me of having effected what was aimed at, I was not to have the satisfaction of seeing my labours crowned with any useful result.—I was told in the same sentence that I had succeeded —and failed.

The question was, and still is, one of very unusual public importance. At this moment of political disturbance abroad it is even of greater national concern than it was when dealt with formerly. The seven years which have elapsed have not rendered it obsolete. It has met with the cold shoulder and been cast aside, but its relations to actual circumstances remain the same as they were.

Is it to be supposed that because gigantic guns can now be made therefore no smaller ones will in future be wanted? To act against iron defences of course the power of artillery must be made superior to the means of resistance. But for all services in which iron defences will take no part, such as opposing the advance of troops, or attacks from vessels, not absolutely invulnerable; for protecting land faces; for commanding sea fronts, where, from insufficient depth of water, no iron-clad ships could approach, in fact, for all the *general purposes* of war moderate-sized guns will surely continue to be wanted as much as ever. Guns of enormous weight and power will never really be used for doing work which does not require such power.

Our position therefore at the present moment is just what it was ten years ago. Little enough has been done to alter it, and the case stands thus.—

At a vast cost we have during past generations accumulated at home and abroad an enormous stock of some forty or fifty thousand pieces of heavy ordnance, with the requisite ammunition adapted for them. Owing however to modern improvements in artillery, this ordnance in its present condition is so inefficient as practically to be of little use. We are therefore in this dilemma:—Either these cast-iron guns must be improved, or else they must be abandoned and others substituted for them, how, and *when* we can.

The loss to the country which the latter course involves is so enormous that it can hardly be stated. It is absolutely one affecting public property to the extent of *hundreds of millions sterling*, in fact, so large a sum that it *cannot be provided*, and it really comes to this that we should have to go without the proper supply, and take the chance of being found unprepared for defence.

To avoid this, to some extent, a plan has been proposed and partially adopted for improving these old guns by strengthening them with an inner gun or tube of coiled wrought-iron. This, no doubt, accomplishes one object, it makes the guns stronger. But in doing this, other considerations of moment are involved.

1.—The expense of so altering or re-making them is no less than twice as much as the original cost of the guns.

2.—It does not enable us to obtain the large immediate supply of rifled guns we need, because the labour required in so treating them is great; special machinery of great power and nicety is wanted for the work, and all the guns must consequently be sent to Woolwich or Elswick to be converted.

3.—It involves the disturbance and revolution of our armaments all over the world, and the moving and transport of the guns to the factories here, and then back again to the forts.

4.—The work would interfere with, and prevent the execution of other urgent demands on the mechanical resources of our national workshops, viz.,—the making of those guns of a different type rendered indispensable by the recent introduction of iron defences.

For these and other reasons, it may be doubted whether the adoption of this plan, the merit of which is due to MAJOR PALLISER, really affords a solution of the difficulty. It is moreover a very open question whether it can be a wise economy to spend from £100 to £200 merely to alter an old gun, when for comparatively little more money, we could furnish ourselves as soon with a new one, possibly somewhat better, and at the same time retain the old one, which certainly has a value as it is.

There is another alternative—(1.) *Cheaper*, because for the same money it costs to strengthen one gun as proposed, *more than a hundred of our guns may be rifled and made efficient*: (2) *More readily available*, because it can be effected simultaneously everywhere by portable machinery, without either removing the guns from where they are, or interfering with the other work of our gun factories; and (3) *not less effectual*, because when so improved they would equal the strengthened guns generally in practical efficiency, and at the same time we should retain the use of the old ammunition in our stores, which for certain services is known to be superior to anything else that can be used.

Such is the plan that was proposed by me; it was merely to rifle the guns as they stand, in such a manner that with projectiles of a particular nature which I had schemed, they might be so employed with perfect safety. The cost of doing all that the guns required was estimated at the Royal Gun Factories to be about 10*s.* a gun. For nine years this plan was tried, and it *never was found to fail;* and it forms the subject of the official report of which I am about to speak.

The conclusion which the Committee came to, is summed up in the following words, which close their report:—

"It will be observed that MR. BRITTEN's results are obtained at a cost of much less strain on the gun than those of either of the other plans, and the Committee believe that *if circumstances of urgency warrant the rifling of cast-iron, it may be done on this system with less risk than any other they are at present acquainted with.*"

"Such guns would, however, if made, be perhaps capable of firing round shot, common shell, shrapnell shell, grape or case shot, with a reduction of the present service charge, (the reduction of the 32-pounder charge from 10-lbs. to 8-lbs., only reduces the velocity from 1690 to 1619 feet,) and apparently with little or no loss of accuracy. They would fire an elongated common shell, *containing* three times the bursting charge of the round shell, and *weighing twice as much,* with half the service charge, or perhaps less; but *obtaining ranges exceeding those of the service round shot, and possessing much greater precision* For those artillery services in which low charges are necessarily employed, such as enfilading short fronts, dismounting ordnance behind traverses, or breaching sunken defences, *they would probably equal wrought-iron ordnance.*"

This decision was formed when really the Committee had no means of forming an opinion with regard to the ultimate capabilities of the scheme. It was quite in its infancy. Matters of detail as regards the rifling of the guns, and also respecting the construction of the projectiles yet remained to be worked out, before anything like perfect results could be looked for, either in the length of range or degree of precision attainable. All I had been attempting was to establish a *prima facie* case, conceiving that if this were accomplished I should have been permitted to carry the matter to its completion.

Taking these admissions of the Committee as I find them, I think I might very fairly put this question.—

If the admitted benefits can, under *any* circumstances, be made available at so little cost and so easily, why should not advantage be taken of them without delay? But I will pass this point and proceed to enquire what really is that "risk" to which the report alludes?

Now, I have a perfect knowledge of all that was done in this matter, and, as it will be seen in the following pages, I have investigated the whole question with considerable care. Speaking then advisedly, I declare that not one fact ever came to the knowledge of the Committee, or can be found in the records of their proceedings, that affords the slightest ground for the apprehension of increased danger from the application of my invention.

All the facts which the Committee had gathered were entirely opposed to this idea. More guns were tried on my plan than on any other having a similar object, the experiments were made on a large scale, thousands of rounds were fired, yet *not a failure of any kind occurred*; nothing came to light which by any logical process could be construed into evidence of "risk."

The fact is that the examination of the subject was made tardily, and it became embarrassed by trials of competing schemes, which, not being similar, raised issues utterly false in their relation to the principles on which my invention is founded. Irrevelant facts thus got mixed up together, and at length the question grew into such a tangled mass of confusion, that I feel it almost hopeless now to extricate it. I shall however make another effort to do so, but I see before me a rather severe work. I have no option left but to dig to the very roots of the difficulty, and as far as I can demonstrate the extremely subtle considerations upon which the real issue depends. I shall have to produce and compare a great array of facts and figures, very dry and uninteresting to look at superficially, but which, if properly examined, will be found to produce clear light.

Looking broadly on all that is contained in the printed proceedings of the Committee, it appears to me that the whole enquiry from the very outset was hampered by the assumption of certain *premises* which were wholly unsound. The Committee saw in the results of my experiments a far greater amount of *useful work* performed by my rifled gun, than is obtained with the same gun under the ordinary conditions with a smooth bore. Notwithstanding therefore that I employed only half the usual service charge of powder, the amount of strain the gun had to bear was guessed at from the shooting, not *measured by the real amount of work* which the gun performed in both cases.

The proposition is very simple. Does a 5-lb. charge with a 50-lb. shot cause more strain than a 10-lb. charge and a 32-lb. shot when fired from the same gun? The decision of the Committee really amounts to the affirmation of this. But I am sure no individual member of that body would be willing to uphold such a view.

There is said to be risk from the small charge greater than the large one. But what evidence is there of this? Of the many guns I tried, not one ever suffered, and they were tried in every way that could be thought of, and the trials only stopped at last because the *practical test had exhausted itself*, and so far established the very opposite conclusion to that which was simply taken for granted and acted upon.

As a consequence, the result of all that had been done was negative. Our old guns remain at this moment as they were, except a few which have been strengthened at great cost.

We have been spending vast sums of money, our gun factories have been fully employed, and we have got just

1600 rifled cannon in our service, (besides field guns,) which can be relied upon for actual service, including the strengthened *Palliser* guns. *As many at least as* 19 *out of every* 20 *guns belonging to us are still smooth-bored guns.* What, it is alleged, we cannot do to improve these, other nations have done. Belgium has rifled nearly all her cast-iron guns, and if ours were opposed to them the difference in their effectiveness would be terribly apparent. France has done the same to a very large extent, and so also, I believe, has every other military power *but Great Britain.*

Now in direct opposition to the views of the late Committee I propose to maintain the following proposition, and in doing so, I trust it may be understood that I submit my views with all proper deference.

If our cast-iron guns are serviceably safe with the ordinary charges used for them, there are sufficient grounds for believing that they would be in no degree less safe when employed as rifled guns, with other conditions of charge which might render them thoroughly effective, and inferior only in a small degree to any rifled guns of equal weight that it is possible to construct.

The latter portion of this proposition belongs to that branch of the subject which may be found discussed in the after part of this paper.

I suppose I may assume that cast-iron guns are not too dangerous or uncertain to use with the old-fashioned charges, because otherwise, the charges would certainly have been reduced. A theoretical point therefore presents itself of this nature.—

As the force or the vis viva of the projectile is the resultant of the expansive force of the charge when exploded, acting equally against the bore of the gun exposed to it, as on the sectional area of the shot, so the vis viva of any two projectiles of different weights, fired from guns of the same dimensions, with the same quality, but different quantities of powder, must afford direct means of comparing the relative amount of lateral pressure or strain produced on the gun in both cases: other things being equal, or allowed for.

It is a fact which admits of clear demonstration, that a 32-pounder smooth-bore gun, firing the round shot, with 10-lb. service charges, really does *far more work* than when firing my 50-lb. projectile with only 5-lb. charges.

It is proved by the following figures, based on the actual measurements which have been carefully made of the velocities of the projectiles on leaving the guns.

Comparison of the amount of *work done* by the ordinary service charges of powder in firing round shot from smooth-bored 32-pounder guns, and the *work done* by the reduced charges employed in firing BRITTEN'S heavier projectiles from similar guns, when rifled according to his system.

	32-Pndr. Smooth-Bore Service Charges.	32-Pndr. Rifled Service Charges.
Charge of Powder	10-lbs.	.... 5-lbs.
Weight of Projectile	31.6	.... 50.36
Velocity at muzzle, as ascertained by Electro-Ballistic Apparatus of *Navez*	1690 ft. per sec.	...1209.2
Work done by Powder in moving Projectiles, i.e., Weight × Velocity squared ÷ 64.3 gravity	ft.-lbs. 1,403,600...	1,145,200
Less work done by the reduced charge in giving motion to the heavier projectiles......... ft.-lbs.	258,400	

Proportion, 18.3 per cent. less.

This is only what the merest superficial glance would lead any one to expect, and it accords perfectly with the fact observed in practice, that the *recoil* of the rifled gun, or the result of the rearward action of the charge, was, as nearly as could be observed, proportionate to the diminished force developed in the shot with the smaller charge.

But it may be asked,—how does this agree with the greater efficiency of the rifled gun? There is no difficulty in explaining this. It is only necessary that a proper distinction should be made between the *real or total work*, and the *useful or available work* done by each gun.

The 32-lb. round shot is delivered by the 10-lb. charge with a velocity of 1690 feet per second, or nearly half as much again as the speed with which air will rush into vacuum, which is 1334 feet per second. So great is the consequent resistance to the shot, formed by the air compressed in front of it, and the vacuum formed in the rear, that *in the first 30 yards of its flight* it is found to lose as much as 36 feet per second of its velocity. The 50-lb. shot, however, leaves the gun with only a velocity of about 1209 feet. The fluid penetrated has therefore more time to get out of the way of this shot, and re-arrange itself again as it passes through it. As a necessary consequence less of its force becomes destroyed, and it was found to lose only 9½ feet per second in the same distance traversed. These facts have been established by accurate measurements taken at this distance, and I quote them from the official report.

From these times of short flight we can calculate exactly what is the *amount of force* lost in each instance, and it will be seen to be as follows.—

Loss, from atmospheric resistance, of the vis viva of projectiles of different weights fired with different velocities, from 32-pounder guns of the same length and calibre, in a range of 90 feet from the gun.

	Weight of Shot.	*Velocities ascertained.*		*Vis Viva.*	*Difference.*
	lbs.		feet per sec.	ft.-lbs.	ft.-lbs.
Smooth-bore charge 10 lbs.	31.6	At muzzle,	1690 ...	1,403,600	
		At 30 yds.	1653.7 ...	1,361,000	
			36.3	vis viva ...	42,600
Rifled, *Brittens,* charge 5-lbs.	50.36	At Muzzle,	1209.2 ...	1,145,200	
		At 30 yds.,	1199.7 ...	1,119,200	
			9.5 ...	vis viva ...	26,000
Total difference of loss of effect in travelling the distance of 30 yards from the muzzle of each gun...					16,600

In longer ranges the difference becomes much more marked, and the actual results may be determined with tolerable exactness relatively by the observed times of flight which have been noted. I compare the same guns and projectiles thus:—

Loss of Range and vis viva of solid round shot, fired from 32-pounder service guns, with service charges, compared with that of the heavier projectiles fired with half the same charge from similar guns rifled on *Britten's* system.

	Smooth-Bore 32-pounder, Charge 10 *lbs., Shot* 31.6 *lbs.*				*Britten's Rifled 32-pounder, Charge* 5-*lbs., Elongated Shell.* 50.36 *lbs.*			
Ascertained velocity at Muzzle	1690 ft.		Vis Viva	1,403,600	1209.2		Vis Viva	1,145,200.
Ditto at 30 yds.	1653.7		"	1,361,000	1199.7		"	1,119.200.
	Range yards.	Time of Flight.	Mean Velocity, ft. per sec.	Vis Viva ft.-lbs.	Range yards.	Time of Flight.	Mean Velocity, ft. per sec.	Vis Viva. ft.-lbs.
2° elevation*	1172	3.59	979.3	477,200	1010	2. 9	1045	849,200
5° " *	1882	6.59	856.7	365,200	2100	6. 4	984.3	753,400

From this it is perfectly clear that with the ordinary charges adopted for smooth bore guns, a very large proportion of the work done is simply expended in beating the air; while, with the conditions which I applied to the guns, there was very much less waste. The 10-lb. charge does more actual

* The round shot practice given here shews the mean results, as stated in the Committee's report, of 20 rounds at each elevation fired at Shoeburyness, in August, 1861, with full service charges and common round shot, out of *Britten's rifled gun,* to compare with an equal number fired at the same time from a similar gun, smooth-bored The ranges of the rifled and smooth-bored guns proved equal, but the accuracy of the rifled gun was somewhat greater.

The object of this experiment was to test the rifled gun as regards adaptation for firing the spherical projectiles of the service. The gun was in no way injured by it.

work than that of 5-lb. in the proportion of 140 to 114 But as the lighter and more active round shot penetrates through the resisting medium, its living energy is more rapidly destroyed than that of the slower and weightier projectile, so that in the course of 1000 yards the latter retains more life in it than the other, in the proportion of no less than 85 to 48. In 2000 yards the proportion is 75 to 36.

These facts fully account for the phenomena which presented themselves in obedience to physical laws, and they prove indisputably that the rifled guns could not have been doing any *extra* duty as it was assumed they did. If the rifled gun had been fired with charges which produced more force than that of the larger service charge in the smooth bore, *this must have shown itself in the force of the shot as it emerged from the muzzle.*

It is very remarkable that this view of the question does not appear to have suggested itself to the Committee who had to investigate it, for in no part of their proceedings is any allusion made to it. They do not appear to have attempted any diagnosis of the results, but merely took the bare results as they showed themselves in the longer ranges of the heavier projectiles, and assumed these to be the proper criterion of the duty performed by the gun in controlling the charge.

But it may be said with perfect justice that this line of reasoning only applies to cases where the projectiles would be equally free to move through the gun, and one gun being rifled an allowance has to be made. There might be a very serious obstruction arising from this; and the Committee had before them the undeniable fact that many of these cast-iron guns had burst when firing charges which produced no more force in the projectile than I obtained. I shall presently endeavour to trace the causes to which I consider these failures may fairly be attributed, and which do not exist in my system;—but in the first place let it be estimated to what extent the rifling could affect the safety of the guns as I employed them.

It is by no means difficult to determine, with tolerable precision, what extra work the rifling involved with my system. There are two forces to be measured.—That which is employed in giving rotatory motion to the projectile, and there is the resistance due to the friction upon the guiding sides of the rifling while this work is being done.—It is moreover to be remembered that the rifling itself would take away something from the substance of the gun. What then does this altogether amount to?

The grooves I employed were one-tenth of an inch deep, and the thickness of metal round the bore is $7\frac{1}{4}$-inches at that part where the strain is at all severe; this consequently could not interfere much with the strength of the gun. One of my competitors boldly employed helical channels just three times as deep as I did, and this gun, a 32-pounder, similar in all other respects, never failed, although fired 2000 rounds with 1-lb. more powder than I used, and shot as heavy as mine. The twist in the rifling of my guns was one turn in 48 feet, (90 calibres;) at the velocity imparted the shot, if it strictly followed the course of the grooves, would thus make 20 turns in every second, (in the *Whitworth* gun, the rifling has one turn in 8-ft-4, and the shot makes 240 turns per second.)

The force then required to make my projectile spin at the above speed can easily be estimated, and may be seen to be comparatively insignificant. Treating it like any other cylinder revolving about its axis with the power applied directly to its periphery, and allowing for the centre of gyration to be somewhat beyond that of a solid cylinder, the force required to turn it would be something less than 2 per cent. of that represented in the vis viva of the shot. The resistance from friction may likewise be reckoned. Making full allowance for the nature of the rubbing surfaces, it could not possibly amount, in mechanical effect, to more than about $\frac{1}{6}$ *of the pressure that is required to turn the shot*, so that really there is nothing in these forces taken together of sufficient magnitude to be worth regarding. They could not be more than equivalent to the resistance of an additional 20 ounces to the weight of the shot, if free from any rifling.

If however an allowance were made of twice as much force as a true calculation shews to be the correct estimate of the resistance due to the rifling in this gun, there would still remain a difference of *nearly* 15 *per cent. less total work done by the rifled gun* than the smooth-bore with the heavier service charge.

I may mention a fact which affords a practical proof of the resistance from the rifling being but small.—The distinctive principle of my system of projectile, is that the rifling shall only act upon yielding surfaces of soft metal, such as lead. The shot go into the gun without any studs or projections upon them; instead of these I have an envelope of lead, securely attached to the rear of the projectile going next to the powder, and so formed that the force of gas upsets and squeezes the soft metal into the grooves for about an inch and a half up the cylinder. The lands of the shot, so moulded by pressure, become more or less sheared away, in doing the work for which they are designed, that is, to guide the shot round on its axis. They cannot offer any greater obstruction to the shot passing out of the gun, than the force it would take to cut them off altogether.—This actually occurred in my earlier experiments with two cast-iron 9-pounder service guns, which were rifled, (contrary to my desire,) with a rapid twist (one turn in 5-ft-6.) The guns were never injured by the firing of about 70 rounds, with considerably heavier charges than I have since employed; but the shot recovered after being discharged, shewed that the lead had been properly forced into the grooves, but the grooves had simply sheared the lands away like so much putty, all that remained were indications on the lead of where the lands had been.

As I employed the 32-pounder guns, the work done by the rifling can be fairly measured by its effect in shearing away so much of the lead it acts upon, and it amounts to this.—After being fired, it is found that every land on the shot is just about a quarter of an inch narrower than the grooves of the gun, the difference being caused by just so much lead being rubbed off in the performance of duty. What work is thus done is represented by the grinding or shearing away four little slices of lead, 1¼-inches long, quarter of an inch wide, and a tenth of an inch thick. This is all.

Now considering what is involved, if the conclusions which I have thus been led to form should really be correct, I feel that it is not too much to ask that the several points I have here brought forward may receive careful consideration.

I am fully sensible of the situation I am placed in when urging this. Personally, I am satisfied that there was no one member of the late Ordnance Select Committee who would not have been glad to recommend the adoption of these improvements, if he could have done so with a conscientious belief that they would have been productive of public benefit. I am also duly sensible that the gentlemen who formed that Committee, all of them highly scientific military or naval men, commanded from their high official station the widest range of knowledge that could be acquired, respecting a technical subject like this. But on the other hand, I may have devoted probably more time to the study of this particular question, than any member of that body can have been expected to do, in the laborious routine of multifarious official duties; and this special study has only shown me more and more clearly that the views the Committee formed, must have been based on error. How widely these views differed from mine, may be plainly seen by the following explicit statement in their report.—

"It remains to answer a question of much greater public importance than the relative success of different Competitors, in their endeavours to meet the requirements of the Secretary of State, namely, whether any of their plans, or of the others tried with them, are suitable for adoption, and whether it is desirable to introduce cast iron rifled guns for land or sea service. The Committee must avow a considerable mistrust of cast-iron of the quality turned out by English foundries, as material for rifled cannon, except with such restrictions as to charge, as would limit them to the uses of *Howitzers.* THERE IS PROOF THAT CAST-IRON GUNS OCCASIONALLY POSSESS AMPLE STRENGTH; this is evidenced by the *Lowmoor* gun, oval bored for MR. LANCASTER, having resisted 2000 service rounds, and by MR. BRITTEN'S having stood an equal number; but the ordinary inequality of endurance, which causes some cast-iron smooth-bored guns to be condemned much earlier than others, must attach to the material in any form, and in rifled guns would produce a greater number of failures, and failures at an earlier stage, in proportion to the *greater strain upon them.*"

But is there any greater strain? If so, how can the figures be explained which I have given? Their evidence is powerful, and unless it can be shewn that they are fallacious, the whole superstructure of the above conclusion falls. And it is founded after all on an assumption. No evidence is adduced to support it; and there is the contrary evidence of the fact that my guns stood every test applied to them. Were they *all* exceptionally strong? They were made by different makers and at different dates.

It does not appear that the convictions of the Committee were very strong or clear upon its being unadvisable to adopt these improvements, for I find by their report to the War Office, dated 3rd June, 1861, the following sentences.

"It is their opinion that it is not, *at present*, worth while to rifle "cast-iron guns *on a large scale*." Further on.—"Muzzle-loading "rifled guns, such as the service guns will be, if rifled, are likely "to be preferred, in some situations, to breech-loaders; and that "economy and facility of supply, if combined with a good degree "of efficiency, must constitute advantages not to be lightly over-"looked. On these grounds, however great the absolute supe-"riority of wrought iron, when perfect, over cast iron, they consider "the hope, of at least being able to rifle the latter, should it become "necessary, had better not be abandoned. They consider also "that the time and labor devoted by each of the competitors to "the perfecting of his own system, requires that a decision should "be come to as to their relative merits, and also that the present "opportunity should be taken for setting at rest the question "whether the material itself *is capable of standing the strain put* "*upon it when heavy projectiles are fired.* The only way to satisfy "these ends is to conclude the competitive trial, and afterwards to "fire all the guns with their proper service charges and projectiles "till they burst. If so many as seven 32-pounders, rifled on "different systems, all exhibit a satisfactory degree of endurance "by standing 1000 or more rounds *no hesitation need be felt in rifling* "*cast-iron guns*, should the demand increase beyond the power of "supply in wrought iron; should even a few of them do so, and "their strength be referable to any special principles of construc-"tion or system of projectile, a definite result will have been "obtained by the whole enquiry; but to stop it at this moment will "be to throw away all that has been done, and to leave grounds "for reopening the question at a future day." "Looking to the "importance of the question, both in a military and financial point "of view, the Committee do not think the cost of doing this would "involve an extravagant outlay."

These judicious recommendations were duly carried out. All my guns were tested for endurance till the War Office became tired of supplying them with ammunition, and up to this day not one of the guns has failed. One gun has fired 2000 rounds, twice the number which the Committee stated would be required to give satisfactory proof; and there is nothing to shew that it could not fire hundreds of rounds more as successfully.

But since this report an official discovery has been made which entirely alters the aspect of the whole question.

For many years the powder we have been using for heavy ordnance has been stigmatised by foreign artillerists as "poudre brutale," it being subject to such rapid combustion that its effect on the gun was unnecessarily destructive. This subject was at length referred to a Committee of scientific officers at Woolwich, and they have examined it with great care and ability, experimenting with instruments of extraordinary precision. This Committee has within the last few months presented a preliminary report of what they have already done, and the result is that powder is now being made and supplied for heavy guns, which, while it produces with equal charges greater velocity in projectiles, the intensity of strain it occasions to the gun is *only half that which the guns had to bear when firing the "poudre brutale."* As the guns never failed with the destructive powder which I used, there can I think be no question about their being safe with the new.

If then the authorities were solely influenced in their decision not to take advantage of my invention by a vague apprehension of "risk," which they admit it was impossible to refer to any positive reason, *this plea can no longer be urged.*

It is therefore simply for the present government to decide whether they choose to keep these guns in their present inefficient state, or to improve them at once. To abide by the other alternative which has been admitted, viz. not to rifle them till they are strengthened, is to hamper the gun factories with needless work, and to spend £120 or £150 a-piece in converting the guns, when a few shillings would suffice, and in that case we must be content to wait for an indefinite time before obtaining that reinforcement of our strength in artillery which is needed to place this country on an equality with other nations, which have done the work while we have been hesitating.

But it may be asked.—Supposing the cast-iron guns were rifled in their present state, would it be possible to get as much out of them as would make it worth while to have the work done?

There is no doubt that a wealthy nation like Great Britain, cannot afford to be armed with inferior weapons; and it must be admitted at once, that no reasonable expenditure ought to be spared, in providing ourselves with the best that can be obtained. But at the same time it would be mere folly to incur any expenditure that did not produce an adequate return; and even assuming that there is a prospect before us of attaining in time to a point of perfection in our artillery, only to be reached however by much labour and delay, it might still be a policy of doubtful wisdom to refuse in the meantime to make the best of what we possess, if it can be done at not too great a cost. I might point to the fact, that by a mere trifling outlay, our cast-iron guns, when rifled, would have an immeasurably greater efficiency than they have at present, inasmuch as *they would command a distance of* 6000 *yards with greater precision than they now have at less than half the distance, and this with projectiles half as heavy again as the solid round shot, and consisting of shells* *that hold three times as heavy bursting charges as the spherical ones. This has been established.* These advantages moreever, would be but *additions* to their present capabilities, for there is no service for which they are adapted in their present state, which they would be *in any degree* less adapted for when rifled. All the old ammunition, including red hot shot and molten iron shells, might be used precisely as hitherto, And these *additions* to the efficiency of our guns may be made *without causing any violent revolution in the service.* At first the new projectiles might be regarded as merely for special services. Why should there not be a supply of them kept, to be used if desirable, as there is of shrapnell, case, or other particular kinds?

But even this might not possibly be thought enough, because it may be said that the guns must be judged by the standard of other rifled guns, and must have some relative degree of efficiency to the modern artillery, which they might have to compete with.

This point is discussed by the Committee very clearly, in the following extract from their report.—

"The Committee assume that the intrinsic superiority of wrought-" iron guns, as manufactured by SIR WM. ARMSTRONG, over cast-iron " guns, is a fact which will be universally admitted. The almost " immeasurable superiority of the former over the latter, in point " of strength and endurance, has been placed beyond dispute; and " although more liable perhaps to total destruction by the effect of a " blow from an enemy's shot, this is a contingency of small practical " moment; the general effect of any direct blow being to make a " cast-iron gun also unserviceable, as is fully evinced by 56 cast-iron " guns disabled in the siege of Sebastopol. The question then " appears to turn chiefly on first cost, and facility of supply. With " regard to cost.—

" A smooth-bored 32-pounder service gun of cast-iron, costs by " contract, about £58, *the rifling will add less than £1 to this amount.* " *An* ARMSTRONG *40-pounder, which may be treated as the rifled*

"*equivalent of the 32-pounder, costs at present £360. The difference*
"*is indeed considerable.**

"But a consideration of equal, if not of greater importance "than that of the greater endurance of wrought-iron guns, is the "facility of supply. Cast-iron guns exist in vast numbers, and "many of them are doubtless as fit for rifling as if they were newly "cast for the purpose. They could be procured from the usual "contractors in numbers with great rapidity, and at a small advance "on what they now cost in a smooth-bored state. The question is.— "Does so urgent a demand exist for heavy rifled guns as to make "it expedient to draw upon this source, *instead of waiting until* "*wrought-iron guns can take their place?*"

Evidently then the idea entertained was to abandon all the old stock; to sacrifice the millions of money it has cost, and to take the chance of our not requiring to use arms, until we can find the means and the time to make new ones.

Within two years of this date, it came out before a Committee of the House of Commons, that two millions and a half of public money had been spent on the *Armstrong* guns and projectiles. Nearly 3000 heavy guns of this "superior" kind had at that time been constructed, and as specimens of skilful workmanship they were perfect; but they are all now laid up *in store*, and it is probable they will remain there—*they are condemned.*

As regards the shooting qualities and the strength of the *Armstrong* guns, there can be but one opinion, they are absolutely perfect; and, but for an unforeseen difficulty about the moveable vent pieces, they would, no doubt, be retained in the service, and be thoroughly good guns. They are made of such material, that in fact it would be almost impossible to burst them: without the smallest risk, they may be fired with any charges of powder. But though so strong, it has been found that there is something which

* Wrought Iron Guns of this size can now, (1871) be made for about £300.

prevents more than a certain amount of work to be got out of them. The inexorable laws of nature ruled, that *as action and re-action are equal, and contrary*, so every pulsation of force, which is brought to bear against a projectile in a gun must, of necessity, have an equivalent, acting against the gun itself, to drive it backwards; if all other conditions were the same, the gun would fly as far in one direction as the shot does in the other. To prevent this, the gun must have weight in proportion to the force employed. If the strength of the material it is made of were infinite, so as to resist any amount of lateral pressure, still so much of the material, or something else in lieu of it, must be used, in order that there shall be a mass of matter sufficiently ponderous to absorb the rapid reaction of the charge against the closed end of the bore, so that the recoil of the gun may be controlled. To check or manage this recoil in the wrought-iron guns, everything was done which genius, backed up with unlimited mechanical resources, could effect. Inclines, compressors, hydraulic buffers, all sorts of contrivances were tried, with more or less success, and at length the limits *of the power in the gun that was available* were fixed.

The 40-pounder *Armstrong* gun which the Committee allude to, as the equivalent of my rifled cast-iron 32-pounder, happens to be the most perfect example of the *Armstrong* system of strong guns. The service charge adopted for it was of course *as large as could be used* with it, regard being paid to recoil. Now it happens that the charge adopted for this gun, was precisely the same as I used for my cast-iron 32-pounder; I will therefore endeavour to carry this comparison further than the Committee did, and show the results obtained with both guns, firing equal charges of powder. I shall also include among the figures a comparison of two other guns.

Effective Work done by service charges of powder in Rifled Cast-iron service Guns, on Bashley Britten's *system, compared with* Armstrong *Breech-loaders, and* Palliser *or Wrought-iron Guns.*

Britten's **32-pounder Rifled Cast-iron service Gun, charge 5-lbs., projectile 50-lbs., initial velocity 1213.5, Vis Viva at muzzle 1,145,200 foot-lbs.**

Armstrong **40-pounder Breech-loader, (long,) charge 5-lbs., projectile 41-lbs., initial velocity, 1164.2, Vis Viva at muzzle 875,000 foot-lbs.**

Guns compared.	Charge.	Weight of Projectile.	Elevation.	Time of Flight.	Range.	Vis Viva.	Vis Viva to every pound of Powder.	
			degrees.	*seconds.*	*yds.*	*ft.-lbs.*	*ft.-lbs.*	
Britten 32-pr.	5-lbs.	50-lbs.	2	2. 9	1010	849,200	169,800	The Vis Viva is calculated on the mean velocities taken from the observed time of flight to first graze, and is therefore somewhat in excess of the actual terminal Vis Viva, but affords a fair *relative* comparison.
Armstrong BL 40-pr.	5 ,,	41 ,,	ditto	3.35	1095	598,700	119,800	
Britten 32-pr.	do.	50 ,,	5	6. 4	2100	753,400	150,700	
Armstrong 40-pr. ...	do.	41 ,,	do.	6.65	2160	590,200	118,000	
Britten 32-pr.	do.	50 ,,	10	11.6	3450	618,700	123,700	
Armstrong 40-pr. ...	do.	41 ,,	9	11.45	3510	539,000	108,000	
Britten 68-pr.	7½ lbs.	90 ,,	2	3	1002	1,410,900	188,000	
Palliser, or Wrt. Iron	8 ,,	64 ,,	1.25	2.08	761	1,199,000	148,000	
Britten 68-pr.	6 ,,	90 ,,	10	11	3150	992,300	165,400	
Ditto	8 ,,	do.	do.	11.6	3560	1,184,700	148,100	
Palliser or Wrt. Iron	8 ,,	64 ,,	7.6	9.2	3004	977,600	122,200	

Precision of BASHLEY BRITTEN'S *Rifled Cast-iron Service Guns.*

Guns.	Projectile.	Elevation.	Charge.	Time of Flight.	Mean Range.	Mean deviation from line of aim.	
68-pr. rifld. 4 rounds	90-lbs. Bursting Charge 8-lbs.	23°	7½-lbs.	23.9	5480 yds.	8 yds.	Several points of detail have yet to be determined before the ultimate degree of precision attainable can be properly estimated.
32-pr. ditto 12 rounds	50-lbs. Bursting Charge 3½-lbs.	26°	5 ,,	26.6	5752* ,,	8.8 ,,	
32-pr. ditto 10 rounds	ditto	23¾	5 ,,	23.8	5585 ,,	7.5 ,,	

Equal to** 3¼-**miles. **This Gun, from the Tower of London, would thus command the circle which has Buckingham Palace to Greenwich for its diameter; the radii extending to the Regent's Park, Stoke Newington, Homerton, Bow, Poplar, Dulwich, Brixton, and Pimlico.—Can such guns be worthless?**

There is nothing uncertain or merely conjectural in these figures. They represent actual results officially ascertained and recorded—stubborn facts not to be gainsaid. I ask then, where is the evidence of vast superiority in the new gun, costing £360, over the old one improved for a few shillings? It is true that its great strength enables a heavier charge of powder to be used in proportion to the weight of shot, but what does it do with it?

The weaker gun is far the more powerful of the two. As regards flatness of trajectory or length of range, at such elevations as are for the most part employed, *the Armstrong gun has no advantage;* for up to 5° or 6° elevation, the range is equal.

I suppose there can be but little doubt, that the best test of artillery efficiency is hard hitting; if so, this wrought-iron gun is seen to be ***very far inferior to the rifled cast-iron gun, at any distance within which either of them would ever be used in warfare.*** Of course against iron defences neither would be of any use, nor would any gun of less than three or four times their weight.*

At about 1000 yards, the distance which it is of the greatest moment to consider, as it is that at which artillery is most valuable, the cheap old gun, with its equal service charge, will strike a heavier blow in the proportion of 849 to 599, and even up to 3500 yards, which may be considered as the limit of practical ranges, it is still superior.

I see no way of reconciling this fact with a statement in one of the foregoing extracts, that rifled cast-iron guns would be "limited to the uses of *Howitzers*."

In this table I have also compared my rifled 68-pounder gun, with the *Palliser* or wrought-iron muzzle-loader. For these latter guns, the charge which has been provisionally adopted for service, is extreme. The force of recoil produced

* The question of *penetration* is considered in the after portion of this paper.

by it is so enormous, and tells so heavily on the carriage and platform, that under many circumstances it would be seriously objectionable, if not inadmissable.

Every attempt to employ still heavier charges has resulted in either the destruction of the carriage or the wood platform from the shock occasioned by the resistance of the compressors. Several 68-pr. guns were lined with inner tubes, so as to convert them into 7-inch guns to fire shot of 115 lbs., with 14-lb. charges, but it was found utterly impracticable, as the recoil smashed everything that had been specially provided of double strength.

***My* 68-*pounder gun, with* 7½ *or* 8-*lb. charges, hits harder than the other at short ranges in the proportion of* 141 *to* 120 *and at a distance of* two miles *its force would be superior in some such measure as* 118 *to* 97.** The recoil of my gun is only about two-thirds of what it has when fired as a smooth-bore with a full service charge.

As regards ***precision***, I regret that I have not the means of instituting a fair comparison, owing to the imperfect conditions under which my guns were tried.

Neither the rifling of the guns, nor the projectiles supplied for them were sufficiently perfect of their kind to afford anything like the accurate shooting that might eventually be obtained; and although I may candidly admit that I do not believe my system could ever ***fully*** equal the ***Armstrong***, for precision, I can appeal with some confidence to what has already been done under most disadvantageous circumstances. I give in the table a few average results obtained at Shoeburyness, when firing at long ranges. It is my conviction that if the system were allowed to be worked out, the degree of its inferiority in this respect, (resolving into a question of inches rather than yards,) would be found too small to be of the slightest practical importance. It might show itself in mere target practice at known distances, but would never be felt in actual service where mathematical niceties could not be observed.

It might be said that the *Armstrong* gun is lighter than the other. It certainly should be so, or its superiority in strength goes absolutely for nothing. Let this be compared. I take the vis viva of the shot at the muzzle as affording reliable data determined by accurate measurements, and I find the proportions between the weight of the two guns, to the force of the shot fired from them, to be but slightly dissimilar, and altogether out of proportion to the relative strength of the material of the guns.

	Vis Viva of Projectile at muzzle in proportion to weight of Guns. 5lb. charges.
Coiled Wrought-Iron *Armstrong* 40-pr., weight 36.5 cwt....... ...	23,970 ft.-lbs. to 1 cwt.
Cast-iron Rifled 32-pr., weight 56 cwt.	20,450 .... ditto.

At distances a similar comparison shews the approximate proportions to be,—

	Armstrong 40-pr.	*Rifled* 32-pr.
At about 1000 yards' range	16,400	15,160.
„ 2000 „ „	16,170	13,450.
„ 3300 „ „	14,770	11,050.

The consideration of what is indicated by these figures may possibly suggest a point which it is my intention hereafter to discuss. Here are two materials employed, one having a greater tensile strength than the other, in the proportion of 60 to 19; all that is done with it is to produce somewhat greater effects at long distances, where they would be but little required, and in order to do this, greater effects at those distances which are more important to consider, are absolutely sacrificed. *The gun has yet to be designed, which shall properly utilize the strength of the fine material we have now brought under command.*

There is another point to which I must allude: *durability.*

It is alleged that the wrought-iron guns are "immeasurably superior," because they would wear longer, and although nearly five times as costly, we ought to make them, as, in the end, they might not prove greatly more expensive.

In reference to this I ask, how many guns of this class, or perhaps of any other, ever are *worn* out? We have thousands of guns yet in the service as good as when they were first made, which are more than a century old. Of the twelve or fifteen hundred guns in position or in store at Malta alone, how many of them have ever fired 500 rounds? Of the scores of thousands of guns that altogether we possess, and must have in case of need, have ten in every hundred ever fired fifty rounds?

The siege and bombardment of Sebastopol was by far the severest trial of artillery for endurance upon record. There were 233 British guns, (besides mortars,) employed; most of these guns fired above a thousand rounds; those first placed in position averaged 1500, and many of them fired between 2000 and 3000 rounds. Out of all these there were only five failures, either from some fault in the hurry of loading, or from the bursting of shells in the gun, or from some other cause not known, five of them certainly burst.

But this can hardly be called shewing want of endurance, when the 233 guns are known to have fired in all about 250,000 rounds: had they been all wrought-iron rifled guns, would they have done better? Does the experience of Shoeburyness justify the belief that there would have been fewer failures? There might not have been a single gun burst: but endurance does not depend only on the strength to resist pressure, it involves the chapter of accidents, including the occasional premature explosion of shells before leaving the gun, the effect of which is invariably to render it wholly unserviceable till it has been re-lined, re-bored, and re-rifled. This could not be done in the trenches. Then there is the wear, not upon the guns strength, but upon the surfaces of the little narrow spiral ledges of the rifling. There is the scour of the gas worked at extreme intensity of pressure at every discharge, doing some injury to these, and there is the friction acting upon them unequally in places. The rush of gas over the top of the shot at starting scoops out channels in the bore of the gun, which has been technically termed at Shoeburyness "guttering." So serious is this found to be that the guns are now made with the trunnions placed central to the axis, in order that when one side of the gun is worn out by the "guttering" it may be turned over on the carriage, and a new vent made on the opposite side.

Anything, no matter what, which may have the effect of bruising or injuring the well-defined edges of the rifling in one of these guns instantly put it as completely hors de combat as if it had burst. A blow no harder than what a child could strike with a hammer, directed against the edge of one of the grooves, would effectually prevent the studs on the shot from passing down the gun. With *Armstrong* breech-loaders the supply of vent pieces might fall short.

As there is every reason to believe, from the trials made, that any cast-iron gun, properly rifled, and fired under such conditions as I applied to them may be expected to last for 2000 rounds at least, I can hardly believe that this would not *be sufficient,* even if it were beyond all question that wrought-iron might last longer.

Cast-iron guns have served us well hitherto, and though an occasional accident has occurred from the bursting of a gun, either from being defective, or from not being properly served, the instances are rare, and the danger so arising can hardly be deemed a great addition to the perils of our gunners, and certainly it has never yet been found to make them afraid to perform their duties.

I have now to deal with another branch of the subject, which requires careful attention.

The committee had tried a great many cast-iron guns, rifled according to the suggestions of several other persons besides myself, and so many of these had failed with only moderate charges, that a general distrust in cast-iron became engendered.

I propose therefore to endeavour to explain the probable causes of all these failures.—

It is not without great reluctance that I approach this part of the enquiry, for I would willingly avoid the unpleasant task of criticising the efforts of my competitors; but it is necessary that it should be done, because till these failures have been traced to their proper causes, and it can be shown that these may be avoided, confidence in rifled cast-iron guns can never be thoroughly established.

I find in the Committee's report sufficient information to enable me to make out a correct list of all the rifled cast-iron service guns which have been experimented with, and to distinguish those that burst.

It appears that *eight* different rifle systems were tried, all of them more or less distinct in principles, which seriously affect the strain on the guns. To class these all together without considering what is involved in the distinctive features of each system would obviously be absurd. Every rifle-shot is of course but a piece of metal of the nature of a screw. It is so formed that there shall be an inclined plane projected on its surface to act on a corresponding inclined plane within the gun, so that there shall be a more or less direct opposition to motion. If then this inclined plane be steep, or what is the same thing, the thread of the rifling make a rapid turn, and so approach nearer to that angle to the direction of active force which would cease to be an incline, but present absolute opposition, the resistance of course would be greater. In like manner if the inclined plane had inequalities on its surface which presented *points* of direct opposition, the resistance would then be absolute, unless these points gave way. The smallest pebble on a hill-side would be sufficient in itself to stop a carriage-wheel, whatever might be its speed, unless the wheel could jump over it, or crush the pebble out of the way.

In making out the list of guns I shall do what the Committee do not appear to have attempted, that is to divide them into two distinct classes.

CLASS I.

List of the rifled cast-iron service guns, which were tried with projectiles *liable to jam or get locked in the gun in consequence of the rifling acting upon rigid projections or lands upon the projectiles.*

Guns, 32-prs. of 58-cwt. each.	Charge. lbs.	Projectile. lbs.	Rounds fired.	
1 Armstrong, Shunt.........	5½	56	40	(burst.)
1 Ditto......... ditto	do.	do.	327	do.
1 Ditto ... hooped	do.	do.	4	do.
1 Ditto ... ditto	do.	do.	12	do.
1 Capt. Scott's	6	48	78	do.
1 Ditto	do.	do.	309	do.
1 French	5½	64	107	do.
1 Mr. Haddan's	7	54	215	do.
1 Mr. Lancaster's	6	50	2000	(not burst.)

CLASS II.

List of the rifled cast-iron service guns, which were tried with projectiles *not liable to jam in the bore, the rifling acting only on yielding lands of lead.*

	Guns.		Charge. lbs.	Projectile. lbs.	Rounds fired.	
1	32-pr., 58-cwt....	Mr. Jefferys...	5½	49	363,	(burst.)
1	32-pr., ditto ...	Mr. Thomas...	7	57	67,	(not burst.)
1	9 -pr., 17-cwt....	B. Britten's	1¾ to 2	15	12,	do.
1	ditto ditto ...	,,	1¾	15	54,	do.
1	32-pr., 56-cwt.	,,	5 to 6	49	345,	do.
1	,, 58 ...	,,	5	50	2000,	do.
2	,, 58 ...	,,	5.5	50	10,	do.
1	68-pr., 95 ...	,,	6½ to 8	90	110,	do.
1	,, 95 ...	,,	7½	90	10,	do.
1	,, 95 ...	,,	7½	90	10,	do.
1	,, 95 ...	,,	7½	90	300,	do.

Further trial *a l' outrance* of *Britten's* unstrengthened rifled cast-iron service guns, with similar projectiles, but of increasing weight.

32-POUNDER, 58-cwt. No. 1.

10 rounds	....	Charge 5½-lbs.	Projectile 48-lbs.
10 „	....	„ „	„ 72
10 „	....	„ „	„ 96
10 „	....	„ „	„ 115
10 „	....	„ „	„ 140
4 „	Burst ...	„ „	„ 165

32-POUNDER, 58-cwt. No. 2.

10 rounds	....	Charge 5½-lbs.	Projectile 48-lbs.
10 „	....	„ „	„ 72
10 „	....	„ „	„ 96
10 „	....	„ „	„ 120
10 „	....	„ „	„ 144
7 „	Burst ...	„ „	„ 163

68-POUNDER, 95-cwt. No. 3.

10 rounds	....	Charge 7½-lbs.	Projectile 90-lbs.
10 „	....	„ „	„ 135
10 „	....	„ „	„ 180
10 „	....	„ „	„ 225
10 „	....	„ „	„ 270
10 „	Burst ...	„ „	„ 315

68-POUNDER, 95-cwt. No. 4.

10 rounds	....	Charge 7½-lbs.	Projectile 90-lbs.
10 „	....	„ „	„ 135
10 „	....	„ „	„ 180
10 „	....	„ „	„ 225
10 „	....	„ „	„ 270
10 „	....	„ „	„ 315
10 „	....	„ „	„ 369
10 „	....	„ „	„ 405
1 „	Burst ...	„ „	„ 450

It will be seen that out of ***nine*** guns in the first class which have been tried, ***eight of them have burst***; while out of ***twelve*** guns in the second class, ***only one has failed***, and that under circumstances which I will presently notice. There were a few other cast-iron guns tried under entirely different conditions, and these will be also referred to.

It is true that the projections or studs on the projectiles for the Shunt and French guns were sometimes *faced* with zinc, shewing that the advocates of those systems were alive to the impending dangers, still, in each case ***the iron projections were there, forming part of the cast-iron body of the shot***, and consequently in the event of any overriding or overrunning of the thread of the rifling, these projections would offer irresistible opposition to the egress of the shot from the gun.

The amount of danger likely to arise from the employment of rifled shot having projections on them of hard or tough metal that would not give way, may be very well conceived, by regarding the bore of a rifled gun as analagous to that of a railway tunnel, which has a curve in it equal to the turn of the rifling. This turn in my guns was equal to a curve having a radius of 30 feet; in the ***Armstrong*** shunt gun the rifling would be something like a curve of about 9 feet radius. In no railway for passengers would a sharper curve than one 600 of feet radius be permitted by the Board of Trade, where the speed of the trains ever exceeds 20 miles an hour. The projectile or carriage, in the supposed case, fits the tunnel to within a tenth-of-an-inch all round, and it has to be driven through this curved tunnel at a speed of about fourteen miles per minute.

So long as the surfaces of the guiding lines continue perfectly intact, all might go well; but let any point of inequality present itself on the lines, so as to interfere with the true course and give rise to opposition, the whole force of the onward career is instantly accumulated against the obstacle, and unless it yields, the projectile must stop, or the gun must release it by flying to pieces.

The difference between all these systems in Class 1, which produced failures, and mine, in this respect will be seen at once. When the rifling only acts on a plastic material, such as lead which would yield like putty, before such forces as are here at work, no amount of inequality on the surfaces of the rifling could produce anything like a formidable resistance.

The surfaces might indeed be so rough and jagged, that numberless points of positive opposition might be presented, or the inclined plane might be so steep that the shot could not climb it, the effect would simply involve the destruction of the coherence of particles, or the bending of the lead into a different form. The old-fashioned pocket pistol will be remembered; the barrel was made to unscrew, so that a ball could be placed over the charge, considerably larger than the bore; when fired the ball had to adapt itself to the dimensions of the barrel, and the lead yielded without causing any dangerous strain. At page 15 I refer to the effect that was produced when my projectiles were fired from guns rifled with a sharp twist. *The whole of the lands were simply sheared away, without doing any injury to the guns.*

The Committee certainly state their opinion that of all the different systems of projectile which they tried, the liability to get jammed in the bore was *least* in mine. But this is scanty justice. It might be a question of *degree* with all the plans which are put together in Class 1; but it is an essential principle in the system which I advocate, that this danger shall not exist at all. *It is as impossible for one of my projectiles to get entangled among the grooves as it would be for a round shot.*

This liability of the shot to become locked, is the only element of *risk* which appertains peculiarly to rifled guns, for everything else must be merely a question of what charge or force can be properly employed; and this risk is simply less or more in proportion to the amount of resistance that the materials, which become opposed, can offer by their natural strength or tenacity. Opposition of this kind is absolutely inevitable, so that when hard metal projections are used, inequalities must be produced by friction in the wear of the surfaces which are brought into contact to do the work required. It is quite worth while to follow this point further, and trace the mechanical effects which are involved.

All projectiles for muzzle-loading guns must of necessity be made of so much less diameter than the bore, as will enable them to go down easily in loading. According to the old regulations, the round shot used to be about an 8th-of-an-inch less than the bore; but this has been reduced and a difference of only one-tenth or even less, is now allowed.

When, therefore, projectiles have studs or projections upon them which have to be adjusted in the grooves at the muzzle, on the shot being thrust home, these projections, must be guided down by the opposite side of the rifling to that which they have to follow, in coming out again; consequently, as the shot lies in its place against the charge, the projections are all as far as they can get away from what is properly the driving side of the rifling. When fired, the shot moves some distance and acquires considerable velocity before the projections on them touch their bearings; and at this point of first contact, the edges of the rifling are struck by the projections a *blow*, with a force depending on the velocity which the shot up to that instant had acquired. Now we know from the experiments at Woolwich, detailed in the report of the "Committee on Explosives," which I have referred to at page 18, that a projectile which leaves the gun with a velocity of 1330 feet per second, will attain in the first inch of its course a speed of no less than 360 feet, and in 3 inches about 510 feet per second. If then the projections were but one-tenth of an inch narrower than the grooves, and the grooves had a curve of 1 in 9, (which is about that of several of the guns tried,) the shot would advance nearly an inch quite free, and then it would strike the inclined sides of the grooves when it was moving at the rate of 200 miles an hour.

Repetitions of these powerful blows upon such small surfaces would necessarily produce indentations from friction at these particular points, and these becoming deeper at each discharge, ledges would at length be formed, from which the shot could not extricate itself, and if the material did not yield, the gun must inevitably burst.

Several of the guns which failed, were fired with shot which had cast-iron projections on them, ***which would not yield in the smallest degree,*** and these guns burst as a matter of course. That their failure was caused by the jamming of the shot was clearly shewn by the marks left on the bore of the gun, shewing plainly where the sides of the rifling had become worn and indented. It is not necessary that these indentations should be very deep; a ledge no thicker than 1-50th part of an inch would be quite sufficient to produce in the shot a resistance of many tons, in addition to the shot's inertia. Cast-iron guns of course could not resist this, neither should they be called upon to do so, when all the desired effects can be obtained without it.

But the failures which had the greatest influence in throwing discredit upon cast-iron guns, were those which resulted from the ARMSTRONG SHUNT system. This plan was applied to a great many of the guns before it had been properly tested, and these were all condemned afterwards without having fired a shot; the few that were tried all burst.

It is not easy to explain without diagrams the peculiar nature of this shunt system. Its object, as explained by the Inventor, was to enable a shot to go into a gun from the muzzle easily, and without expanding to come out *fitting tight.*

For some distance down the gun, the grooves were of unequal depth; half of each groove was as deep again as the other half. About three feet from the muzzle, the higher part of the grooves was bevilled off at a sharp incline, and from this point to the breech end, the grooves were wholly as deep as the deeper part at the muzzle.

The shot were so made that the projections on them would *as nearly as possible fit the dimensions of the bore in the shallower part of the grooves*, this shallower part being on that side which would guide the shot in coming out: but in order to enable the shot to go into the gun freely, the projections could only be of such width as would go easily into, and down the deeper channels past the contracted part of the bore.

A more ingenious contrivance to enable a projectile to lock itself in the gun could hardly be conceived.

It was quite possible by this means to load the gun with a shot which could not possibly be fired out of it; for if by accident the projections which were intended to fit the contracted grooves at the muzzle, were made one-thousandth of an inch too high, they might still go into the gun with perfect freedom, but could not possibly get by when shunted on to the higher step in the rifling. The mechanical effects produced by this arrangement are worth considering. The projections on the shot being necessarily no wider than the deeper channel of the grooves they have to enter, would lie nearly $\frac{3}{4}$ of an inch away from their bearings when the shot was set home against the powder. The incline of the grooves being about 1 in 9, the shot on being fired would travel nearly seven inches without touching the rifling. With the ordinary powder it would then have a velocity and force more than half of that with which it would leave the gun, and with this force the projections must strike the sides of the grooves, which present an angle of $6\frac{1}{2}$ degrees. A very violent oscillation of the shot would be the consequence, this would continue til the shot reached the shunt points; here, another angle, far sharper than the former one, is struck by the projections, the force of the shot having increased to nearly its maximum. All oscillation has to be then stopped at once by the projections riding up into the contracted channels where there is only just room for them to pass. The shot used for these guns had ribs of zinc dove-tailed into and against a cast-iron shoulder; if, therefore, any one of these got started by the first blow against the rifling, it might get athwart the shunt point where there was no space for it; and it was not an uncommon thing to find these ribs displaced after the shot had been fired.

Even supposing all the parts worked as smoothly and perfectly as possible, it is still a fact that twice in the gun's length the natural course of the projectile was interfered with by striking against two targets in the interior of the gun, and it was found practically that its career was affected by this to such an extent that when shells were fired with concussion fuzes, they very frequently acted before it was by any means desirable, and burst before they left the gun.

When these several points therefore are fairly considered it ceases to be a matter of surprise that the cast-iron shunt guns failed, the only wonder is that any one of them ever proved strong enough to fire as many as 300 rounds.

The system was tried in several wrought-iron guns, but it failed with them also, and the plan was entirely abandoned.

Now, it is worthy of special observation that this system, plausible in appearance, yet so full of hazard and danger, being utterly unsound in all its principles, was at one time adopted for cast-iron guns.

In the report I find it stated "The Committee believe that *Mr. Britten's* method will be found to strain the guns less than the shunting plan, *understood to have been provisionally adopted by order of the Secretary of State.*" Before a single gun had been tried, beyond a few score rounds, an order was given to have several hundred of the old guns hooped, and converted on this plan. A very large number were really operated upon at a great cost to the country, and they were condemned as fast as they were delivered. They may now be seen lying in hundreds in the store yard at Woolwich, so many mementos of past folly, which ought to be put out of sight and cease to be a monument of disgrace to English science and engineering skill. It was mainly in consequence of these failures that cast-iron got into ill repute. The powerful advocates of the system of wrought-iron guns, who contemplated the reconstruction of all our stock, could easily attribute the failure to the material, and it appears to have been nobody's business to point out clearly that the fault was not in the guns, but in the vicious system applied to them.

The Lancaster Oval Bore plan now requires notice. It will be seen that the only gun of all those in class 1 which did not fail, was rifled on this system. This method of rifling, singularly enough, was designated by the Committee as that which rendered the shot "most liable" to get jammed in the bore of all the systems tried, and its success in this instance was attributed to the gun being exceptionally strong.

I may observe however that had there been *any* jamming of the shot in this gun, no amount of strength that any cast-iron could have, would have prevented its bursting.

It is well known that about the time of the Crimean War a very earnest effort was made to apply this system to cast-iron guns, but it was abandoned in consequence of the bad shooting obtained with it, and the failure of several of the guns. The cause of this disappointment is susceptible of the following explanation.—Although two or three of these guns burst, it is a fact which will be found to be indisputable that this arose from no other cause than the premature explosion inside the gun of the shells, which carried an enormous bursting charge. Very large charges were used for these guns, far exceeding those which I have employed, the shells contained from 11 to 12 lbs. of powder each, and when the true character of the projectiles which were then used is considered, it must only occasion surprise that the accidents which occurred were not more numerous and serious than they really proved to be.

The old *Lancaster* shell, formerly made at Woolwich, was of the simple oval form; the cylindrical part was shaped without any regard whatever to the helical curve in the gun; there was no corresponding twist in its external form to fall in with the twist in the rifling. Rightly to appreciate this it is only necessary to imagine a hexagonal *Whitworth* iron shot, made with perfectly straight longitudinal lines. How would this be likely to suit the *Whitworth* gun? Yet *such was the old* Lancaster *shell.* Marvellous as this may now appear, the fact is undeniable. Could any failures, under such circumstances, even if they could be traced to the jamming of the shot, afford the slightest evidence which touches the general question here at issue.

The shell, having a *straight* thread on its surface which was required to work smoothly along the curved female thread of the rifling, could only touch the sides of the gun at two very narrow points opposite each other; on these two points the whole force of the blow, caused by the reversal of bearings at starting, would fall. As might have been expected, the shells were crushed by this. It was found that cast-iron could not be used, and therefore *wrought-iron shells were made.* They were wrought in halves, and then welded together. About £70,000 was, I believe, spent in machinery for forging and welding these projectiles, yet the plan failed; either the wrought-iron gave way, or the flame from the explosion penetrated through unperceived fissures or imperfections in the welding and exploded the powder in the shells before they left the gun. The *Lancaster* guns which did fail *all burst at the chase near the muzzle*, where the shells would explode, ***but the Shunt, and all the other guns in Class 1, burst at the breech behind where the rigid shot would stick.***

This serious defect was remedied in the projectiles which *Mr. Lancaster* employed for his competitive gun before the Committee. The cylindrical portion of these was carefully turned in an eccentric lathe, so that their external surface should have a skew corresponding with the spiral in the gun. By this means the extent of surface bearing on the rifling was largely increased, which of course improved the shooting immensely, and the risk of jamming was necessarily reduced by this to a minimum.

What appears to me to constitute an essential objection to this form of rifling is, that the force which operates to turn the shot acts *obliquely* instead of *directly*. The sides of the rifling present an inclined plane, which produces an extremely fine wedge-like lateral action, tending to press the sides of the gun *outwards* and the shot *inwards*. When grooves with perpendicular sides are used, the projectile is guided round by the force acting at right angles to the axis, and consequently this outward and inward pressure does not exist; the direction of the force is all in the line desired.

For this reason the actual strain from lateral pressure on the sides must necessarily be greater whenever the plane of the thread of the rifling is at a greater angle than 90 degrees to the axis of the gun, whether the bore is oval, hexagonal or other form. I cannot however acquiesce in the opinion expressed by the Committee that the oval bore involves any greater liability of the shot becoming *jammed* than the Shunt system; all the mechanical conditions are certainly in favor of its being otherwise: the surfaces of contact with the elliptical bore are far broader, and there is the absence of any angles on which the shot could impinge. It appears to me that the simple explanation of this gun not failing, while ***all the others of the same class did fail,*** is that it was ***not liable*** to the accident of the shot getting fastened in the gun, while ***all the others were;*** and that it proved itself strong enough to bear even the increased lateral pressure due to the form of the rifling, merely because it was not called upon to resist the whole force of the charge when pent up in the bore by the shot getting jammed. This distinction is of great importance to this enquiry.

The failure of Mr. Jeffery's gun has now to be considered. This was the only gun of the twelve tried with lead rifling projectiles, which shewed any want of endurance; it burst at the 363rd round. This gun did not fail from the shot getting locked in the rifling, for such a thing ***could not possibly be*** as there was nothing but lead for the grooves to act upon; and there is no reason for supposing that it was any weaker than either of the others. It is not difficult however to shew that this gun was tried under certain peculiar conditions, which entailed upon it a degree of strain at every discharge very far beyond what any of the others were subjected to, at least when there was no hitch: and they were conditions irrespective of the rifling; had it been a smooth-bored gun the result would have been equally unsatisfactory. The charge was not excessive, neither was the projectile very heavy. Half-a-pound more powder was used, but rather a lighter shot than I employed.

Mr. Jeffery's projectile consisted of a cast-iron body with a leaden cup attached mechanically to its base. Its character will be best understood by reference to the drawing at page 58, representing sections of this shell, and also of mine, copied from the Report.

In regard to these projectiles the Committee make the following remark.—"They conceive the cavity at the end of *Mr. Jeffery's* projectile to be unnecessary and to be injurious, causing additional friction of the rear of the shot against the bore. They are also more susceptible of injury, not having the protection of the disc of wood at the base." The idea of the inventor was, in designing this shot, that when the cup was pressed down against the cartridge a considerable portion of the powder would be actually ignited inside of it, and its sides would be pressed outwards against the bore and into the grooves.

This no doubt occurred, but what was the consequence?

When the charge was fired, the sides of the cup, which were for some distance nearly parallel, were pressed outwards and against the bore with nearly the same force as was acting on the gun in rear of it, the only difference being that, as the lead sides were about $\frac{3}{8}$-of-an-inch thick, the diameter of the inside of the cup was about $\frac{3}{4}$-of-an-inch less than that of the bore. The cavity being just an inch deep, its circumference when expanded presented an area of 18 square inches on which the powder would act laterally with its full power of an unknown number of tons per inch pressing the outer sides against the bore. The amount of surface, lead on iron, thus pressed against each other would be 20 square inches; so that if the resistance from the friction so produced be measured according to the recognised rule, the projectile must have been *held back* by a force which was positively enormous. A precisely similar action, though not so severe from the diameter being less, took place with the Enfield bullet when first introduced, the cavity not being filled up with a plug. It was found to be no uncommon thing for the front part of the bullet to be blown away from the hollow cylindrical part, which was retarded by the friction, and actually remained in the barrel. When the plug was introduced, and the gas was prevented from occupying the cavity, this ceased to occur. In designing my projectile I took care to have the base of the lead so shaped, that while there should be sufficient yielding metal to be upset into the grooves and form lands long enough to yield the force required for turning the shot, there should be no surface to be acted on laterally by the gas, to produce pressure and friction against the bore; I also employed the disc of wood as a further security against this, as well as a means of protecting the lead from being bruised in transport. Instead of wood, iron or other metal plate might be used, secured to the lead in the same way and at the same time as the lead is attached to the shot, and it would never separate when fired.

The effect of this resistance caused by the employment of the cup in *Jeffery's* shot shewed itself plainly in the shooting. The gun was precisely the same as mine in length and calibre, there was very little difference in the rifling, and, when fired with charges of powder exactly one-tenth of the weight of projectile the initial velocity of *Jeffery's* shot was found to be only 1181.2, while mine was 1213.5 feet per second. But for friction the velocity of *Jeffery's* shot might be expected to have been more than mine, because the expansion was more perfect, there may be said to have been no loss or escape of the gas; I purposely did not employ sufficient thickness of lead to fill the bore absolutely; there was always an escape through one of the grooves sufficient to ignite a common time-fuze. I considered this desirable in order to diminish atmospheric resistance to the projectile in the gun.

It seemed to me that there would be less compression of air in the bore if a blast of gas passed through it commencing at the instant of ignition; where there is no passage of gas through windage the shot would be like a piston, subject to a full atmospheric pressure in front of it.

It will be observed that there was one more gun tried with expanding projectiles in which the rifling acted only on lead. The shot *Mr. Lynal Thomas* used were, in principle, *precisely* similar to mine; the only difference in construction being that he employed a wedge-shaped ring of iron below the lead, for the purpose of forcing it to bulge outwards and fill up the bore; and he attached his lead to the shot by merely casting it into grooves on the iron, whereas I secured it by a process, which I was the first to *discover* as well as apply, and which is now used for all the Prussian and Russian breech-loading artillery.* *Mr. Thomas's* gun fired 67 rounds, and it was then withdrawn perfectly intact; and when it is observed what charges he ventured to employ, the indirect value of these experiments will be appreciated. He used *forty per cent. more powder, and shot fourteen per cent. heavier* than I did.

At page 9, I compare the work done by the 32-pounder gun as a smooth bore, with service charges, and the work done by the same gun rifled, when firing the charge which I judged it prudent to employ for these preliminary trials. The figures shewed that after making a full allowance for the extra work attributable to the action of the rifling, there was at least *fifteen per cent. less work done by my rifled gun* than the smooth bore. But making a similar comparison of the work which *Mr. Thomas* gave his gun to do, the difference will be seen to be as follows :—

	Charge of powder.	Weight of projectile.	Velocity at muzzle.	Vis viva of projectile at muzzle. *ft.-lbs.*
Mr. Thomas' rifled 32-pr. cast-iron service gun unstrengthened	7-lbs.	57-lbs. ...	1395 ...	1,725,100
	Add for rifling say 3 pr. cent.			51,800
				1,776,900
Smooth bore 32-pr.	10	31.6	1690 ...	1,403,600
More work done by *Mr. Thomas'* rifled gun ... ft-lbs.				373,300
Proportion 26.6 per cent. more				

* This method has ever since 1860 been used for the *Armstrong* projectiles, and I received from Government *a reward of £500 for the invention.* Without it the *Armstrong* gun must long ago have been abandoned, owing to all other means having failed to prevent the lead from stripping when fired.

If, then, we consider what charges were used for the guns which burst *when firing rigid projectiles*, it may be seen that all the eight succumbed under a pressure of work which, but for purely adventitious causes, was only about half what is shewn in the above figures. *Mr. Thomas' gun remains uninjured, and also all the other* 12 *guns which were tried with similar projectiles.*

Of course it might not be safe to tax cast-iron guns in service with work such as this rifled gun endured, but it shews what margin of strength they possess beyond what the ordinary service charges demand, and still further beyond what is required to meet the conditions which I applied—Conditions, let it be remembered, which rendered the guns, which it has been resolved upon to discard, *more powerful* than the new expensive guns which were made to be substituted for them.

I find in the Committee's final report the following words:

> "*The Committee prefer the facts furnished by the bursting of guns, to any conclusions based on mechanical considerations, which involve many discordant elements.*"

It has been my object to deal with the question as it was so left by the Committee; merely effects having been regarded without reference to their causes. The decision was, that my scheme involved "risk," although, in the course of nine years' trial, no danger whatever had manifested itself. The plan was suspected for *no other reason than could be found in the failure of other schemes*, but in what way related, there was no proper attempt made to distinguish. I have therefore endeavoured to investigate and reconcile the "discordant elements" which presented themselves, and, by applying "mechanical considerations," I think I have found good reason for the conviction that the "bursting of guns" may be avoided if systems of rifling and projectiles are not applied to them which are beset with peculiar dangers easily avoided.

That good cast-iron as it can be, and has been supplied for ordnance, is not the uncertain and brittle material which it has become the fashion for some time past to regard it, may be judged of by the fact, that not five guns in every thousand which have been supplied by British Foundries to the Government during the last 50 years have failed, under the enormous proof to which they have been subjected before passing into the service. Of the last 3,300 of all kinds, (not made at Woolwich,) which were proved, only *seven* failed from defective castings. The proof charge for cast-iron guns has always been just 100 *per cent. more than the service charge*; whereas the proof for wrought-iron guns has been reduced to only 25 *per cent. above the service charge*, yet it is a fact that of about 750 of these new guns, of over 7 tons weight yet proved, *four of them have burst*, *one flying into* 18 *pieces.*

That cast-iron when properly made is a material capable of making powerful guns, there is the following piece of evidence sufficiently conclusive, as far as it extends.—

The greatest amount of force which as yet has ever been communicated to any projectile in this country, was produced out of a cast-iron gun of less weight by* 30 *per cent. in proportion to the force obtained with it than the most powerful wrought-iron guns we have yet made.*

This gun was the American 15-inch gun, (weight 385 cwt.,) firing with 100-lbs. of powder a round shot of 450-lbs. The velocity at 70 yards was 1522.2 feet per second, which represents striking force of 16,216,000 of ft.-lbs. Our coiled wrought-iron 600-pounder, (weighing 500 cwt.,) delivers its shot with a velocity of 1180 feet, and a force of 12,992,900

* The 35-ton Wrought Iron gun had not then been tried. It is now the sole exception. The force of its shot at muzzle is 18,968,600 foot-lbs. with 120 lbs. powder.

foot-lbs. at the muzzle. The ordinary charge for these American service guns, with which they have proved perfectly safe and endurable, is 60-lbs. of American powder, which is rather more than equal to 50-lbs. of our English powder, or one-ninth of the weight of the shot. The charge which I have used is only one-tenth; my projectiles are far lighter in proportion to the whole weight of the gun; and they also offer far less resistance to the expansion of the charge by their weight in proportion to their sectional area, than the large round solid shot. This very important point will bemore clearly seen by reference to the table at page 69.

Besides the rifled cast-iron *service* guns which I have mentioned there were several other guns of the same material, but of a different character tried.

About the year 1858 several persons obtained leave to have some blocks of cast-iron guns bored to a smaller calibre than is usual. SIR JOSEPH WHITWORTH had a 95-cwt. 68-pr. block, bored and rifled on his hexagonal system, the calibre being $\frac{5}{5.5}$ inches instead of 8.12 inches; also two 32-pr. 63-cwt. blocks bored to $\frac{4}{4.5}$ instead of 6.375 inches.

MR. JEFFERY also had four 56-pounder blocks of 87-cwt. bored to the calibre of the 32-prs. and 24-prs. of the service; and MR. MUNTZ had a 68-pr. 95-cwt. block rifled with a 32-pr. bore. These all failed very soon, not one of them ever fired 50 rounds. It was supposed that, by thus obtaining a greater thickness of metal round the bore, the guns would be much stronger, they were therefore fired with very heavy charges, and under conditions which involved such an enormous strain as no cast-iron could withstand; unfortunately these conditions were not properly considered, and their bursting was ascribed to the material as being uncertain in strength. It was forgotten that the lateral pressure by expansion on the interior of a cylinder to burst it is a radial force acting through the surrounding mass tending to drive all the substance away from the centre in columns. It is not like force upon a beam or bowstring bridge, where the strength to resist is made up of two forces supporting each other on each side of a neutral point, one side being stretched and the other compressed; and consequently, if a pressure is thus exerted within a gun greater than the tensile strength of the material, no advantage is gained in having a greater thickness of substance than can be reached by the limits of the natural elasticity of the material by which the force acting upon it is distributed through the mass. It will begin to rend at the weakest point, and be gradually torn through as a sheet of paper is torn. This was clearly shewn by the Hydraulic Presses which were made for the erection of the Brittannia Bridge. Beyond a certain thickness cast-iron afforded no additional strength to resist pressure from within.

Mr. Jeffery and ***Mr. Muntz*** both employed for their small bored guns, expanding shot, having deep lead cups, so that a considerable part of the charge was actually exploded inside the projectile, and so much of its force was consequently exerted to hold the shot immovable against the inside of the gun instead of driving it forward. ***With such shot, charges of powder were used very nearly as large in proportion to the calibre of the gun, as are now used for the heaviest battering charges for wrought-iron guns which are made half as heavy again as these cast-iron guns were.*** For instance, ***Mr. Muntz'*** 95-*cwt.* ***cast-iron*** gun was fired with 16-lbs. of powder, occupying 15 inches of the bore, and shot of 80-lbs.; the 140-*cwt.* ***wrought-iron*** ***7-inch*** ***gun*** fires a full battering charge which occupies 17 inches of the bore.

The ***Whitworth*** cast-iron 68-pounder of 95-cwt. was rifled with such a pitch of the screw, that it made ***more than a*** *whole turn in the length of the gun.* The shot were entirely iron made to *fit* the bore exactly, and it was fired with charges which occupied 16½ inches of the bore, while the projectile took up about 13 inches more, consequently, nearly *one-third of the whole of the bore was filled uith ammunition at each round.* One gun went to pieces at the 4th round, another at the 14th, and another at the 20th. Upon these trials cast-iron was adjudged to be a material of "uncertain" strength and not to be relied upon.

I have now presented the reader with a complete statement of all the facts which have been ascertained, bearing upon the important question—why should our existing guns be suffered to remain in their present comparatively impotent state, when for a trifling outlay, not exceeding a few shillings each, they might be all improved—and improved to such an extent, that they shall not be merely makeshifts, but be rendered thoroughly efficient weapons, even when judged by the standard of any artillery they might have to compete with of equal weight; ranging with precision far beyond the extreme limits within which human vision can direct them, and *equalling, if not exceeding in the strength of the blows they deliver, any ordnance equally ponderous which as yet has been constructed?* There are the figures denoting actual measurements shewing that this is not mere hyperbole.

Why it has *not* been done, admits of no other explanation than the want of a proper understanding of the causes which led to the failure of the nine service guns which burst. That these did not burst because the material was unequal to the pressure of work they had to perform, is obvious, because the labour was not so severe as they are subjected to every day. That their failure, with the very moderate charges employed, did not afford the slightest evidence that the material is of "unequal and uncertain strength," is proved by the fact that such a hypothesis would involve the impossible circumstance of *all* the guns so tried having been *exceptionally* weak, while all the other fourteen rifled guns which ***had more work given them to do, and did not fail, were all of them exceptionally strong;*** the whole twenty-two guns having been taken indiscriminately from store, and being made at various foundries and at different dates. On the other hand it is clearly seen that the eight guns which burst were liable, under the conditions applied to them, to certain adventitious contingencies very likely to arise, producing such a derangement of their working parts as would necessarily involve their destruction, and to this alone, their failure is to be attributed, and which contingencies can be entirely avoided.*

THE PRINCIPLE OF THE MODERN IMPROVEMENTS IN FIREARMS CONSIDERED.

The manufacture of ordnance has of late years become a great engineering question. Twenty years ago there was no gun in the British service which could not be made for £100, now we are making guns which cost from two to three thousand pounds each.

So long as nothing but cannon *balls* were used, the designing of ordnance was a very simple matter, and demanded no higher considerations than attention to certain data empirically determined. A block of iron was made of a certain general conventional form, (which by the way happened to be incorrect,) and when a hole had been bored in it, it was fired with as much powder as experience proved that it was likely to stand. Now however that we are not limited to

* Vide calculations of forces, *p* 69—71.

the weight of the round projectile, or rather, are not circumscribed as to the degree of intensity with which we can make the powder act, because we can add to the length and weight of the shot, and thereby increase the resistance it shall offer to the expansive force of the charge, questions arise of very great importance, involving many points of interest, not only to military men, but to the public at large. Gun-making has become a *science*, which in old times it certainly was not.

In designing guns, which are to cost as much money and labour as so many first-class locomotive engines, we ought to make sure that we adopt sound principles, or we may fail to employ our time and resources to the best advantage, and it is absolutely certain that we yet have something to learn.

To investigate these principles cannot be deemed the exclusive duty of only one class of scientific men, however well qualified they may be. How to employ the force of gunpowder with the best effect so as to produce in a projectile the utmost force and truest flight, is a problem, which must be open to general discussion, and has no more right to be confined to Woolwich than that of how to build the best ships which are to carry the guns when made, to make the best iron to plate them with, or the best engines to propel them. Hitherto, however, gun designing has been more or less regarded as properly a close question. Civil engineers and scientific men generally have not been able to deal with it for want of facts to guide them; and not having correct data they have often been led into great mistakes when they have ventured to touch the question.

The expansive force of exploded gunpowder is so intense, and its effects are produced within such extremely minute intervals of time, that very little can be done by mere theoretical reasoning, and calculation to determine how its energies should be directed: the only safe foundations are the data, furnished by accurate observations of experimental results.

It is but within the last year or two, that any definite idea has been obtained with regard either to the ultimate force of gunpowder expansion, or its rapidity of action.

So recently as four years ago, the very best authorities were divided in opinion as to whether its initial pressure was as low as 15 tons per inch, or as high as 25 tons; but within the last few months, its pressure has been actually measured up to 30 tons per square inch, and there is nothing to shew that even this is nearly its maximum. With such uncertainties upon fundamental points, it is less surprising perhaps that so many and such serious blunders should have been made as are recorded in the strange history of English gunmaking; these difficulties however are rapidly disappearing. Fortunately we have now able men officially engaged in resolving the elementary conditions of the problem, and when these are settled we shall *know* how guns ought to be made, and cease to do it by guess work.

To ascertain, and note all the facts which bear upon this question, is a labour which can only be performed by the scientific artilleryman who has command of the necessary instruments; but to reason upon and apply these facts is the work of the scientific engineer, not necessarily the soldier or the sailor; and surely those men whose whole lives are devoted to the practical application of mechanical laws, and who succeed in producing perfect machinery and engines of other kinds, may well be expected to be able to assist the soldier in making the gunpowder engines he needs.

The public clearly have a right to demand the best, but also the cheapest guns obtainable; whether however this person's or that person's invention shall be adopted, is a question of no moment whatever except to the inventor or contractor who aims at honors and emoluments. The interests of contractors are necessarily, to a great extent, at variance with the interests of the taxpayers. Sooner or later, as knowledge extends, the public always become able to judge of the quality of the article chosen for them, but sometimes only when mischief has been done, and it is too late to fix the responsibility attaching to the judgement exercised. The country wants the weapon that will do its work best, whether it is a breech-loader, or muzzle-loader, a new gun, or *an old one*. The respective merits of any of the guns tried, ought not to be a matter of opinion demanding endless discussion, it is a mere matter of fact which is settled off hand by trial. But for want of knowledge the public are unable to form any opinion on this subject for themselves, and therefore, although they may properly repose entire confidence in the *intentions* of those who are officially deputed to act in the matter, the nation has not that security against errors of judgment involving the most serious results, that there would be, if the question were allowed to be a perfectly open one, and criticisms were invited instead of being more or less repressed.

To treat such questions entirely as *secrets*, as is done on the Continent, is so absolutely opposed to the spirit of all our institutions, that it is merely not attempted because it is impracticable; but to *restrict* their investigation, while leaving what is done partially open to all the world, is surely a middle course which, while it does not diminish the liability to err, effectually shuts the door to valuable suggestions, that might possibly be made by outsiders.

After all, the question is,—*how sh'll the best gun be* *known?* There surely exists no reason, *a priori*, why engines to be used with gunpowder should not be constructed on as sound *principles* as steam engines, or any other instruments. Now, all other machines are adjudged to be either well or ill, contrived by a test which is infallible;—*they must utilize all their forces and waste nothing.* If a steam engine burns fuel extravagantly, or is needlessly costly because expensive material is used for subordinate parts where cheaper metal would answer all the purpose, we do not consider it an example to be copied, but call it a *bad* engine, although it may work well. May we not apply a similar test to guns? For those we are now making, no expense is spared to render them absolutely perfect, the material used is the strongest that can be obtained; but it is worth while to enquire whether it is so employed by the designer, that *its strength is duly made use of?*

It is true we fire with safety, tremendous charges of powder; but again,—*does the powder, as it is employed, yield all the results of which it is really capable?*

These are points which obviously are essential, and I propose to examine them carefully with reference to facts alone.

A short time since, I published a small pamphlet* with a view to call attention generally to the subject I am now treating more fully; in this, I ventured to make two statements which I am led to believe were regarded as hazardous.

One was to something of this effect.—"If the principles which are being applied in the designing of the expensive guns now being constructed *specially for acting against iron defences* are extended to the designing of *all the other* guns we need, which are not required for such special service, a very grave error will be committed." I also went so far as

* "Our effective Artillery." MITCHELL, *Charing Cross.*

to state my conviction "that the old service cast-iron guns, as they were employed in the experiments made with them as rifled guns, were the exponants of higher principles of mechanical economy than those of the modern type which has been officially determined upon."

Now reverting to the comparison, which at page 23 of this paper, I have made between the results which were obtained with the rifled cast-iron service 32-prs. and the *Armstrong* 40-pounder breech loader, I ask which of these two guns represented the highest principles? One cost less than £60, the other £360; the material of the latter is *three times as strong as that of the former*, but what did it yield? The cheaper gun fired 2000 rounds of projectiles, and, if these had all been directed against an object 1000 yards distant, that object would have been punished with 2000 blows of a force, represented in the aggregate of the vis viva of the projectiles, of 758,000 foot-tons.

If the gun which costs £360 had fired an equal number of projectiles at the same object, would the punishment inflicted have been more severe in proportion to the cost? On the contrary, the aggregate force of the 2000 blows, inflicted by the *wrought-iron gun*, would have been only 534,000 foot-tons.

To take another example.—We have just completed the largest and most expensive gun ever attempted to be made in this country: its weight is 35 tons, and it is 16 feet long, or nearly as long again as any of our old guns. Every pound of powder which is consumed in this gun, is shewn to produce a living force in the shot on leaving the muzzle of 70.6 foot-tons; but every pound of powder burnt in the old cast-iron 32-pounder gun, shews a force in the projectile of ~~102.2~~ 121.7 foot-tons, or *nearly* ~~45~~ 72 *per cent.*

more than is obtained with the large gun. To take another case.—The American cast-iron 15-inch service gun, firing shot of 450-lbs., may be compared with our last new gun. One can be made for about £350, the other costs nearly £3000.

The more expensive gun is made of iron, *more than three times as strong as that of the other;* but when we look at the force with which the shot issues from each gun when fired with service charges, we find that the only advantage obtained with 1-cwt. of the *coiled wrought iron* over 1-cwt. of the *common cast-iron*, is that the former yields 13.6 foot-tons of work, and the latter 12.1 foot-tons with the ordinary charge.

What proportion does this bear, either to the greater cost or the greater strength of the English gun?

The following comparisons will also be found to have considerable interest:— (*Vide Table*, *page* 58.)

Work done by every lb. of powder in the Service charges used for various kinds of Ordnance.

Service charges.	Vis Viva of projectile to every lb. of charge, at Muzzle.	Vis Viva of projectile to every lb. of charge. at stated Ranges.	
	Thousands ft.-lbs.		*Thousands ft.-lbs.*
68-pr. Cast Iron service guns, rifled	251.9	at 3560 yds.	148.1
32-ditto ditto ditto	272.6	,, 3450 ,,	123.7
Palliser or Wrought Iron gun	170.3	,, 3004 ,,	122.2
9-in. Wrought Iron, 12½ tons	161.3	,, 1200 ,,	130.6
Ditto ditto ditto		,, 4000 ,,	95
Armstrong 100-pr.	183.6	,, 3470 ,,	92.8
American 15-in, smooth-bore	208.2	,, 1021 ,,	146
New Field gun	152.5	,, 3422 ,,	57.4

The full significance of these figures demands attentive consideration. They represent the principle adopted in the general type of our modern guns, which has been selected and stamped with the official seal. The 35-ton gun which has just been made, and the new field gun lately adopted, are the highest examples of the principle chosen. That they are both admirable guns for service need not for a moment be questioned, but that, *as instruments constructed with due regard to the economy of force*, are they correctly designed?

If the 9-inch wrought-iron gun employed the charge used with it as advantageously as the 32-pounder, the shot would leave it with a force of 5,200 tons, instead of only 3,098 tons. And the strength of the material it is made of would be equal to do more than even this, if economically employed in the design of the gun, although it may be doubted whether it would be possible to restrain the recoil that would be so occasioned.

It would require every cwt. of the gun to produce 20½ foot-tons. The cast-iron American gun, when fired at Shoeburyness with 100-lbs. charge, actually produced at 70 yards a striking force of 19 foot-tons per cwt of cast-iron, and from coiled wrought-iron, which is more than three times as strong, we get but 12¼ tons of work at the mouth of the piece with the 9-inch 12½-ton guns, and still less with our 600-pounders.

The conditions as regards the economical employment of the force of the charge, which is involved in the design adopted for our new guns will be found indicated by the diagrams, which I give at page 58, representing the bore of several of the guns, and the proportions which the charges employed, bear to the interior.

It will be seen, that although the new 35-ton gun is nearly as long again as our old guns, its charge of shot and powder occupies no less than 5 feet 6 inches, or nearly *one third* of the whole bore. This has to be considered in connection with the fact, that the *power* applied to the shot is *force of expansion, and expansion requires space.* We may tax the strength of a cylinder with any pressure of steam we like, but to gain the smallest advantage from it, we must have a certain *length of stroke in the piston.*

Now in order that the whole of this important subject may be laid open to the light of general enquiry, I have been at considerable pains to collect and tabulate, in such a way as will facilitate comparison, what appear to me to constitute all the chief established facts which bear upon it.

In the table which is annexed, I have shewn the results of experience with all the different kinds of ordnance which have been used in this country, giving at the same time the particulars of the conditions under which the projective power in each is developed. I have made the table as complete as I have been able to do, from a limited command of records, but, as far as they go, the figures, I believe, may be perfectly relied upon, for I have been careful to admit nothing without the warrant of official documents I think a more satisfactory view may be obtained of any particular system of artillery from this table, where all are closely compared, than by any process of individual examination.

It will be found that there are many things which at first sight seem singularly anomalous, but which are still susceptible of satisfactory explanation, when their relations to other circumstances are properly traced.

This table contains an epitome of all the practical results ascertained in our numberless experiments. I propose to examine these facts simply as I find them, without referring to, or explaining them by any of the rules and formulæ by which they are generally accounted for; but rather to treat

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VIVA OF P
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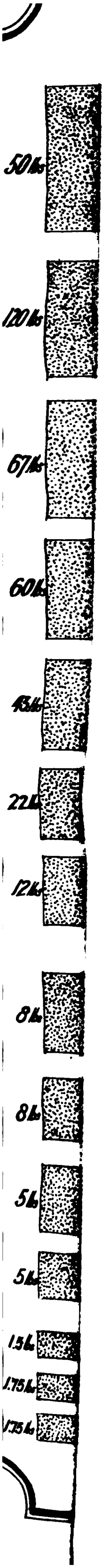
MEDIUM	
RANGE Yards	*MEAN VELOCI* Feet per seco
—	—
2,500	1,090.
—	—
2,600	1,040
—	—
—	—
2,600	1,109.
2,200	1,087.
2,800	1,127.
2,300	1,032.
2125	861



50 lbs
120 lbs
67 lbs
60 lbs
12 lbs
8 lbs
8 lbs
5 lbs
5 lbs
1.5 lbs
1.75 lbs
1.75 lbs

them merely as phenomena, which if carefully compared may possibly explain themselves, and shew what laws they follow.

A gun may be rightly regarded as a *pressure engine of the simplest possible form.* Its object is to produce motive power; and this is done by means precisely similar to those which keep the cranks and axles of a steam engine at work. The cylinder of a steam engine is truly a gun; and every movement, from the primary vibration of the beam, down to the twirl of the jennies of a cotton mill, is only the result of successive *shots* fired with a certain charge, which exert a cumulative power on a piston having a certain "range" or stroke. There are high pressure and low pressure steam engines, and there are also *high and low pressure guns.*

It may be said that the application of the principle of the rifle accomplished the same thing for artillery as was done about seventy years ago, when engines were first made without condensors, and the higher powers of steam became utilized. So long as only round projectiles of a certain specific gravity could be used, no advantage could be derived from applying more than a comparatively small intensity of force to them; but directly we began to use elongated projectiles, a new problem presented itself.—With long heavy bolts we can restrain the expansion of the charge to almost any extent, and so *work the powder* at any degree of pressure; just the same as by loading the safety-valve of an engine, and superheating the steam we may increase the intensity of its energy indefinitely.

The designer of a gun has no greater occasion to be embarrassed with considerations as to the extreme power of the agent he is going to employ, than the designer of an engine which is to work with steam; because there is no evidence that one agent really can exert any greater force than the other. The ultimate, or what is termed with more or less correctness, the "initial" force of gunpowder, is beyond all measurement, but so also is that of water when turned into steam under extreme pressure. The question for the Engineer is simply,—how much of it he can employ with advantage? And he has to economise his resources and adapt them with judgment.

In making steam machinery, he is limited by the cost of labor and the value and strength of the materials he can use. It may be said that practically this limitation does not exist in regard to the construction of such simple machines as guns. But there is yet one limit which cannot be exceeded for them—a positive restriction which it is impossible by any means to avoid. We may perhaps disregard the matter of cost, and, now that we have conquered the difficulty of forging wrought-iron in huge masses, we have become independent also as regards strength of material, for it will be found that we have really more of it than we can profitably employ.

Action and re-action being equal and contrary, there is the vis viva of the gun to manage, and the only way to control this is by diffusing the force over so much matter in the gun itself, that it shall be absorbed by so much weight; and thus, by gaining time, we reduce the force within conditions that can be dealt with. These elementary principles must be borne in mind when considering what is signified by the figures in the table.

The guns which I have selected for comparison are those which, while representing the various systems that have been adopted for the British service, or have received a considerable share of attention, still widely differ as examples of their respective kinds, so that what is peculiar in each may be distinctly seen. The cardinal point however, which it is my object to illustrate, is the distinctive feature in modern rifled ordnance of being all ***very high pressure guns***, or guns which, by reason of their small calibre in proportion to the charges used with them, are required to be made of enormous strength to enable them to resist the pressure of the charge. It will be seen that the strain on a gun to burst it, does not depend solely on *the amount of the charge* employed, but also in a very large degree upon *how it is disposed* and made to act in the gun. It is important to ascertain what is thus gained or lost by working the powder above a certain degree of pressure.

The several columns in the table, which for convenience of reference I have distinguished by letters, shew the nature of the tests which may be applied to the elucidation of this point.

Columns A to E shew all the particulars relating to the construction of the guns, their length, weight, bore, the nature of the rifling, if rifled, and also the weight of shot and charge of powder with which they are fired.

Column F gives the speed with which the projectile from each gun leaves the muzzle. These velocities have all been measured by an electrical apparatus, which is found accurately to record intervals of less than a thousandth part of a second. The comparatively low velocities which all the elongated shot have in comparison with the old round ones, will be observed,—the former seldom exceeding 1300 feet, while the latter vary between 1600 and 1800 feet per second.

Column G denotes the vis viva or force of the projectiles. This is calculated by multiplying the square of the velocity by the weight of the shot, and then dividing the product by 64.3, which, comparing the power with that of gravity, reduces the terms to the standard of *foot-lbs.*, by which "work" is usually expressed, and ordinary "horse power" is estimated; it having reference to the unit of work done in raising one pound weight to the height of exactly one foot. The figures in this column represent the force with which each shot would strike any object in its course, at the distance given, stated in the terms which are now generally employed for that purpose.

The several columns in the *division H*, shew, as nearly as can be measured by the time of flight, the velocity and *vis viva* of each projectile at short ranges of about 1000 yards, at medium distances of about 2000 yards, and at long ranges of between 3000 and 4000 yards. These figures being calculated on the *mean time* of flight, of course do not shew precisely what is the actual force of the shot at the distances mentioned; but still, a fair *relative* comparison of results is so afforded. The actual terminal velocity would in each case be somewhat less than is here given, because the *mean time* of course includes the higher speed at the earlier part of the shot's career; but the additional force which the projectile would acquire in consequence of its descent from the highest point of its trajectory is also not included. We can at all events thus obtain a correct view generally of each gun's performance, as the same test is applied to all.

The advantage which is gained by the employment of elongated shot is exemplified most fully in the very different results obtained with the two guns, Nos. 7 and 23. It will be seen that the projectile fired from the smooth-bore 10-inch gun, starts with a velocity of 1292 feet per second, and being a round hollow shot which has a weight of only about ¾-lb. to every square inch of its sectional area, its velocity is rapidly destroyed by the resistance of the air, so that in a range of 2660 yards its mean rate of speed is seen to be only 694 feet, the difference being 46 per cent. less than it started with. The projectile from the 9-inch gun leaves the muzzle with a velocity of 1336 feet per second, but being a long solid shot which has a weight of nearly 4-lbs. to every square inch of its sectional area, its velocity is far better maintained than that of the lighter one, owing to the resistance of the air being so much less in proportion to its density; consequently in a range of 4000 yards its *mean* rate of speed shews a difference of only 23 per cent. less than it commenced with.

The following examples from the table will illustrate this point forcibly in regard to the ***vis viva*** of different projectiles.

(23) 10-in. Cast-iron Smooth. Charge 12-lbs., Hollow Shot 88.5.		(24) 68-pr. Cast-iron. Charge 16-lbs., Solid Round Shot, 66.4		(26) 32-pr. Cast-iron. Charge 10-lbs., Solid Round Shot, 31.6		(20) Britten's Rifled 32-pr., Cast-iron. Charge 5-lbs., Elongated Shell, 50-lbs.		(7) 9-in. Wrought-iron Rifled. Charge 43-lbs., Elongated Shot, 250-lbs.	
Range, yds.	Vis Viva ft. lbs.	Range yds.	Vis Viva ft.-lbs.	Range yds.	Vis Viva ft. lbs.	Range yds.	Vis Viva ft.-lbs.	Range yds.	Vis Viva ft.-lbs.
Muzzle.	2300	Muzzle	2575.7	Muzzle	1403.6	Muzzle	1145.2	Muzzle	6939.7
925	1177.5	720	2193.	1172	477.2	1010	849.2	1200	5616
2190	900	1750	1057.5	1882	365.2	2100	753.4	2600	4784.5
2660	662.6	3200	585.7	—	—	3450	648.7	4000	4110.4

It will thus be seen that while the light hollow round shot loses nearly ¾ths of its force in a range of a mile-and-a-half, the long heavy bolt from the 9-inch gun, in a range of more than 2¼-miles loses little more than a third part of the force with which it leaves the gun. The other guns shew similar facts, but to a less degree.

With spherical projectiles this conservation of force during flight is limited by the specific gravity of the material which they can be made of, either lead or iron; but with elongated shot it is only limited by the length of the projectile which can be inserted in the gun, and be forced by the rotatory motion communicated by the rifling to travel through the air with its axis, coinciding generally with the line of its flight like an arrow. But *to what extent* advantage can be taken of this remains to be considered. There must be some limit; and we have therefore to endeavour to find out what the principle involves in its relation to the right economy of the forces which we have to employ.

To do this it is necessary to apply several processes of dissection to the results which have been ascertained; and it seems to me that those which are specified in the subsequent columns of the table are best calculated to throw light upon the matter.

Column I. Vis viva of projectile at muzzle, produced by every pound of powder in the charge.

Some very remarkable facts are revealed here. I select the following examples as specially noteworthy.

No.				Thousands foot lbs.
28—24-pr. Smooth-bore,	Charge	8-lbs.	Vis viva ⅌ lb. of powder	137
27—32-pr. ditto ...	„	„	ditto	160.9
17—Palliser, Rifled ...	„	„	ditto	170.3
22—10-in. Smooth-bore	„	„	ditto	201.2
18—Rifled 68-pounder...	„	„	ditto	251.9
20—Rifled 32-pounder...	„	5-lbs.	ditto	272.6
12—Armstrong 40-pr. ...	„	„	ditto	175
7—9-inch Rifled	„	43-lbs.	ditto	161.3
31—15-inch Cast-iron ...	„	50-lbs.	ditto	208.2
32—15-inch „ ...	„	100-lbs.	ditto	162.1
1—11½-inch Wrot. Iron	„	120-lbs.	ditto	158

It is to be seen that the ***same quantity of the same kind of powder*** may be so employed in two different guns that it shall produce ***one hundred per cent. more projective force in one than it does in another, and the guns may be of the*** *same length.* How then may this be accounted for? It is not to be attributed to any peculiarity in the kind of gun or the nature of the projectile employed. Here are two *rifled* guns, one yielding 158,000 and the other 272,600 foot-lbs. of "work" per lb. of powder; and it happens that the gun which does less, is nearly twice as long as the other. And here also are two smooth-bore guns, which shew a difference almost as great in their economy of the charge as any of the others that are compared. These two smooth bore guns are both fired with a service charge of 8-lbs., but one of them delivers its projectile with a total force of 201.2 thousand foot-lbs, and the other yields but 137 thousand. Now the only material difference between these two guns lies in their calibre; one has a bore of 10 inches diameter, the other, a 24-pounder, is only 5.82 inches. In consequence of this, the 8-lb. charge is very differently disposed in them. In the large bore, the pressure is exerted upon a far larger area on the shot, and *therefore* so much more "work" is done with it, and it is done with really less effort. *Why* is it then that so much greater force can be obtained with the same quantity of powder out of large bored ordnance than out of smaller? this I think may be comprehended by paying due regard to what is indicated by the figures.

In the first place let this point be investigated in its reference more particularly to the gun itself, and the strain which is produced by the force which developes power in the shot. The three next columns which I have inserted in the table will throw light on this.

Column K. Weight of projectile in proportion to the charge of powder.

Column L. Weight of powder in the charge in proportion to the area of the bore.

Column M. Weight of projectile in proportion to the area of the bore.

I have alluded to the modern rifled ordnance as being all of them *high pressure* guns, yet it will be seen by column K that for none of them is so much powder employed as is used for the old service guns, in proportion to the weight of the projectile, or even to the weight of the guns themselves. For the wrought-iron guns, the quantity seldom exceeds a sixth part of the weight of the shot, while for the cast-iron ordnance the service charge sometimes exceeds a third. When however the figures in columns L and M are regarded, we shall see that it is not alone the *quantity* used which has to be considered in reference to the strain on the gun, *but the form in which it is applied, depending on the bore.*

In column M I have shewn what is the approximate weight which each projectile presents, in every square inch of its sectional area, as *specific resistance* to the expansion of charge. This resistance of course increases in proportion to the length of the shot, if solid. It is the same thing as if the projectile were a body of greater density, or made of a material of higher specific gravity. If, for instance, a round shot for a 32-pounder were made of lead instead of iron, it would weigh about 51-lbs. instead of only 32-lbs. For the same reason if the shot which is employed for the 700-pounder were spherical instead of being elongated, it would require to be made of a material which is more than *twice as heavy as lead, or nearly half as heavy again as gold,* to offer the resistance which it does of 6.73-lbs. per square inch. In order to produce any motion at all in this shot, the power must accumulate against it up to an intensity equal to this resistance concentrated in the area which it acts upon, and this has to be multiplied in order to obtain velocity. The strain upon the gun in doing this becomes enormous.

These figures in Column M will, I think, be found useful presently as indicating the store of power in the shot when fired, enabling it to ***maintain*** its course against the opposition of the atmosphere: and also against opposition from the ***inertia*** (simply) of any matter to be removed in its course, not including, however, obstructions from the ***coherence*** of solids penetrated; this is ***as the circumference.*** Vide page 86.

There is a very prevalent idea that, in some way, there is an advantage gained in *force* by using long shot, and cartridges of the shape of bolsters, or sausages, but is this possible? The force of gunpowder lies in the energy which it exerts in the form of elastic gas to enlarge itself into a volume indeterminately greater than its original bulk. If *free*, it would do this with a velocity which cannot be measured. Under the pressure of the atmosphere it was estimated by *Robins* to have a velocity, at its greatest heat, of 7000 feet per second, and this is probably far below its real speed; but if the rapidity of this expansion be hindered, then its force, as an active power, becomes increased in proportion ***to the time*** which it takes to ***carry the burden which hinders it.*** But the powder will naturally exert its *whole force*, whether the burden be more or less, and we may collect much of its energy in projectiles as either great speed accompanying less weight, or great weight with less speed, but the life power of the shot represents only so much of the life of the charge as the density of the shot can absorb in the interval of communication. The projectile which offers in its sectional area the greatest resistance may absorb more of the force of the charge, but ***only when there is room in the gun for the shot to traverse while it is subject to the pressure.*** This will be found to be a point of great interest and considerable subtlety.

Nothing can be gained by intensifying the pressure through increasing the resistance from the *same weight*, by using longer shot, unless the dimensions of the gun admit of continued action of the pressure. Therefore to reduce the capacity of the gun out of proportion to the charge appears to me to be a wrong principle. To economise the force we ought to employ as much as we can of its activity as an accelerating agent, not half fill the bore with powder and leave it little room, *and consequently time*, in which it can perform its duty.*

The figures in the column M shew what is the actual quantity of powder contained in the several charges of the guns compared, which can operate upon every square inch of the sectional area of the projectile; or at least it is a sufficiently close approximation to this, for I have assumed the area of the bore to be equal to the area of the shot; there is of course the difference of windage, but this need not be regarded. A good notion is thus obtained of the pressure which our modern guns have to sustain, in the way we employ the material used for them.

It will be observed that the 15-inch cast-iron gun is found perfectly competent to fire shot of 450-lbs. weight, and, as an experiment, it has successfully fired this shot with 100-lbs. of powder, a very much more powerful charge than is used for *proving* our 10-inch wrought-iron guns, although the shot for the latter is 50-lbs. less in weight, while, not only is the material of the English gun three times as strong as that of the other, but there is actually about two inches more thickness of metal in it round that part which has the great work to do.

Why did not the cast-iron gun burst? The simple fact that it did not is entirely incomprehensible, unless we examine closely the conditions under which the charge was employed. These may be better understood with the help of the following figures:—

* This point will be found further discussed at *p.* 88—95.

The Columns below refer by letters to the general Table.

	Pressure of Powder. Weight of the Column of Powder in the charge to every square inch of the sectional area of the Shot L	*Resistance of Shot.* Weight of the Column of Shot which is opposed to every square inch of the pressure from the charge M	*Vis Viva of Shot* resulting from every lb. of Powder. K
	.lb. = ounces	.lb.= ounces.	foot. lbs.
11½-in. Wrought-iron Gun (1) Weight 700 cwt. Length 192 inches Charge 128-lbs. Shot 700-lbs.	1.15=18¾	6.73=108	158,000
10-in. Wrought-iron Gun (5) Weight 360-cwt. Length 144 inches Charge 60-lbs. Shot 400-lbs.	.764=12¼	5.1= 81	174,600
15-in. Cast-iron Gun (31) Weight 385-cwt. Length 165-inches Charge 50-lbs. Shot 450-lbs.	.28= 4½	2.54=41	208,200
10-in. Cast-iron Gun (22) Weight 87-cwt. Length 109-inches Charge 8-lbs. Shell 117-lbs.	.102= 1¾	1. 5=24	201,200
32-pr. Cast-iron Smooth-bore (26) Weight 56-cwt. Length 108-inches Charge 10-lbs. Shot 32-lbs.	.313= 5	.99=16	140,300
32-pr. Cast-iron (Britten's rifled) (20) Weight 56-cwt. Length 108-inches Charge 5-lbs. Shell 50-lbs.	.156= 2½	1.56=25	272,600
68-pr. Cast-iron, (Britten's rifled) (18) Weight 95-cwt. Length 113-inches Charge 8-lbs. Shell 90-lbs.	.155=2.48	1.75=28	251,900

I particularly commend these figures to the consideration of all who may yet entertain apprehensions as to the safety of employing our cast-iron guns, when rifled, and fired as I proposed. It will be seen above what was really involved. For the rifled 32-pounder, the service charge I suggested was made up of so many columns in the bore representing, in every square inch of the area, 2½-ozs. of powder restrained by 25-ozs. of shot. The service charge of the American *cast-iron* gun shows 4½-ozs. of powder to 41-ozs. of shot. Now when my four guns were tried at Woolwich up to the bursting point, the 32-pounders were fired with a tenth more powder than I proposed for service, and the weight of shot (similar in principle) was increased 50 per cent. at every successive 10 rounds. Finally, when they burst, the resistance was 83-ozs. on every inch, or rather more than that which the 400-lb. shot offers in the 10-inch wrought-iron gun. For my 68-pounders, the powder was equal to 2⅓-ozs. per inch, and the increased weight of the shot employed at the 81st round, shewed a resistance of 140-ozs. to the inch. The resistance of the 90-lb. shell I proposed for service being, as will be seen, only 28-ozs.

The fact is that we call the *weight* of a shot is a term that is deceptive; it really has little or no meaning in regard to the force which is required to set it in motion. For instance, the projectile for the large American gun actually weighs more by 50-lbs. than the shot which is used for the 10-inch wrought-iron gun, but the same *degree* of pressure, as it is applied to both, that would lift the heavier shot, would not move the lighter one in the smallest degree; therefore, in order to give both projectiles nearly the same velocity, the intensity of pressure upon one has to be just about twice as much as will suffice for the other. The two extreme cases in regard to this point which may be noticed in the table, are number 25 and number 1. The 8-inch shell used in our naval service is fired with a charge which exhibits the proportion of less than 5 *ounces* of powder to every square inch of the shot's section, and in the same way, to every square inch of the shot for the new 35-ton gun, there is no less than $18\frac{1}{2}$-ozs. of powder; but as the specific resistance of the shot in one case is only 16-ozs., while in the other it is 108-ozs. per inch, it is less surprising that the velocity which is really obtained with the smaller degree of pressure is 1810-feet per second, while that of the other, subjected to nearly four times more pressure, is only 1320 feet.

But this is not the only reason of this great difference of velocity, as will be seen by regarding the succeeding details in the table.

Column N.—Length of bore occupied by the charge of powder.

Column O.—Number of full expansions of the charge permitted by the length and capacity of the bore.

Gunpowder is a combination of matter in a convenient form for use, which is capable of becoming converted by a sufficiently rapid, but not too quick, combustion into elastic fluid in a state of high tension. There is every reason to believe that all solid matter is susceptible of being similarly transmuted or sublimed. When matter is dense, and more or less coherent, as in solids or liquids, it is made up of atoms which are so related that they are *mutually attractive*: or inclined to approach each other, and when the particles are free this attraction causes them to arrange themselves into the form of the sphere. This is witnessed in the drop of water, the globule of mercury, or the lead converted into solid spheres in falling through the air. May it not then be said that all material bodies, irrespective of size, for this is a mere relative term, are congeries of atoms which resemble *planetary systems*, without their centrifugal force? When however any such a combination or system of matter becomes acted upon by a higher degree of heat than its *specific* nature can endure as a *latent* and more or less inactive principle, the relations between the atoms of which it consists undergo a radical change; they lose their attractiveness for each other, and become *mutually repulsive*: they break away from the bonds which previously held them together, and become impelled outwards from each other, and away from the centre of the sphere, to which, under the law of attraction, they were immediately connected.

It seems as if the only way in which these remarkable phenomena can in any way be satisfactorily accounted for is upon the hypothesis that Caloric is not, as it has often been considered, a mere quality or property of matter, but that it is really a mighty *force or principle* akin to that of gravity, but *acting in opposition, though subordinately to it.* There certainly is a sense in which caloric may be fairly said to exert a power probably only inferior, in the extent and importance of its operations throughout nature, to the law of gravity itself. Caloric, with Electricity, and possibly Light, as adjuncts, may be the powers which are required to rule over and regulate matter as it exists in that diffused state in which the atoms are beyond the reach of *each others* attraction, and when gravity can only govern them in their aggregations. We see the operation of heat in the enlarging of the volume, and diminishing the density of all solids; then reducing many of them into liquids which is that neutral state at which the *specific attraction of the atoms towards* *a common centre* is just balanced by the force which would divide them, or destroy their cohesion; a higher degree of heat converts the liquids into fluids, having a greater or less elasticity in proportion to the measure of caloric they are subjected to. We can continue to observe the action of this mysterious agent upon the gaseous elementary representatives of the earth's materials, as they float in the lower strata of our atmosphere,—held by gravity within our general sphere, but their own particular systems literally "dissolved by fervent *heat*,"—but, as the field of operation extends all physical science comes to a fault, because the condition of diffused matter becomes too subtle and etherealized for our senses to appreciate: we seem to approach that ultimate boundary line probably subsisting between *matter* and those entities which can only be dealt with in metaphysical reasoning.

Gunpowder is converted into gas by the heat accompanying its combustion, just as water is into steam, or quicksilver, or any other metal, mineral or substance, iron and stone, as well as wood and coal are into elastic vapours; and in this form they become diffused and intercommingled, to be again re-combined and re-constructed by the ceaseless action of the chemistry of nature.

As therefore the power from exploded gunpowder is wholly derived from the mutual repulsion of its atomic constituents, its mechanical force must be one which acts in radiating columns, and consequently it becomes a pressure which is equal in every direction. A beautiful familiar example of the uniform action of elastic force is seen in the soap bubble which children blow out of pipes. The delicate film of water, rendered more coherent by holding the saponaceous matter in solution, severs all connection with the outer system of atoms in the atmosphere, and therefore the pressure from within is seen to extend the confines, not in the direction of the blast, but in *every* direction with exquisite precision, and a globe is formed; this globe would be mathematically perfect in its proportions but for the weight of the film and the gravity of the air itself.

If then, as no doubt it will be freely admitted, the force of a charge of powder in a gun is the result of pressure acting equally in every direction, I invite attention to the different circumstances under which the various charges must act in the guns represented in the accompanying diagrams, page 58.

At first sight there might appear to be an advantage likely to accrue from the employment of powder in small-bored guns with long cartridges, on the assumption that it might bear some analogy to the case of liquids in the pipe of a fountain, in which the pressure on the sides of the pipe is known to be far less than it is on the end where the jet is formed; but it will at once be seen that there is no similarity whatever between the two circumstances, because the pressure which produces the fountain jet is solely due to the superincumbent weight, by gravity, of the column from the reservoir above the fountain, but the pressure of the gas within the gun is force solely emanating from the body of the gaseous mass.

If gunpowder be exploded in a perfectly spherical chamber, its force, being equal in every direction, would tend to drive every part of the surrounding substance, with equal velocity, away in lines radiating from the centre of the charge. If however the chamber were not spherical, but of other form, such as that in which steam engine boilers are made, or as the cylindrical chamber of a gun, still the pressure over the whole interior would be equal in intensity, whether the cylinder filled by the charge be long or short in proportion to its diameter; on the ends therefore, as on the sides, the pressure would be in proportion to area. If then, the bore of a gun be large, the surface of the shot acted upon by the force, represents a greater proportion of the whole area of the chamber, and would necessarily be pressed by a greater number of columns; on the other hand, if the bore be small, the shot would receive impulse from fewer of the columns directly, but they would be deflected from the sides and flow like a stream, and so continue the pressure, which would diminish less rapidly because the space or volume of *an equal measure of expansion of the charge would represent a greater distance moved through by the shot.* The result however in the vis viva of the shot would, if nothing else had to be considered, be precisely the same in both cases, *provided the total resistance or weight of the shot distributed over the whole area were equal*, which of course would involve one projectile being shorter than the other, or else of a less density. The greater amount of pressure on the larger area would produce motion more rapidly, but the pressure would proportionably decrease more quickly; while the less force upon the smaller area would be slower in its operation, but it would in similar proportion be maintained for a longer space, and consequently the gun must be made longer to enable it to do so. It must be observed, however, that the effect of narrowing the outlet of the gas by reducing the bore of a gun, necessarily involves the sustained action of the full pressure of the gas on the gun for a longer interval, tending to burst it, and also that there must be a positive loss of force occasioned by the *reduction of the heat of the gas* through its continuing to be absorbed for a greater length of time by the metal which confines it.

The question has next to be considered in relation to the space into which the charge is capable of expanding before the shot issues from the muzzle, and all further power in the gas is simply expended on the air. Theoretically, the elastic gas would continue to accelerate the velocity of the projectile till its tenuity became such that its pressure was only equal to support, without moving, the load of resistance it encounters, just as about 30 inches of quicksilver, and no more, is supported by the atmosphere in a barometer tube, or so much weight of water in a pump. So long as there is more pressure from behind urging the shot forward, than there is in front to retard it, its motion would continue to be accelerated.

It has only been within the last year-and-a-half that anything definite has been known as to the degree in which the force of gunpowder diminishes as its vapor expands. The valuable experiments made by the Woolwich Committee on Explosives have however thrown much light upon this point, and judging from the facts disclosed in their published preliminary report, it is evident that the elasticity of this gas is not maintained in the ratio of its density, according to *Marriotte's* law, which is generally accepted as sufficiently accurate for determining the pressure of gaseous fluids, where loss of heat is not an element of importance, but that, owing no doubt to the very high temperature of the gas thus evolved under vivid combustion, and the reduction of heat by dilatation and its absorption through the metal which surrounds it, the tension is reduced so rapidly that the charge, in enlarging itself into double its volume, loses considerably more than two-thirds of its force.

It was found by actual measurements, very carefully made by means of the Chronoscope in an 8-inch gun constructed expressly for these experiments, that with shot of 180-lbs. weight, and a charge of 30-lbs. of the common powder which has been used in our service, the internal pressure when starting the shot, amounted to 29.8 tons on every square inch; but by the time the projectile had advanced 19 inches, which was sufficient for the charge to expand into twice its original volume, the pressure had come down to 8½ tons per inch.* The necessary arrangements within this gun admitted only of the effects of rather more than 4½ full expansions of the charge being observed, as the shot had only 4½ times the length of the cartridge, or 88 inches to travel between the points where the cutting wires were placed. The first full expansion of the charge produced a velocity of 940-feet per second; the second increased this to 1150-feet; the third to 1250-feet; and the fourth to 1310 feet per second. The last 19-inches of expansion, added but 25-feet per second to the velocity, already so great that that there was no time for much work. But what does this *additional* velocity represent? It is an extra 185,000-foot-lbs. in the vis viva of the shot. Had then the gun permitted more of the expansive force to act, there would necessarily have been a further considerable addition to the force of the projectile. But this point must be considered in reference to the specific resistance of the shot to the charge, and not merely to its weight in a scale.

When this shot left the gun it was still subject to a pressure of 16 cwt. per square inch, or *nearly* 120 *atmospheres.* The time within which the whole velocity was acquired was .0076 of a second. This was with our RLG powder.

The projectile was a long heavy one, like all those which we are making for our plate punching ordnance, and its actual resistance amounted to 3-lbs-9-ozs. on every square inch of its sectional area; and therefore as the force of

* Vide Table, page 111.

the charge became partially exhausted it would act more feebly than if it had a lighter burden to carry, for the same reason that the pressure of the atmosphere will produce far more motion in lifting a column of water, than a column of mercury of *equal length.*

It becomes therefore of great importance to determine how far, or up *to what degree* it is really practicable to utilize the expansive force of the gunpowder we employ in ordnance, and this will be found materially to affect the general question of *calibre* and whether we are doing right to restrict ourselves to small-bore rifled guns generally, as it seems to be the intention to do at present. If the *principle of reducing the bore* be right, why should it not be carried much further than it is, and instead of shot of about two diameters in length, why not have them much longer still? *Sir Joseph Whitworth* has employed projectiles no less than ten calibres in length. If there is really an advantage to be derived from employing elongated projectiles, as no doubt there is, what are its proper limits?

In the Enfield rifle, the service charge can expand more than 31 times its own volume in the barrel; and when the gun is made shorter, I am told that there is a positive loss of range, and the bullet does not hit so hard. The resistance of this bullet is in the proportion of 6½-ozs. per inch of its sectional area. The bullet for the smaller bore *Whitworth* rifle offers a far greater resistance than this, it being as much as 16-ozs. per inch, although both bullets weigh the same, (530 grains,) and, with the *same charge of powder*, the velocity of the latter, as well as its striking, (not penetrating) force at the muzzle, is less than that of the Enfield bullet.

These points however are more perfectly illustrated by the facts which the table discloses in the examples, No. 5 and No. 20. The full service charge of 60-lbs. of powder which is employed for the 10-inch wrought-iron rifled gun, occupies very nearly 23-inches of the bore, and although the gun is one fourth longer than used to be considered desirable, the charge can expand only 6.3 times, and then the residue of the elastic force is expended on the air. The charge used for the other gun (No. 20) occupies only 4.7 inches in length, and although the bore is 3-feet shorter than that of the 10-inch gun, the powder can expand into 23 times its volume, and so to this extent continue to accelerate the velocity of the projectile In the 10-inch gun, the initial pressure of the charge is exerted upon 719 square inches of the sides of the bore, tending to strain or burst it, and on 78½ square inches on the ends, tending to propel the shot in one direction and the gun itself in the other, so that the profitable employment of this greatest pressure is in the proportion of only 1 to 9.1 of the whole surface acted upon. In the other gun, a similar calculation shews the proportion of useful expenditure of the initial pressure on the shot to be as 1 to 2.9 of the whole.

Then with regard to the measure of expansion. In the 10-inch gun the charge of 1800 cubic inches of powder will continue to act on the shot only till it has enlarged itself into 11,400 cubic inches of gas; but in the other case the 150 cubic inches of powder will continue to accelerate the velocity of the projectile till it has expanded into 3400 cubic inches, the proportions of course being the same as I have before stated, viz 6.3 times the volume in one, and 23 times in the other. The practical result of this is that every cubic inch of powder in the large gun yields 5822 foot-lbs. of force in the projectile, or 161,300 foot-lbs. to every lb. of powder; while in the other gun each cubic inch of powder gives 7633 foot-lbs. of force, or 272,600 foot-lbs. to every lb. of the charge.

When the same proportion of charge to the weight of the shot is used for both guns, viz., one-tenth, there is still a difference in favor of the gun which has the larger bore in proportion to its length, as 272 to 194, in the "work" performed, (vide No. 6); and if these two guns are yet further compared, as regards the striking force of the shot obtained with an equal quantity of powder at long ranges of three or four thousand yards, it will still be found that the relatively larger bore 32-pr.yields higher results. The fact of these two guns being of different powers can scarcely affect the calculations, so as to disturb the comparison because it is wholly *a question of principle*, which is involved, and as such may be carried out to any extent. What was true in the case of my rifled 9-pounder service guns, was equally true with respect to the 32-pounders, and also the 68-pounders. *Would it not therefore be equally successful in guns of very much larger calibre such as the American ordnance.*

There is however one thing to be considered in reference to the nature of the projectile employed for the cast-iron gun (No. 20.) Being an expanding shot, there was certainly less escape of the gas through windage. As I have before stated, I made such an arrangement of the parts that the gas should not be wholly prevented from passing the shot, as was proved by there being sufficient of the flame to ignite an ordinary time-fuze in front, but still there was doubtless considerably less escape than with the studded projectiles, and this would affect the results, but it could not go very far to account for the great difference observed. In the *Armstrong* breech-loaders there is literally *no escape* of gas, yet it will be seen that the velocities obtained with them are in fact absolutely less than that of other guns, and this can only be attributed to the increased friction and atmospheric resistance within the gun.

I have now to refer to other points of very great importance in the consideration of the efficiency of ordnance.

Generally it may be said that the power of artillery depends upon three main qualities, besides the question of range. (1.) *The force with which the projectiles fired will strike.* (2.) *The extent to which they will penetrate on striking.* (3.) *The diffusive effect they will produce as shells to burst and scatter their fragments.*

As regards the latter quality, it can admit of no doubt that any reduction of calibre must be attended with disadvantage, because, if other things were equal, the shell which has the greatest *capacity* must necessarily be the most effective; and capacity increases in a higher ratio with diameter than with length. But as regards the *striking force*, and the *penetrating power* of missiles, these are not correlative qualities: there might be great power, but comparatively little penetration. Penetration depends upon the quantity of matter to be displaced, and therefore the force to do this most effectually should be concentrated within the narrowest compass. The conditions are exemplified in the cutting edge of the knife, or the point of the needle. There can therefore be no question as to the advantage of the small calibre for this, so far as we can obtain sufficient power to drive the point; but to get that power we must have *breadth of area.* This becomes a very nice question to consider. We must have area, or in other words, *calibre,* in the gun, because we must have space for expansion, and we cannot get it lengthwise in cannon, as we may in small arms.

In penetrating an elastic fluid, such as the air, upon which the question of *range* mainly depends, the resistance to be overcome is directly as the number of particles of matter which have to be displaced in a given time, and the velocity with which they must move. It seems to me therefore that the truest general expression we can employ of the power in the several projectiles, which are under comparison, to overcome this in the first instance is found in

COLUMN P.—*Vis Viva of Projectile at muzzle in proportion to the area of section.*

It must always however be borne in mind that these figures represent the force of the shot *at the muzzle of the guns*, where the velocities have been accurately observed or determined. In order then to judge of the *degree* in which these would be diminished in the course of their flight, by having to penetrate the air, reference must be made to Column M, which shews the weight of the shot in proportion to its area, and the greater this is the longer the force will be maintained.

As the range of a projectile is simply the extent of its penetration through the elastic medium of the air, (for we may leave gravity out of the question, as it only changes the course without impeding it,) the amount of this penetration will, so long as two projectiles travel with *an equal amount of vis viva*, be relatively greater or less in the proportion which their respective weights bears to their area of section; because the only resistance they have to overcome in moving forward arises from the atmospheric pressure, which is *as their area.* There is so much matter in the air to be moved out of the way, and so much force must be expended in doing this. Thus all shells, or light shot fired with the same charges as solid or heavier shot have, at very low elevations, a longer practical range than the others, by reason of their higher velocity. This may be seen in all tables of gunnery practice; and it is a matter of very great importance where short ranges have to be considered. But the vis viva of all projectiles must naturally diminish as the work of penetration goes on. The more air there is to be displaced in the projectile's path, and the less time there is to do it in, so much more rapidly will the vis viva of the projectile be destroyed.

It is desirable therefore to have some means of judging of the degree in which the various shot will *maintain* their power of penetrating the air. The necessity for such a discrimination may be seen by comparing the examples 20 and 26 in the General Table, No. 1. The 32-pounder solid shot, fired from a common smooth-bored gun with the service charge of 10-lbs., starts with a force of 1,403,600 foot-lbs.; the elongated shell of 50-lbs. fired with 5-lbs. charge from the same gun, when rifled, starts with only a force of 1,146,200 foot-lbs, or about 19 per cent. less than the other. Owing to the higher velocity of the light shot, (1690 feet instead of only 1213 feet,) the range of the round shot, up to about 2° of elevation, is the greater of the two. But when both these shot have gone about 2000 yards it will be seen by Column H that the heavier shot, although starting with so much *less* velocity, is then travelling with a considerably *greater* speed than the other. It has not lost so much of its force, and has consequently overtaken and passed it, winning the race by its lasting powers. Other similar instances will be found throughout the table. One of considerable importance, for example, is seen in No. 24 and 17, where it will be seen that the mean velocity of the 68-pounder round shot, with the service charge, in a range of 720 yards, is 1440 feet per second, while that of the shot, nearly the same weight, from the *Palliser* gun is only 1097 feet per second; the latter gun requiring an elevation of

1.°25′, for a range of 761 yards; and the other covering it with an elevation of 1°.5′; and the round shot at this distance having a greater force, as 2193 is to 1097. *The trajectory of the round shot therefore up to this point is so much flatter than that of the projectile fired from the converted gun; and it is really flatter for any range up to about a mile.* It has a larger charge.

As the velocity of the several projectiles, in consequence of their different weights, diminishes during flight in a constantly varying degree, it is not possible to find a correct measure by which to judge of their relative power of maintaining their course throughout a long flight. But the figures in Column P indicate, I think, correctly, the power of each, with their respective *initial velocities* to overcome the resistance they meet with from the quantity of air, or any other matter, (as regards mere weight,) which may be an obstacle in the shots path to be removed: and so by making an allowance for the varying velocities we may form a tolerably accurate computation for *short ranges.* When, however, in the course of flight the velocities *have become equal,* we may, by referring to Column M, which shews the weight of each to its area, ascertain something more definite. At this stage the power of continuing to do the work before them will be relatively greater or less in each shot, according to the figures shewn. In a general way then this may be taken as a fair measure of the comparative power of each at *medium ranges.* But it is in very *long* ranges that the advantage of greater weight chiefly manifests itself. To employ much heavier shot for short ranges might be as disadvantageous as to use light shot for long distances, as we must employ higher elevations, and thus having a higher arch of trajectory, the command of intermediate distances between the gun and object is less effectually commanded: a flatter course at the end of a flight of four or five thousand yards would necessarily imply a shorter point blank range, which might be of greater general value.

Reverting therefore to the particular examples I have just referred to, (Nos. 20 & 26,) it will be observed that although the *power* of the 32-pounder round shot with the service charge, is greater, at first, than that of my 50-lb. shell, from the same gun, rifled, and fired with half the charge, as 44 is to 35.9, (Column P,) yet, at about 1000 yards the velocities have come down so differently that here the heavier shot has rather the greater speed, and at this point it has more power of continuing to overcome resistance in about the proportion of 1.57 to .99. We are therefore prepared to find, as we do, in Column H, that at considerably more than 3000 yards, the 50-lb. shell has a higher mean velocity than the round shot at about 1900 yards.

But these terms in Column P do not correctly represent the relative penetrating power of the shot into solid *coherent* matter, for in this case there is the union of particles to be severed. The highest example of this kind of resistance which we have to deal with is found in the iron armour plate.

In order to punch holes in boiler plates, the engineer has to consider the thickness of the iron, and *how much of it* has to be torn or cut through, and he therefore applies power in proportion to the *depth* and *circumference of the holes* to be made. The smaller the holes are, the less power is there required; consequently the smaller the *circumference* is of a projectile moving with a given force, so much the greater will be its penetration when exerting its force to overcome the resistance of this kind opposed to it.

By the same rule therefore that we may estimate the power to overcome resistance, which is *as the area*, we may also determine the power to conquer resistance, which is as the *circumference.*

I have therefore introduced the following figures into the table.—

COLUMN Q.—*Vis viva of projectile at muzzle, in proportion to circumference.*—

This must be the punching power of the several projectiles with the velocity at which they start, and have work to do in proportion to their size.

COLUMN R.—*The same in proportion to every lb. of Powder in the charge.*—

These also being the forces *at the muzzle of the gun,* they must, in regard to penetration of solids, be considered in reference to

COLUMN S.—*Weight of Projectile in proportion to circumference.*—

This will determine the relative punching power at *equal* velocities, or in a general way we may say at *medium* ranges.

Two shot, of equal size but of different weights, moving with the same velocity, might effect partial penetration, but the heavier shot will *continue to penetrate* longer, and go deeper than the lighter one, because in its greater weight it has a greater store of force.

Previous to the introduction of iron defences, the penetrating power of projectiles, although important, was a matter of far less consequence than it is now, when, unless the armour of a vessel can be pierced she is invulnerable.

For defensive works of other kinds, such as those of wood stone, rubble, or brick, powerful projectiles can work destruction by what is termed technically their "racking" effect, or the effect of the general force of the blow in shattering and shaking down the edifice. But the tenacity of iron serves to prevent this by distributing the momentum over the whole mass struck, while its density absorbs so much of the vis viva of the shot striking it as the time of its action will allow it to take up. It is consequently necessary to intensify the action of the penetrating body, so that the time of the force, (or the velocity of the shot,) shall be reduced as little as possible in having to remove the substance in its path: and if this velocity is greater than the *elasticity* of the substance struck is able to diffuse, the coherence of the matter becomes destroyed, and the shot will continue its course with so much vis viva remaining in it as the obstructive matter had not time to absorb.

To make projectiles penetrate iron armour plates, the work to be done is this:— we have to break up and destroy the *cohesive* force which binds together the atoms of iron, by directing upon them the *repulsive* force of so many atoms of matter in the form of gas; the projectile being the mere vehicle for the transmission of the power.

Every grain of gunpowder when resolved into the gaseous state represents an effective force so many atoms strong, capable of overcoming the coherence of a certain limited number of the combined atoms of iron confronting it. There is comparatively but little difficulty in conquering the iron when its atoms are spread out and open to attack on a broad field, as in plates of moderate thickness, because then we can set in motion a sufficient army of atoms of gas to attack it with: but owing to the restrictions we are under as to the length of our guns, the amount of power we can bring to bear on a given space is practically limited by the quantity of powder we can inflame within corresponding limits. When therefore the iron is very thick, the atoms support and protect each other in their formation as a deep column, and therefore the *numbers* we might effectually cope with in 5 or 6-in. plates, can defy us when they present a much narrower front in very much thicker plates. Their resisting power then increases in a higher ratio than our power of assailing them; *the line of* CIRCUMFERENCE *being the line of cohesion*, or front open to assault; while the power of attack diminishes as *the* AREA *of front lessens*, because we cannot bring so much powder to bear upon it.

The powder, to gain life and motion, must have space to move in; every cubic inch of gas must increase into and pervade so many more cubic inches, and it is only *as it does this* that the projectile can become imbued with its active qualities. To concentrate the diffusive force, we must collect it in the mass of the projectile we place before it, every atom of matter in which will gather to itself so much of the force, *in proportion to the time it is being acted upon*, until an equilibrium becomes established between the resistance of the projectile, and the strength of the gas to move with the burden which loads it; at that point the shot will have acquired its maximum velocity. But just as we tax the strength of the gas, and reduce its speed by giving it a greater weight to move, we shall lose instead of gain, unless *in the same proportion* we provide *greater* space for the gas to work in. We might continue, up to the ultimate strength of the elastic force, to collect more power as we extend the time of action but in order to accomplish this we must have extended acceleration. Instead of the gas expanding as it would do naturally into the form of a globe, we force it to enlarge itself as a column, so as to drive the shot before it; and if we do not utilize the full available length of the column, we must fail to obtain the highest result.

A full head of steam will propel a locomotive engine, by itself, on a railway at the rate of seventy miles an hour, or perhaps more, in doing which, every atom of matter in the locomotive is impressed with this velocity, as every atom in the projectile is also affected. If, however, the engine is attached to a heavy train, the same pressure of steam can only propel the greater weight perhaps 20 miles an hour, impressing this lower velocity on every atom moved; and just in the proportion as the whole weight moved is greater, so much longer will it take for the engine to get up its maximum speed. When it has but its own weight to move, the engine will attain its full speed in less than half-a minute, while it is travelling about 150 yards; but, if it has a train to draw, it must continue to move for several minutes, and pass over a quarter of a mile of ground, or more, before it will have acquired its maximum velocity.

These general observations are founded entirely on the facts which I see before me in the practical results obtained with the various guns, as they are exhibited in the table; and I believe that a careful study of the figures as I have collated them, will be found to corroborate what has been stated.

In looking down the column R, which shews what may be considered to represent the *primary penetrating force* in solids *obtained from every lb. of powder* in the various charges, the prominent feature is the vastly greater force resulting from the explosion of the same quantity of powder in small guns than in the larger ones. It will be seen that in the rifled *Field* guns it varies from 16,000 to over 19,000 foot-lbs. of work done by the *pound of powder;* while, in the heavy wrought-iron battering guns, made specially for penetrating iron armour plates, the work done varies from only 5,000 to 7,000 foot-lbs.

This is mainly to be attributed to the enormous *resistance* which the great *long* shot offer to the expansion of the charge. For instance, the work done in the *Whitworth* 3-inch gun

(No. 15,) is seen to be as much as 19,200 foot-lbs. per lb. of charge, while that of the 11½-inch gun (No. 1,) is only about 4.370 foot-lbs. This however ceases to be surprising when we find that the powder in one gun, besides having more than one-third less room to expand in, encounters a deadening *resistance* to its expansion, of 6.73-lbs. per square inch, (column M) while in the other it is only 1.98-lbs. Yet the large gun is generally regarded as designed, as nearly as may be, on the same principle as the small one, save as respects the peculiar rifling and metal it is made of. Both are examples of *very small bore guns* in proportion to their length; the new 700-pounder is in fact only an exaggeration of the 12-pounder, as regards the principle of its general design. *Sir William Armstrong* was the first to apply the *reduced bore principle* to ordnance in this country, and *Sir Joseph Whitworth*, following in the same track, carried out the idea still further, and no doubt with great success in small guns. It was a natural inference that a plan which proved so eminently valuable for small arms might be advantageously applied to large ones. But it appears to me that the principle upon which all the great modern improvements in fire-arms are founded;—that principle which, when first seen applied in the old *Minié* rifle, created such a sensation about 20 years ago, is even now very generally misunderstood. The greater efficiency of the elongated projectiles has been ascribed to various causes, which really are mere *accidents* of the system. It has been called *the principle of the small bore,* and as such it has been applied, or adapted, in the construction of artillery.

It may be seen, however, that just as we reduce the calibre, and increase relatively the length of the shot and cartridge, we in fact depart from the system which is so successful in small arms, unless in the same degree as we increase the length of the charge, we also increase the length of the guns, which is what we simply *cannot do.* To apply the *Minié* rifle system to ordnance, it is of course necessary to respect all the conditions involved; if therefore it is treated as a question of small calibre, and we attempted to make a 12-inch cannon of similar proportions to those of the *Whitworth* small arm, the gun would have to be 78-feet long, which I suppose may be set down as an absurdity. And if we were to make a *Whitworth* small arm, following the proportions which we see in our new 700-pounder *small bore, allowing precisely the same space in the barrel for the powder to expand in,* its length would be just eight inches; it would be nothing else than a *pistol,* and no amount of overloading will make a pistol shoot with the force of a gun properly charged.

The real principle involved in the elongated *Minié* bullet in no way requires the slightest reduction of calibre. The bore of rifles was reduced merely as a matter of necessity, arising from the excessive weight of the ammunition that must be employed for it. The greater length of the bullet conducing as it does to precision of flight and force of penetration, if the ordinary bore were retained, the gun would become too powerful a weapon to be used from the shoulder, and it had therefore to be made on a smaller scale. The principle of the improvement was this.—*By employing a greater weight of shot in proportion to the charge, the elastic force being restrained by the weight, the projectile gains time for absorbing its force, and its greater mass possesses a higher capacity for carrying it;* but if there is not the space in the gun for the expansion to take place, we cannot gain this time.

Now there are two perfectly distinct methods of working out this principle.—

The method which has been followed consists of *limiting the calibre,* and obtaining the greater weight of shot by greatly increasing its length. I have shewn what effects arise from doing this, as guns increase in size. (1) The charge is necessarily extended through a very considerable proportion of the gun's length, leaving comparatively little room in which it can expand and propel the shot. (2) The resistance of the shot is increased because the gas can only exercise its force on the area exposed to it, and it consequently has to labor more over its work; its vigour is oppressed and prevented from becoming developed, as the speed of a train when starting is lessened by the weight it has to carry. (3) Besides this, there arises an enormous increase of strain upon the gun, *far beyond the proportion of force which is expended on the shot.*

The *other method* is to obtain the greater weight by employing a *greater calibre,* and having only such a length of cylinder in the projectile as may be found sufficient to give that steadiness to it in passing through the gun as will afford the required precision of flight. By doing this we obtain (1,) greater capacity in the gun, as the charge occupies less of its length, and can expand more fully; (2,) the shot presents a greater area to the charge in proportion to its weight, and consequently offers less resistance to the expansion; it is therefore moved with less effort, and at a higher velocity, by the pressure continuing longer to accelerate it; and (3,) the gun is far less strained, because there is less accumulation of force required in first moving the shot. (*Vide diagram, page* 58.)

This is the principle represented in my rifled cast-iron service guns; and I contend that it is in fact a much more faithful rendering of the principle of the small arm than that which has been generally followed. That it is a sound principle there is this evidence.—*Every lb. of powder yields a greater result; and besides this, guns of any size or power may be made in accordance with it;* whereas on the other plan the difficulty of providing strength in the gun to resist the presssure necessary for overcoming the resistance of heavy projectiles when it is applied at such disadvantage, limits the power to be obtained, even with wrought iron.

The thickness of expensive coiled wrought-iron round the bore of the 700-pounder small calibre gun, is no less than 22½-inches; the length of the bore is 16-feet. In this direction I think we could hardly go farther. But if the strength of material which there is in this gun were differently applied, it might yield far greater force, and even greater weapons might easily be made at far less cost. *The small bore, or high pressure principle, involves waste of the force, not only of the powder we burn, but also of the material we use to control it.*

Column T. *Vis viva of Projectile in proportion to the weight of gun.*

The great fact which is brought out here is that notwithstanding the vast superiority (and cost) of the material which we are now employing for ordnance, we really get little or no more force out of it, weight for weight, than we do from ordinary cast-iron; the use of which material is proposed to be given up, because it is said to be not strong enough. It will be seen that every cwt. of cast-iron in our old 68-pounder smooth bore guns (No. 24,) yields over 27,000 foot-lbs. of power; and that out of coiled wrought iron, which is stronger in the proportion of 60 to 19, we get only about the same. All the various new wrought iron rifled guns, with full battering charges, yield no more per cwt. of metal than from 27 to 29 thousands foot-lbs. Yet, out of our old brass 12-pounders, we have always got more than 35-thousands foot-lbs. of work per cwt.; and it will be seen that with the American *Rodman* 15-inch gun (No. 32) as much as 42-thousands foot-lbs. per cwt. has been obtained out of cast-iron.

It is not to be supposed that after ten years' experience we do not load our wrought-iron guns as heavily as we might do. In one sense we *overload* them. The inevitable conclusion therefore is, that either we *cannot* employ the whole strength of material we have at command, or else that *we do not apply it wisely* in the design of our weapons. But is there any remedy for this? All our new guns have been carefully schemed according to the dictates of experience. After plunging somewhat hastily, years ago, into a new system which landed us in a very serious difficulty, we have latterly been very cautiously feeling our way towards the object we have in view, advancing only step by step as we found practically the ground was safe beneath us. And the work we have been now for some years turning out is doubtless good useful work. This may be admitted; but yet it may also be true that we possibly have been following a single beaten track too far, and that a closer examination of the general principles which govern the question might carry us into another path which is broader and more direct.

I have alluded to the principle which is implied in the elongated projectile; defining it as that which consists of the employment of heavier shot in proportion to the charge of powder, with the absolute condition that the shot shall have greater time, while in the gun, to absorb the force with which the gas expands. Now that it is truly so, I think can be proved to demonstration by the evidence of practical results. In the following table I have re-arranged the figures which are found in the general table I have been referring to, simply changing the order in which they there stand, and bringing the various examples into numerical succession, according to the proportions which the several charges employed bear to the weight of shot fired with it, as shewn in Column K. I begin with the lowest, and end with the highest charge

General Table, No. 2, shewing the increase of *striking* and *penetrating* force obtained with the same quantity of powder, by employing projectiles of *greater weight in proportion to the charge* when the bore of guns *has capacity to allow of sufficient expansion of the gas.*

	K	I *Force. per lb.*	L *Pressure.*	M *Resistance.*	O *Expansion.*	*Penetration.* S	*Penetration.* R		G *Total Force*
	Weight of Projectile to every lb. of Powder.	Vis Viva of Projectile at Muzzle to every lb. of Powder	Weight of Powder to every square inch in area of bore.	Weight of Shot to every square inch in area of Bore.	Number of lengths of Cartridge in the Bore	Weight of Projectile to circumference of Bore.	Vis viva of shot at muzzle per lb. of powder to circumference of Bore.	GUN AND CHARGE.	Vis viva of Shot at Muzzle
	lbs. lbs.	thsnds. foot-lbs.	lbs. lbs.	lbs. lbs		lbs. lbs.	thsnds. foot lbs.	*lbs. charge.*	thsnds. foot-lbs.
1a	14.6	201.2	.102	1.5	35.7	3.7	6.4	10-in. smooth 8	1609.8
2a	11.25	251.9	.155	1.75	24.4	3.6	9.9	68-pr. rifled (Britten) 8	2015.5
3a	10.	272.6	.156	1.57	23	2.5	11.5	32-pr. ,, (ditto) 5	1145.2
4a	10	194	.51	5.1	9.4	12.7	6.2	10-in. W. I. rifled... 40	7761.
5a	9.96	201.7	.442	4.4	8.7	13.2	5.3	12-in. ,, ,, ... 50	10065.3
6a	9.33	183.6	.313	2.92	10.5	5.09	8.3	100-pr. *Armstrong*... 12	2203.3
7a	9	208.2	.28	2.54	19.4	9.5	4.4	15-in. American ... 50	10416.5
8a	8.95	193.9	.593	5.31	8.3	15.9	5.1	12-in. W. I. rifled... 67	12992.9
9a	8.52	162.2	.227	1.94	11.6	1.8	13.7	20-pr. *Armstrong* 2.5	405.5
10a	8.36	175	.281	2.36	12.3	2.8	11.7	40-pr. ,, ... 5	875.
11a	8.33	184.1	.472	3.93	9.	8.8	6.5	9-in. W. I. rifled 30	5524.
12a	8.21	193.2	.365	3.	11.6	5.2	8.8	7-in. ,, ,, ... 14	2705.6
13a	8.	170.3	.256	2.05	12.8	3.2	8.6	32-in. *Palliser* ... 8	1362.5
14a	7.94	174.5	.214	1.7	11.3	1.26	18.5	12-pr. *Armstrong* 1.5	261.
15a	7.4	182	.593	4.4	8.3	13.2	4.8	12-in. W. I. rifled 67	12491.8
16a	7.4	191.7	.106	1.12	24	2.8	6.1	10-in. C.I. smooth 12	2300.
17a	6.8	174.6	.29	1.98	9.3	1.3	19.2	12-pr. *Whitworth* 1.75	305.7
18a	6.66	174.6	.764	5. 1	6.3	12.7	5.5	10-in. W. I. rifled 60	10480.1
19a	*5.83	158	1.15	6.73	5.65	19.3	4.37	11.5-in. ,, ,, 120	18968.6
20a	5.74	161.3	.676	3.93	6 3	8.8	5.7	9-in. ,, ,, 43	6939.7
21a	5.23	166.2	.573	3.	7.4	5.2	7.5	7-in. ,, ,, 22	3657.2
22a	5.14	152.5	.25	1.29	7.16	.95	16.1	New Field Gun 1.75	266.9
23a	4.5	162.1	.565	2.54	9.7	9.5	3.4	15-in. American 100	16216.5
24a	4.25	161.	31	1.29	12.3	2.6	6.32	68-pr. C.I. smooth 16	2575.7
25a	3.95	160.9	.25	.99	14.4	1.58	8.0	32-pr. ,, ,, ... 8	1283.
26a	3.24	165	.31	1.	12.3	2.0	6.33	68-pr. ,, ,, ... 16	2639
27a	3.18	154.6	.241	.765	10.6	.9	10.6	12-pr. Brass ,, ... 4	618.6
28a	3.16	140.3	.313	.99	11.5	1.58	7.0	32-pr. C. I. ,, ... 10	1403.6
29a	2.97	137	.3	.895	12	1.3	7.5	24-pr. ,, ,, ... 8	1096.
30a	2.95	131.1	.273	.8	13.2	1.07	7.9	18-pr. ,, ,, ... 6	786.7
31a	10	228.8	.395	3.95	19.1	14.9	4.9	15-in. (proposed) 70	16018.‡
32a	†7.57	†189.7	.038	.29	31.2	.043	105.4†	Enfield Rifle ...70 *grs.*	1.89
33a	,,	171.1	.059	.446	27	.054	120.	Whitworth do. ... ditto	1.71

* Pebble powder used. All the other results are from ordinary powder.

† These figures represent magnified proportions. The charge for the small arm is seventy grains, or exactly one hundredth of a lb.

‡ Estimated from analogous cases.

I must bespeak a careful study of the facts which are brought out in this table. Their significance will grow on our appreciation the more closely they are examined. I believe it is the first time that any such general view has been presented of how the propulsive effects obtained by the explosion of gunpowder in different kinds of ordnance stand related to their causes. By thus bringing together systematically a great body of affiliated facts, that they may be compared and examined by the same equal tests, we shall find far safer grounds for forming general conclusions about them than any abstract theoretical reasoning can afford.

In the course of the investigation I have been making, a great many facts of an apparently irreconcileable or anomalous character have presented themselves.—We shall find in this table the means of perfectly explaining and accounting for them; and as we thus trace them to their source, we may also find in them some important lessons for our guidance.

It is impossible to avoid being startled as we look down the figures in column I, and observe the remarkably different results in the amount of force which the various guns produce with the same quantity of powder;—difference which in some instances, considerably exceed a hundred per cent., and which cannot be attributed to the length of the guns, for in this respect there is little or no discrepancy in these particular cases. We have shorter guns yielding more than long ones, and we may also see absolutely weaker guns giving forth far more power than stronger ones. It is moreover a fact which is worthy of no little attention, that the highest examples of the utilization of forces, are by no means to be found among the latest adopted improvements.

It may perhaps be urged, that as all we need care about is to get the weapons we want, we may be prodigal of our powder, and prodigal of iron, and perhaps also prodigal of our money; but this is simply to shut our eyes to the true principles of scientific economy, and to try to win by brute force instead of skill. *The gun which wastes its forces cannot be rightly schemed;* however successful it may, in certain respects, appear in comparison with others, there must be yet a higher attainable standard—a really better gun, or more perfect instrument, in which sound mechanical principles are thoroughly respected in its design.

A glance at the two first columns, K and I, will at once establish the general truth of the theory, that *as we increase the weight of projectile in proportion to the charge used with it,* AND ALLOW THE FORCE TIME TO ACT, *we obtain a more perfect result.* At first sight there will appear among the figures to be exceptions to this rule; but on closer scrutiny, we may find by the other columns exactly *why* this is. If the lower proportion of charge does not appear to yield a higher return, we may generally see that it is either because the resistance of the shot, (col: M) compared with the pressure (L) is excessive, (in other words that *the elastic power is overloaded;*) or else it is that the charge has not space in the gun to duly expand, (col: O) and so the force is wasted.

We may get a clear idea of what is signified by the figures in Column M, *Resistance of Shot*, (as something distinct from the actual weight,) by supposing the projectile to be a piston, in a cylinder, loaded according to the amount of resistance denoted by the figures; and that we had to raise the piston by pumping in air below it. In the example 1 *a*, a compression of one-tenth of an atmosphere beyond what is required to balance the external pressure would be sufficient to establish an equilibrium above and below the piston. But with example 6*a*, we should have to go on pumping till we had a compression of nearly one-fifth of an atmosphere before any force which we had expended on the work produced the slightest effect in moving the load of weight. To lift the piston we must go on pumping, and the work will get harder at every stroke. When we have accumulated a sufficient force, the piston will rise, but then only with a velocity in proportion to the power with which we could go on pumping; we should have *to labor nearly twice as hard* to move the shot, 6*a*, which shews a resistance of 2.92-lbs. per inch, as we should with the shot, 1*a*, which exhibits a resistance of 1.5-lb. per inch, in order to produce in each the same rate of motion in the same time. Yet it will be observed that here it is the *heavier shot* which is moved with *half the power that the lighter one requires.* No. 1*a* is a 10-inch shot of 117-lbs. weight, and 6*a* is a 7-inch shot of only 112-lbs.

The analogy between the loaded piston and the shot in a gun is not quite perfect, because in the case of the piston the resistance is due entirely to the gravity of the load, while that of the shot is from matter to be set in motion. The cases however become more parallel if the gun is fired at higher elevations; if vertical, there is the absolute weight of the shot to lift. But even when the gun is fired in a horizontal position there is still a fair analogy. There would not, in fact, arise such an accumulation of dead force against the shot before *any motion whatever* was produced, as there would be against the piston: the shot will begin to move, however slowly at first, the instant that the blast from the first grain of powder ignited reaches it. The chief resistance to the *first* movement would be from friction of the shot lying on the gun. Yet the force will have to accumulate in order to overcome the resistance which the shot will offer. What is the nature of this resistance?

In the projectile there is so much matter which of itself is wholly indifferent to either rest or motion: this matter must be so acted upon that its condition shall be changed from a state of rest to one of very rapid motion. This cannot be done without the exertion of a definite amount of *active* force upon it. The active force applied meets with opposition, not less real because its character is somewhat difficult to define. Whether it is called "inertia," as *Newton* named it, or by any other term which may be preferred, is of no moment. The shot will not move unless it is made to move by an effort of force exciting it, and the exact result of this effort is found in the *vis viva* of the mass after it has been subject to so much force, and by which it has been animated or quickened.

I must cite another case. Compare 7*a* and 18*a*. The 450-lb. shot for the 15-inch gun, shews a resistance to the charge of 2.54-lbs. per inch, while the 400-lb. shot for the 10-inch rifled gun offers 5.1-lbs. per inch. It will also be seen by column O, (*Expansion*) that the charge in the 15-inch gun can expand into nearly 19½ times its volume, while that of the other only about 6¼ times. What is the consequence? The *fifty* pounds of powder produces, in the large bore, as much active force in the shot as *sixty* pounds does in the smaller bore. We find the following figures by referring to the tables.—

	Charge.	Shot.	Velocity.	Total vis viva at muzzle.
10-in. Rifled Gun (18*a*)	60-lbs.	400-lbs.	1298-ft.	10,480,100 ft-lbs.
15-in. American (7*a*)	50 ,,	450 ,,	1220 ,,	10,416,500 ,,

Now in order to get this force produced under the different conditions, one of these guns must be made of wrought-iron, or it could not safely discharge shot which offer such obstinate resistance. This renders the gun about five times more costly than the other which is merely cast-iron. It is no doubt true, that although the force of the projectiles from both these guns is about the same at the muzzle, those from the rifled gun would *penetrate* iron plates of a thickness which the others would not. This of course is very important. But still we see here the plan at work which the authorities of the United States have adopted, and I believe, still thoroughly believe in; and it may be a question whether any ironclad vessel which we have built, or can build, would stand much of the racking effect which such blows as the above will produce. When we tried the experiment on targets at Shoeburyness, the effect of the 15-inch shot was very severe upon the bolts and fastenings of the plates.

The actual penetration was inferior to that of the elongated shot, and this was greatly owing to the *form* of the round shot which is essentially weak. The matter does not find that support in its coherence that there is in lengthened cylinders; the iron breaks up around a perfect cone like a snowball. Still there is a significance in the above figures which we shall do well to study, perhaps more closely than we have hitherto done.

As I understand the figures in the foregoing table, they point to a certain *definite* proportion of resistance being absolutely required in projectiles for different guns, in order to develope the full available power of the charge. The strength of powder of course has a limit, and it *may be overloaded;* we may give it more work than it can properly accomplish when restricted in its range of action by the time and space it has to work in: and the power of powder may likewise be sometimes *undertasked*; more of it may be used than can yield the full effect which it is capable of. There might not be *sufficient resistance* to its expansion. That this would not be detected by merely considering the proportion which the charge bears to the gross weight of shot, will at once be seen in examples 3*a* and 4*a*, when two very different guns are fired with charges of one-tenth of the weight of projectile: in one of these, the resistance which the charge meets with in expanding is considerably more than *three times as much* as in the other. We find then the necessity for some such discrimination as is afforded by the division in the table L, which for want of a better name I have called "Pressure." The figures denote the quantity of powder which, as the charge is disposed in the gun, is contained in columns of an inch area, and stand against so many corresponding columns of resistance in the shot.

Let the examples 1*a* and 29*a* be compared. These two guns are both about the same length, and they are both fired with the same charge of 8-lbs. of powder. This charge in one occupies 9 inches, or one-twelfth of the whole bore; in the other it takes up but three inches, or one-thirty-fifth of the gun's capacity. The conditions under which the charges act, and the resulting effect are as follows.—

	Charge.	Pressure. *lbs. Powder per sq. in.*	Resistance. *lbs. Iron per sq. in.*	Velocity, *ft. per sec.*	Vis viva, *foot-lbs.*
10-in. Gun, S. B. (1*a*)	8-lbs.	.102	1.5	940.6	1609,500
24-pr. ,, ditto (29*a*)	8-lbs.	.3	.895	1720.5	1096,000

The same quantity of powder thus produces 50 *per cent. more force in the larger bore.*

It will be observed that in this 24-pounder gun the charge has considerably more powder in every one of its inch columns pointing towards the shot, than even the 50-lb. charge has in the 15-inch gun, (7*a*,) where the quantity is only .28 of a lb. instead of .3.

In the 12-pounder brass gun, No. 27*a*, the resistance of the round shot is still less than in the 18-pounders, being only .765 lbs. or little more than 13-ozs. per inch, but the power of the charge being less in proportion to it, (.241 instead of .273,) the economical result is better. The *velocity* attained is greater, being 1769.8 feet per second, and the vis viva of the shot, per lb. of powder, is seen to be 154,600 foot-lbs instead 137,000. In the 18-pounder the conditions will be seen to be yet more unfavorable than in either of the others, and the result is seen to be only 131,000 foot-lbs. of force to every pound of powder. The effect of larger charges in proportion to the weight of shot, with the *density* of the shot diminishing regularly in gradations is seen clearly by the following figures. As the spherical shot become smaller, their solid contents naturally diminish in a higher ratio than that of their sectional *area which the force of the powder acts upon and increases with.*

Round shot fired with service charges.—

	K Weight of Shot to Powder.	L Weight of powder to square-inch of Shot.	M Resistance of Shot per inch.	I Force produced per lb. of Powder.
(24*a*) 68-pr.	4.25	.31.	1.29	161.
(28*a*) 32 ,,	3.16	.313	.99	140.3
(29*a*) 24 ,,	2.97	.3	.895	137
(30*a*) 18 ,,	2.95	.273	.8	131.1
(27*a*) 12 ,,	3.18	.241	.765	154.
(25*a*) 32 ,,	3.95	.25	.99	160.9

A man in the act of throwing a ball or stone moves his hand with a certain velocity, and in doing this ***according to his vigour,*** the ball or stone becomes impressed with the velocity with which the hand is moved. It is quite clear that there is a certain ***exact weight*** which the ball ought to have, ***in proportion to the power which moves it,*** in order that the utmost propulsive effect may be obtained. A little boy instinctively selects as his missile a smaller pebble than a strong boy; instinct or experience determines for each a particular size and weight. It is not what the boy can lift, or move slowly, but what he can *throw* farthest by moving most rapidly within the range of his hand's motion. If the ball thrown be made of pith, or other excessively light substance, the strength of the arm will be thrown away, because there is nothing in the ball to take up and *carry force.* And also if the ball were 10 or 20-lbs. weight, the strength of the arm is also more or less wasted, because it would be ***over***burdened. In one case there is ***not sufficient*** work to do ***in the time***, and in the other there is ***too much.***

In the production of projectile force economically, there are two elements to be regarded, weight and motion (or velocity,) and neither of these must be sacrificed in order to employ an excess of the other; the power which is employed must be able to assume the perfect command of both. Motion has all to be gathered in increments; and the power must exert successfully its utmost persistent effort to move faster, and so *expend itself within the time* it has to work. The utmost possible effect will be obtained when there has been that exact adjustment of weight of matter to be moved in proportion to the force which is to move it, which permits the whole available force to culminate as ***vis viva*** within the time it acts—in other words, when the maximum velocity which ***so much force*** CAN ***impart to so much matter***, has actually been produced in the gun. A railway engine having exerted the whole of its power for a certain time, and moved the train it is attached to over a certain distance, more or less, according to the train's weight, at length produces the rate of motion which it will never be able to exceed, although it will be able to maintain it.

The theoretically perfect gun should produce a similar *maximum of effect* with its charge. The conditions are that there shall be no lack of weight in the projectile to carry the force which is imparted to it, but yet that the shot shall offer no more resistance than the charge can effectually command; and, at the same time, the charge of powder should be ***the largest that can be used***, so as as to produce ***its highest possible effect within the compass of the gun's length.*** Let it be first determined how long the gun may be, then the problem which *follows* is, what is the greatest effect which can be produced *in this space*, by the elasticity of the gas from gunpowder:

But is it possible to realize these conditions? Certainly not, as it appears to me, by following the course which is now pursued, when we find that every new gun which is designed is more and more wasteful of its forces—the powder, and the strength of the material employed to control it, yielding less and less return for every measure used. Where then lies the remedy? Is not this indicated by the fact that as we obtain the force we want, by employing elastic pressure or *power from expansion* we should let the power expand and employ it to the utmost.

In the *Whitworth* rifle, although a lead shot is used of three calibres in length, it is yet so diminutive that the natural energy of powder meets with comparatively very small resistance from it, and the gas is allowed to expand twenty-seven times in the gun apparently with advantage. In our new wrought-iron cannon we give the powder a vast deal more work to do, and expect a full result to be developed, with only five or six expansions of the charge. (Column O.) In the small arm there is no difficulty about working the powder expansively, as we want the barrel so long; and we also require the densest material we can find for the bullet, in order to *get* weight in which to husband the force communicated. By this means we are able, with the force of 70 grains of powder, to penetrate the air for nearly 3000 yards.

But we want to magnify these effects, and must produce them in *iron* shot which are bigger; and as they become so, they meet with more resistance. The resistance of the air to the *Whitworth* bullet, at starting, cannot be more than between three and four pounds; but to a 12-inch shot, moving at the same velocity, the opposition must amount to the greater part of a ton; and we have only the same propulsive agent to employ for both. For the smaller kinds of cannon we meet with little difficulty, because we are not then embarrassed with *too much* weight; so that with shot of two, or even three diametres long, we find economical effects produced with short three-inch field guns, superior, considering the means employed, to those of the larger kinds. This is seen in the range and penetrative power developed by these guns with small quantities of powder. But as the weight of shot increases in the ratio of the cubic contents, the strength of the powder becomes overburdened, if for the larger kinds we keep to the same proportions of length to diameter which answers very well for the smaller shot; because although we may still load the guns with the same quantity of powder in proportion to the weight it has to move, we cannot also provide sufficient length of gun to afford the requisite time for securing the maximum effect.

We see the regularly diminishing series of results obtained with solid spherical iron shot as they become smaller. The heaviest of these evidently are not heavy enough in proportion to their size to afford the best results. We may use large charges of powder, and blow them out of our guns with a velocity of 1700 or 1800 feet per second, but this is too fast;—the effect is rapidly destroyed by the air.

We see by the table that the 32-pounder round shot, (No. 28*a*,) offers a resistance of .99 of a lb. per inch, and with .313 of a lb. of powder per inch, there is 140,000-foot-lbs. of force produced *by every pound* of powder. With the 68-pounder round shot, (24*a*,) there is, in the service charge, just about the *same quantity of powder to cause pressure;* but, as the shot contains 1.29-lb. instead of .99-lb. per square inch, there is a better result, and every lb. of powder yields 161-foot-lbs. It is the same with all; but if they are not heavy enough *how much* heavier then ought they to be?

For the 32-pounder rifled gun, (3*a*,) I added 50 per cent. to the weight of the round shot, and reduced the charge 50 per cent. I had then .156-lb. of powder acting on 1.57-lb. resistance per square inch of the shot's area. The gun therefore had less to do in governing the smaller charge. I obtained less velocity, and less immediate force; but *every pound* of powder which I employed yielded 272.6 thousand foot-lbs, instead of 140.3; and the gun became far more effective than it was before, at more than *twice the distance.* Should I then have done better by making the shot still heavier? I must in that case have still further lessened the charge, or tasked the strength of the gun more. This I was unwilling to do, although from what I now see, I might have done it with perfect safety. It may however be noticed what the effect is of further increasing the weight of shot in proportion to the charge. I did this with my rifled 68-pounder, (2*a*,) the charge being only $\frac{1}{11.25}$ instead of one tenth, and there being capacity in the gun for nearly $24\frac{1}{2}$ full expansions of the powder. I obtained a somewhat *lower* return from every pound used, viz., 251.9 instead of 272.6

thousand foot-lbs. This is shewn further in the case of the 10-inch smooth bored gun, (1*a*,) the charge here being only $\frac{1}{14.6}$ with room for more than 35 expansions: the result is lower still, viz., 201.2 thousand foot-lbs. This is still a very high rate, compared with what is obtained in the wrought-iron guns, with battering charges. An allowance must be made here for there being more escape of gas through windage, than with my projectiles. These two are the only instances to be found in the whole table where the law *does not* hold good that, "by increasing the shot's weight in proportion to the charge, and providing for full expansion in the gun, a greater result is obtained." Why is this?

Now of course there must be a point at which the gas, by increase of volume, becomes at length too attenuated and feeble to be able to add anything to the force of the shot; and consequently that any length of the gun, beyond a certain amount, would be of no avail. What would this depend upon?

It appears that all we have occasion to consider here is *the resistance which the air will oppose to the shot.* This of course must be greater or less in proportion to the velocity with which it has to move. If, for example, the charge be large enough to produce a higher rate of speed than that at which air, of the ordinary temperature, will re-occupy space, (about 1300 feet per second,) there must then be at least an amount of resistance equivalent to a whole vaccuum pressure; or nearly 15-lbs. per inch of its sectional area.

If the velocity be less than this, the resistance of course must be rateably less. And this resistance would act upon the shot before it left the gun, so *to prevent velocity being acquired*, just as it would afterwards, when destroying the velocity which had been *produced by the greater pressure of the* *powder-gas in the gun. So long then as the pressure of the gas is greater* than the resistance of the air, that pressure must add velocity to the projectile.

It is not very easy for us to realize the idea of such an enormous power being exercised by the atmosphere on projectiles, as it is certain that it does exert. In very early treatises on gunnery, no account was taken of it at all; and in many much more recent ones it has not received that notice which it really demands.

When we vainly attempt with our bodily strength to move in the smallest degree one of the large 600-lb. shot, which we see piled up in heaps at Woolwich, we are naturally led to wonder at the mighty power which must be called forth capable of hurling such a ponderous mass to a distance of six or seven miles. But it is then scarcely present to our minds that, after all, the charge of gunpowder has really *but little work to do in moving this weight*, which we are so sensible of, compared with what it has to do in *moving the air* we breathe, becoming as it does an opposition force in front of the shot, which has to cleave its way through, and finds in the atmosphere a constant drag or impediment to its career.

If this 12-inch shot is propelled at a greater velocity than about 1300 feet per second, its transverse section containing 113 square inches, the resistance of the air to its progress will amount to about 1700-lbs., or nearly three times the weight of the shot itself. This of course becomes less and less as the velocity decreases and the force of the shot dies. At page 10 I have shewn in one instance from exact measurements which have been taken, how this resistance tells upon the force communicated. It will be seen that in penetrating only 30 yards of air, the power of the common 32-pounder round shot is destroyed by the atmosphere, to no less an extent than 42,600 foot-lbs. or units of work, which is equal to more than 29 foot-tons. Such a fact seems hardly conceivable, but it is entirely beyond dispute.

The only exact information we possess as to how gunpowder acts in communicating velocity to shot, by pressure which diminishes as the gas expands, is to be found in the Report of the Woolwich Committee on Gunpowder, to which I have before referred at page 77. The Committee explain how they measured the growing force of a shot as it passed through a gun of the ordinary proportions. The actual speed at different stages was ascertained by instruments of such marvellous accuracy, (electricity being the agent,) that intervals of time, occupied by the passage of the shot from one point to another inside the bore, could be measured to within the ten-millionth part of a second. From these "times of flight," of course, the velocities could be calculated. The Committee were also able by means of the Rodman pressure gauge, and also another gauge, still better adapted for the purpose, made at the suggestion of the Committee, to determine the maximum amount of *pressure* exerted on the gun at the breech end where the gauges were fixed. From the maximum pressure thus ascertained, and the velocities determined at different stages of the shot's progress before issuing from the muzzle, the Committee estimated what the varying pressures must have been to cause the acceleration of the projectiles' speed. Assuming then these deductions to be correct, and that the diagrams of "pressure curves," "time curves," and "velocity curves," which appear in the report are accurate, we may get an idea as to how the elastic force of the gas becomes reduced in expanding. By the calculated pressure curves it appears that the charge of 30-lbs. of the common R. L. G. powder, occupying about 19-inches of the bore of an 8-inch gun, when resisted by a shot of 180-lbs. weight, carefully turned so as to fit the gun as closely as would allow of its being rammed home without extraordinary means, produced in the gun, *before the shot had moved more than a ¼-of-an-inch from its position, a pressure of* 29.8 *per square inch.* This was inferred from the indications of the gauges in the powder chamber, and also from the wonderfully rapid accumulation of velocity which was ascertained.

The powder having all been ignited, the pressure began rapidly to fall, and when the shot had advanced, so that the charge had expanded into twice its original volume, the pressure had come down to only 8½-tons per inch. In the next full expansion it was only 5-tons; in the next, 3-tons; in the next, 26-cwt.; and at the last point shewn in the diagram, representing less than another full expansion, it was only 16-cwt. per inch. In the following table which I have compiled from the Committee's diagrams, the stated measurements will be seen. I have also shewn how different the pressures were when the new "pebble" powder was used, which, from not igniting so rapidly, caused far less *accumulation of force*, (vide page 97.) The shot had more time to get under weigh. Its resistance was overcome by milder means; the power acting more in the nature of a *push* and less as a *blow*. Instead therefore of the gun being strained by a pressure of 30-tons per inch, the maximum was only 15.4-tons, yet the total result was greater. This extremely important point has been for many years recognised in every great arsenal in Europe, and it is a significant fact that Great Britain has been the last to act upon it. We are only now beginning to do so.

Experiments made at Woolwich in 1869, *by the Committee "on Explosives," to ascertain the elastic pressure produced by different kinds of Powder, and the velocities acquired by Shot at various stages* within a gun.

Gun used: 126 inches long, bore, 8 inches.

Shot: cylindrical, 15 inches long, 180 lbs. weight, diameter, 7.995. Charge 30 lbs.

Maximum Pressure ascertained by pressure gauges placed in the powder chamber: RLG Powder 29.8 tons per in. PEBBLE ditto, 15.4 ,, ,,

Distance moved through by the Shot in the gun.	TIME recorded by Chronoscope		VELOCITY calculated		PRESSURE calculated	
	RLG Powder	Pebble powder	RLG	Pebble	RLG	Pebble
	.second	.second	ft. ⅌ sec.	ft. ⅌ sec.	tons ⅌ sq. in.	tons ⅌ sq. in.
¼-inch					29	1.1
1 ,,			360	80	18	6.2
2 inches	.00049	.0026			16.7	10.5
3 ,,			510	260	15.9	13.4
4 ,,	.0008	.0033			14.8	14.7
6 ,,			630	460	13.9	15.4
8 ,,	.0013	.0040			12.1	15
10 ,,			780	650	11.8	14.2
12 ,,	.0017	.0046			10.9	13.2
14 ,,			840	760	10	12.1
16 ,,	.0022	.0050			9.3	11.4
20 ,,			950	900	8.2	10.1
28 ,,			1060	1025	6.5	8.3
32 ,,	.0035	.0064			5.8	7.6
40 ,,			1160	1170	4.7	6.2
48 ,,	.0046	.0075			3.9	5
56 ,,			1240	1290	3.1	3.8
64 ,,	.0057	.0086			2.3	2.9
76 ,,			1305	1350	1.7	1.9
88 ,,	.0073	.0101	1320	1380	.8	1.

It is impossible that anything more conclusive could be conceived as to the necessity for our employing powder less rapid in its combustion than that of the quality we have so long been using. It will be seen that with the old kind, the pressure mounts up to 30 tons per inch before the shot may be said to have scarcely moved; while with the new powder the pressure goes on steadily increasing as the shot moves before it for about seven inches, when it begins slowly to fall; and there being at this stage, so much additional room for its expansion, the maximum pressure never reaches much higher than *half that of the other.* In the whole length of the gun both kinds will find the same space to act in, and both will exert the same total force; but the powder which ignites more slowly maintains its early vigour longer, and thus by greater persistence of powerful effort causes greater acceleration to the shot, and the resulting velocity is higher.

I must here again call attention to the complete answer to be found in these facts to ANY POSSIBLE OBJECTION *which can now be made to the rifling of our cast-iron service guns.* There can be but little doubt that they might be safely fired with nearly twice the charge of the pebble powder that they endured of the other sort WITHOUT ANY FAILURE, and from the large capacity of their bore, and the distribution of metal as they are designed, they are peculiarly adapted for powder of this kind, which requires more room to develope its force.

The gun used for these experiments was of the ordinary pattern and length, and it was fired with the usual battering charges. At the velocity which the shot acquired at the muzzle, the resistance the air would offer to the expansion of the charge in the gun could not have exceeded about 15-lbs. per inch; but we see in the above figures that the force behind this particular shot, as it left the muzzle, was 16-cwt. with one powder, and 20-cwt. with the other, or *from* 120 *to* 150 *atmospheres.* This is a vast force to waste. It is true we do not see that this final force produced as much effect on this shot as might at first be expected. In the last expansion of 19-inches, only 25 feet per second was added to the velocity. The shot had already been so driven by the high pressure at first, that its speed had become so great there was no time for the lower pressures to do much. The last expansion of the charge only acted on the shot for about one-thousandth part of a second.

But in this time the reduced pressure will be found to have added 185,000 foot-lbs. to the vis viva of the shot. This is at once proved by calculating the force by the velocities found at these stages. Had the gun been 19-inches shorter than it was, it would have been that much less effective; and had it been 19-inches longer than it was, we may very fairly estimate that it would have yielded, at least, 100,000 foot-lbs. more than it did as it was fired.

The diminishing pressures stated as taken from the report are ***deduced from the velocities***. Had the charge been less in proportion to the weight of the shot, and ***the bore been more capacious***, the velocity would not have been got up so quickly, and the shot consequently would have derived more benefit from it during a greater amount of expansion.

It would not be correct to infer that the pressure would continue in subsequent expansions to diminish in the degree which is indicated in this gun because such a thing is wholly unlike anything else we know of in similar cases of enlargement of permanent gases. At first the loss of ***heat*** by the gas would account for a greater diminution of pressure than is found in steam, for instance; but after a few expansions, the temperature would become so reduced that there would then be at all events a close analogy to the case of heated steam, the elasticity of which is always estimated by *Marriotte's* Law—the pressure diminishing ***as its density***. If so, there is nothing in these calculated pressures which proves that gunpowder-gas would not, up to a very large number of expansions, be capable of exerting an effective force in adding to a projectile's velocity. But even supposing that after the first few expansions it did continue to diminish in the same proportion as it is represented to do by these figures, we may still find that up to about 20 full expansions it would possess considerably more force than the air could possibly oppose to it, even if the projectile was moving with a greater velocity than the 8-inch shot had when it left the experimental gun.

But it may be urged.—Why need we care about such nice economy of force? The saving of a few pounds of powder can hardly be worth consideration. This may be true with respect to all guns of the smaller natures, and for them there is such ample strength of material at our command, that we might continue as we have hitherto done, to disregard economy.

But when we come to construct those enormous weapons, which of late years have become a national necessity, the question of right employment of force becomes of paramount importance. Guns costing two or three thousand pounds each are serious burdens on the public purse. These gigantic weapons are not only expensive and require much time to make, but they are very costly to *use.*

At all points where they can be employed against us we must have suitable guns ready in case of need. Our fleet will want many of them; and for our own coast defences, as well as for those of our dependencies, we shall want a great many more than our ships require. Our gunners must have experience with them even in times of peace, so as to learn how to *use* them when wanted in earnest; and, if every shot which is fired is to cost the country some *three or four pounds for gunpowder alone*, it becomes important that we should not waste it. And it is not *only* the cost of the powder we have to consider. When these vast quantities are employed for every charge, we may be quite certain that whether we get the full benefit from it or not in the force of the shot propelled, *we must suffer from the full effect of it produced upon the guns.**

The high pressure, or heavy charge system, may do very well, or perhaps be really the right principle for small guns such as *field* or movable artillery, just as the system of high pressure steam is correct for small engines, although it is less economical as regards fuel. But for large guns, as well as for very powerful engines, where force and fuel is employed wholesale, economy must be studied. *The greater the pressure, the greater will be the waste.* In guns as well as in engines, to work the elastic force *expansively* is to work it economically.

Is it impossible to avoid the evils of this high pressure system? We have seen by the analysis of results obtained from the guns we are now making, that when compared with others of a different type they fail to employ their force and fuel to the best advantage. If it is so with guns of moderate size, such as the *Palliser* gun with its 8-lb. charge, compared with the rifled 68-pounder, firing the same charge, (No. 17 and 18, general table,) why should it not be so with weapons of any size? I ask then for careful attention to the figures which appear in the table under example No. 33, A LARGE BORE RIFLED GUN PROPOSED. But before I discuss these figures, I would make one more remark.—

Why is our new ordnance so extremely costly? It is because it has to be made strong enough to resist the pressure of charges, *the force of which is to a great extent thrown away upon the shot, while it tends to destroy the guns themselves.* If they are not wanted so strong they need not be so costly.

At page 28 I have referred to the effect produced called

*In 1868, Five of the 9-inch wrought-iron guns were tested for endurance with service charges. After 500 rounds one was reported "*unserviceable,*" two "*repairable,*" and two "*serviceable*" after 600 rounds. These guns cost just £1000 each without carriages. (*Parliamentary Return.*" *Rifled Guns,*" 1869.)

"guttering." Our guns may never *burst* because we make them so strong; yet as we employ this strength, they will *wear* but very indifferently, and be constantly under repair requiring to be *re-lined.** These repairs can only be done at home, so that these ponderous masses of 20 or 30 tons each will have to be taken from their positions wherever they may be, in any part of the world, shipped to Woolwich, and then returned again, whenever they want re-lining. A few such double journeys would cost as much as a new gun. Now the more intense the pressure is at which we work our powder, so much greater must be this "guttering,"—fissures and channels being scooped out in the metal by the stream of intensely powerful heated gas flowing through the windage space over the shot, rendering it necessary to make provision for turning the guns over on their carriages when one side has been destroyed.

It was simply the amount of this active destruction which compelled us at last to try and improve our powder. Its *lesser pressure* will cause less guttering, and our guns will therefore last so much longer. Still, it will not prevent this destruction. It will be a slower process though not less sure. And it will be found, I think, that as with this slow burning powder the pressure reaches its maximum after the shot has moved some distance, it is *there* the inequalities will be produced, where they will be more likely to interfere with the rifling, and destroy the studs of the projectiles.

The evils attendant on the employment of high pressure have already received at the hands of the advisers of our government, a clear and authoritative recognition. It is stated in the report of the "Committee on Explosives," that the advantages of the new pebble powder consist of "*the reduction in violence of explosion,*" and the "*diminishing the liability of projectiles breaking up in the gun, and also modifying*

*One of the 7-inch ML rifled guns, on board the "Excellent,' in firing 530 rounds with 14-lbs. charges, 85 of 22-lbs., and 22 of 10-lbs. had to be *re-vented twice*, and "*turned bottom part up, the old vent blocked up and a new one bored;*" then returned to Gun Wharf to be re-vented a *third time*. One of 64-pounder MLR after 1759 rounds, service charges, was found to have a fissure of nine-tenths-of-an-inch, and had to be returned.—(*Vide* CAPTAIN HOOD'S *Rep.* in *Parliamentary Return*. "*Rifled Guns*,' 1869.

the scoring action of the gas upon the surface of the bore," thereby "PROLONGING THE LIFE OF THE GUN *and diminishing the risk of accident.*" (Vide Prel: Report, p. 11.) These solid advantages we have determined to avail ourselves of, and it is a great step in the right direction. But may we not go somewhat farther? By the adoption of powder more resembling that which every other state has been using for years, some of the evils of *high pressure* are remedied, and consequently our guns will probably last twice as long, as well as being otherwise improved. The question then arises: "*Why should we go on making guns calculated to resist a pressure of* 30-*tons per inch, when we know for certain that they will never be subjected to more than* 16-*tons, the difference in strength involving an enormous difference in the cost of their construction?* And besides this there is another question.—With all the facts before us which are disclosed in the table of results we have been examining, why should we continue to be so lavish with our powder, when by using it differently we might get more out of it, and at the same time still further "prolong the life of our guns."

When by actual measurements we found out to our great astonishment that we had been using twice as much pressure upon our guns as was needed, an alteration of some sort was of course called for. The guns themselves have been designed for work which they will never again be required to perform. But it has not I believe been proposed to modify the design of the guns; what has been determined upon is to increase the charges. Henceforth, instead of the charges of RLG powder which are given in the table, Pebble powder will be used in the following quantities:

New Charges, Pebble Powder.					Old Charges, R L G. Powder.			
12-in.	Gun	85-lbs-	Expansion	6.4	Instead of	67-lbs.	Expansion	8.3
10 ,,	do.	70 ,,	do.	5.4	,,	60 ,,	,,	6.3
9 ,,	do.	50 ,,	do.	5.34	,,	43 ,,	,,	6.3
8 ,,	do.	35 ,,	do.	6.	,,	30 ,,	,,	6.9
7 ,,	do.	30 ,,	do.	5.38	,,	22 ,,	,,	7.4

The efficiency of the guns naturally is increased by this, but it was for some time an anxious question whether they *could* be so used in consequence of the *additional recoil* occasioned. It appears however that the compressors and fittings for checking recoil are found to be *just sufficient;* but it is a very near thing and there is nothing to spare. Yet the fact remains that the guns have still *at least* 30 *per cent. more strength in them than can be made use of at all;* or, in other words, there are so many tons of valuable wrought-iron used in their construction that is of no use whatever, but as affording *so much dead weight* required to absorb recoil.

It appears to me that the table at page 95 indicates a better way than this of using the improved explosive. What is there shewn in reference to the old powder, which ignites quickly, applies yet more forcibly to the new, which is slower and less violent in action, and requires *more room* for the *full developement* of its energy. Whether the old or the new powder is employed, it may be used in wasteful excess. If either kind is worked only at moderate pressure, but with a proper measure of expansion, by increasing the calibre, as it is not possible to get length sufficient in our guns, greater effect may be obtained with *less recoil.* I can conceive no reason why we should employ such an expensive metal as *coiled wrought-iron merely to form the dead weight in the gun* necessary to check it. Surely a much cheaper metal would do for such a purpose. This point I propose to examine further, not forgetting the importance of considering the question of *penetration.*

THE PRACTICAL APPLICATION OF THE FOREGOING OBSERVATIONS.

If we are right in adopting as we have done for our heavy guns the system of very large charges and extremely high pressure, it is simply a fact that *all other nations must be wrong.* Now with what there stands recorded in the history of English gunmaking, have we a right to feel perfectly satisfied that in other countries the subject has not received in every way as sound an examination as we have given to it here? The Prussians, the French, the Russians, (none of them being *compelled* any more than ourselves to do so,) use far smaller charges than we do; and they have gained their wide experience with that better quality of powder which we have only *just discovered to be beneficial, if not absolutely necessary.* Let us by all means exercise our inventive faculties, but let us take care to work by the light of knowledge, and not presume to teach while we refuse to learn. What better reasons have our authorities *now* for closing their minds against all modification of the plans they have adopted, than they were able to give, and *did give,* when they adopted or supported the *Armstrong* gun, or when we talked, as we used to do, in a knowing way of the *weak* foreign powder.

But there is another great nation pre-eminent for mechanical skill, as well as practical sagacity, and which of late years, unlike ourselves, has had no small experience in the *realities* of war, which has adopted for its service a system of big guns, which may be regarded as exactly *the opposite* of ours. The American guns are *large bored* guns; ours *very small.* We use only six or seven expansions of the charge; they employ twenty. Their guns are greater than ours, and cost but *a fifth part of the price we pay.*

It cannot be imagined that the shrewd men of the United

States act with less careful thought than our authorities in England. They know perfectly well what our English guns will do, and they could follow our example if they thought that the interests of their country required it. But knowing perhaps better than we do the capabilities of their own ordnance, they still prefer their own course, and contrive to save their money. Yet, if it came to actual conflict, should we not probably have as much to contend against in the American system of ordnance as in that of any other State? It is true that our guns will command greater range, and also greater penetration; but the Americans say that this long range is a delusion, and that they do not want to *fire* when they cannot possibly *see;* and also that if by *several* heavy blows they can shake and shatter their enemies defenees to pieces, the work will be as effectual as punching a few holes through it. Therefore they prefer to spend their money in supplying themselves with *numbers* of large guns as they are wanted. For a smaller sum than we shall spend upon the *twelve* new 35-ton guns just ordered, (about £32,000 exclusive of carriages, accessories, and ammunition,) they, in a *tenth part of the time* could make *fifty* guns, which, except under very exceptional circumstances, would, within moderate fighting distance, be hardly less effective. Would the twelve be equal to the fifty, *generally*, accidents or casualties taken into account? This, at all events, is the reasoning of men who are as good engineers as we are, and who have never been suspected of closing their minds to the reception of new ideas, or of refusing to adopt improvements.

It is not for civilians to judge of this, yet they may note the divergence of opinion among those whose duty it is to know, and to whose authority they must defer.

We have tried one of these great American guns, and we see by the table what it is and what it does; and we find that as an *economical engine* we have nothing like it in our service. A *cast-iron* gun of 19-tons delivers blows as hard as we produce with our expensive *coiled wrought-iron* guns, only six per cent. heavier, (*Vide pages* 68 *and* 99.) That it is a safe gun has been proved by experience, and there is reason to believe that it is practically as durable as ours without requiring extensive repairs.—It works with lower pressure and therefore suffers less wear.

The reason that so great a result is obtained from such moderate means, is that its *principles* are sound.—*It does not waste its forces.* The method of analysis which I have applied in the general table to all the various guns, shews plainly what these principles are, and the consequences of disregarding them. This analysis also seems to me to indicate something of higher consequence, and how yet greater results may be achieved.

The American is not a perfect gun, for two reasons.—Being a smooth bore it cannot, like all similar guns, command precision for any distance, and the round shot are deficient in penetrative power, owing to want of weight and *weakness of form.* But why should not rifled guns be made with similar sound principles? There are the examples of our rifled service guns, and as regards their *economy* I have challenged comparison with those of the modern English type, in a way that sooner or later will *compel* for itself a hearing. The adoption of such economy may yet continue to be postponed as it was by the late Ordnance Select Committee seven years ago, till "circumstances of urgency may arise." But the history of Europe in the last twelve months will give a significance to this expression, that even the powerful voice of contractors may not be able to explain away to tax-payers.

I ask attention then to the sketch at page 58. It is that of a gun such as might be represented by the figures in example No. 33 in the table, No. 1, or No. 31*a* in the table at page 95. No weapon of such a character, or of such dimensions has, I believe, ever been made, nor, as far as I know, has this method of construction been before suggested. It is a compound gun, and so far resembles the *Palliser*, but it is distinct from that in several particulars, which will be seen. Setting aside however all question of novelty, I propose to discuss with the help of the comparisons, which the table of actual results affords, why such a gun would, if made, be probably successful. I must do this by a process of induction.

I assume that we shall require for the thorough defence of the country large numbers of extremely powerful guns; we need them at every point where a hostile iron-clad vessel could attack us. Shall we ever be able to get them while they are as expensive to construct as those we now make? If however we could make them cheaper, we might get them all the quicker.

The British Nation has at last awoke from that complacent sense of security which had in it more conceit than wisdom, to something like a real knowledge of her actual position. The struggle in France has shewn us what modern war is, when it extends beyond an attack upon a single stronghold in a remote corner of a foreign state; or is a pleasant tropical excursion, and a bloodless victory over an African savage; but is a *real invasion*—a deadly struggle for homes, with all the incidents of sacking of villages, burning of towns, the maiming and murdering of tens of thousands, and wholesale imprisonments, impoverishment, and starvation. Such things have come near enough for us to see them and teach us lessons. Thus roused from the state of the fools paradise, we have begun seriously to take stock of our means of self defence, and to count up our men and weapons. What do we find? Cannon, such as we must fight with if we *fight* at all, are the things which are essential; but where are they? We cannot compete with other states in the magnitude of our armies, but hitherto we always have exceeded them, in the *force and number of our heavy artillery*, and so maintained our position What have we now to use?

In the last fifteen years we have spent more money upon them than probably France, Prussia and Russia put together, but we are now only able to count up our rifled ordnance by scores, while we absolutely need them in thousands. There is hardly a state in Europe which has not at this moment a larger number of rifled ordnance than we have. We have a few magnificent weapons, but still scarcely enough to arm all our fleet properly, to say nothing of other requirements. Our pride of wealth and conceit of manufacturing skill has betrayed us. We have been dallying over Utopian schemes of perfection in our guns, and frittering away our time and resources to comparatively little purpose.

England with all her wealth cannot afford to waste her money over a few dozen guns which shall merely have a greater name than those of her neighbours. We save our old pens and cut down the well earned salaries of our hard-working public servants, and then go in for guns at three or four thousand pounds each—wonderful guns doubtless to see fired at Shoeburyness, and to talk about and boast of, but which can only be in one place at the same time, and we want them in many places, but cannot get them there because they are so good. We may amuse ourselves with the idea of making these perfect guns which shall last for ever, although *the* gun of to-day will very likely be the rejected of ten years hence; but in the *mean time* our batteries will continue to be starved as they ever have been since we began our course of reconstruction.

For fifteen years our coast defences and foreign dependencies, with their regular and reserve corps, have been waiting in vain for the reinforcements they ask for, but few or no improvements reach them. The men must drill and practice with the smooth bore guns of ancient days, and so learn nothing that is likely to be useful. In this long period we have spared no money or labour, and by hard work and heavy squeezing we have succeeded in turning out ready for service, such as we can rely upon, less than 600 rifled guns of over 7 tons each, and about 700 guns of that and less weight suitable for ships; besides some 200 or 300 converted guns. I leave out the *Armstrong* B L 100-prs., and Shunt guns, for they are things of the past. There has been no want of energy in our factories, but the labour itself has been too heavy.

In actual ***numbers*** this total scarcely exceeds what we have hitherto kept for use at Malta alone. However perfect the guns we have made may be, a few cannot guard our territories all over the world; and however powerful and speedy our ships of war may be they cannot be omnipresent. So long then as we refuse to think of our economies in this matter, and close the official ear to all suggestions of saving, and *choose to use no guns but such as are made of gold,* shall we *ever* be able to get supplied?

In a parliamentary return respecting our "rifled guns," moved for by Lord Elcho in April, 1869, and ordered to be printed on the 10th August, 1869, there is a great body of valuable information as to what had been accomplished by our gunfactories up to that date. A few facts which I gather from this official document may not be out of place here. It appears that we had then two 13-inch muzzle-loaders; 17 of 12-inch; 9 of 10-inch; 314 of 9-inch; 109 of 8-inch; and 680 of 7-inch bore—in all 1131 guns of over 6 tons weight. Besides these there were being made or "intended" to be ordered, and which I suppose have by this time been supplied, 9 of 25 tons, 9 of 18 tons, (10-inch,) 141 of 12 tons, (9-inch,) and 6 of the 6½-ton 7-inch bore—*making, with those we had before, a total of thirteen hundred and six* guns of this class. Now what do we require?

The return states that for our iron-clad ships *alone* we wanted 594 of these large guns; and then there are our other vessels, and also our fortifications. According to this return, for the *new* works "as designed" about Portsmouth, Plymouth, Pembroke, Portland, Gravesend, the Medway, Dover and Cork, we shall require 898 of the large sizes, and 1061 of 95-cwt. and under; of these only *forty-one large rifled guns had then been furnished.* There is no return for the old fortified places, and no reference is made to Harwich or any station on the east coast, or the Channel Islands, or in short any of the other batteries in any part of the kingdom. These however must of course be thought of, and also Gibraltar, Malta, Bermuda, Aden, Canada, India and Australia, and many other places which might be mentioned. We have distributed what could be spared, but it is few.

We also learn from this return that the cost of each of the 600-pr. wrought-iron guns of "mark I" is £2331 17 11½, those of the same size, mark II, is £1772 10 10½. The wrought-iron carriage for it, with hydraulic buffer or Elswick compressor, comes to about £250 more; and besides this there is the platform or slide costing another £300. The time required to build the 600-pounder gun is just about three months; in each carriage there is eight weeks' work; and in each platform from 8 to 10 weeks' labour. But this is assuming "that the factory is well employed, (a single gun could not be manufactured in the time named,) and that the patterns are ready prepared." We obtain from this a rough general idea of the work there is cut out for us.

The sketch at page 58, represents a 15-inch rifled gun constructed for the most part of *cast-iron*, but having at the breech end where all the great strain occurs, a wrought-iron breech, or short inner gun provided to meet this strain. The wrought-iron portion is inserted from the rear, and can be secured in its place by a suitable screw-thread on its outer circumference, running into the cast-iron, and, if need be, it might be rendered more firm in its place by a very slight "shrinking on" of the metal surrounding it.

We see by the table at page 111 up to what point in a gun the severe pressure takes place; it is in the first two or three expansions of the charge. We know this also from the fact that when guns burst it is always in rear of the trunnions. Why then should we have expensive material at that part where the pressure from the charge never can exceed a third of what we know for certain that good cast-iron is equal to sustain?

In the way described, guns of any strength or dimensions might be made—large bored or small bored; for high or for low pressure; muzzle-loaders or breech-loaders; the *principle* being that there shall be *the required strength provided where strength is needed* about the breech; but from the trunnions forward, where but little strength is required,—although in the whole gun there must be *length* to work the charge expansively, and to guide and steady the shot, and also *weight to absorb the recoil;*—for this, cast-iron will do just as well as the best wrought-iron, and we might save its cost.

To make large built up guns *wholly* of forged iron seems to me as unscientific as to make large steam engines entirely of the same material, including the cylinders, condensors, beams, &c. What would they cost if we did? and would they be any the better for it?

Supposing this gun which I have sketched to weigh 23 tons, it might be composed of about 17-tons of cast-iron, which may be had complete turned and bored for less than £20 a ton, while, if it were all of wrought-iron this portion finished, would at least cost four or five times as much, as it is by far the most troublesome part to make and forge into shape. Guns of such construction, in consequence of this saving of expensive material, would be cheaper by *sixty or seventy per cent. than those we use*, and *where strength is needed* they might be of *any strength.*

The particular gun which is shewn in the drawing, if fired with 70-lb. charges and shot of 700-lbs. weight, would, as compared with our wrought-iron ordnance, be a *low pressure* gun. My calculations are based on the results obtained with RLG powder, although of course pebble powder would be the proper kind to employ, and as much more of it as the recoil would admit of.

In estimating as I have done what might be expected from such a gun, I have reckoned upon the same charge being used in proportion to the weight of shot as I employed for my rifled 32-pounder cast-iron service guns, viz., one-tenth. It will be seen by the several columns the proportions which such a charge bears to the dimensions of the bore, and how they compare in this respect with all the other examples.

With the information obtained by the analysis, I think we may collect sufficient evidence to shew what the power of such a weapon would be. I may fairly assume that what we find takes place invariably in the many cases the table contains, would also occur under all similar conditions, so that from the known effects produced in other guns we may learn what would be the probable effects in this projected one. For example: the same quantity of powder (Pressure—Col: L) acting upon the same weight of shot (Resistance—Col: M) throughout the same distance

(Expansion—Col: O) should always produce what is equivalent, or proportionally so, where there is any *variation* in any of the terms. If this be the case there is sufficient reason to conclude that this cheap compound gun might be expected to produce, with the charge named a *vis viva* or striking force in its projectile at the muzzle of over 16 millions of foot-lbs., (Col: G) or *twenty-three per cent. more than we get from our present wrought-iron 600-pounders with the full 67-lbs. charge of RLG powder.* If Pebble powder were used in equally larger proportions for both guns the difference would be still more in favor of the larger bore, as there would be a larger measure of expansion.

But there is this important difference between what these two guns have to do in producing this force. In the 12-inch 600-pounder, the power has to be got up quickly in 8¼ expansions of the 67-lb. charge of RLG; in the 15-inch it would be developed more slowly and gradually, the acceleration of velocity extending throughout 20 expansions of the charge. In the 600-pounder the resistance from the weight of the shot is nearly 5½-lbs. per inch, requiring for the work done a pressure of .593-lbs., (or nearly 9½-ozs. of powder) per inch to drive it. In the other the resistance of the 700-lb. shot is 3.95-lbs., per inch, (or about 3-lbs. 15-ozs.) to be overcome by the pressure of .394-lb., (or about 6-ozs.) of powder per square inch,—a little more than the intensity with which the 14-lb. charge acts in the 7-inch gun, No. 10, or not much more than that of the 10-lb. service charge in the old 32-pounder smooth bore. Cast-iron alone of good quality might almost be trusted to do this work. The great difference being caused by the area of the bore being so much greater, as explained at page 97-99.

An attentive examination of the figures relating to the other guns in the table will, I think, shew that my estimate of the effect of this pressure in communicating velocity is not too high. I think the probabilities are in favour of its being more rather than less than I have estimated. The same charge of one-tenth of the weight of shot produces 1213 feet per second in the rifled 32-pounder service gun, (No. 20,) and I have put down the same for the large gun; but it must be observed that the twenty expansions of the 70-lbs. charge represents continued acceleration during 19 feet of space, while in the other gun it is only through $8\frac{1}{2}$ feet; and throughout this distance there would be the same quantity of powder at work in proportion to the resistance, and it seems to me this *ought* to produce rather more speed. In the instance of the 15-in. American gun, a charge of one-ninth gives 1220 feet per second in a shorter distance; and here there would be some loss of effect from greater escape of gas, as I have supposed the large rifled gun to be firing an expanding projectile.

The following figures relating to analagous cases taken from the table will speak for themselves, especially with regard to the effect of the expansive working of the charge.

	10 inch Rifled Gun. Charge 40 lbs.	15 inch Smooth Bore. Charge 50 lbs.	Rifled 32 pr. Charge5 lbs.	Proposed 15 inch Rifled Gun. Charge 70 lbs.
CHARGE.—Proportion of Powder to Shot, (Col. K)	one-tenth	one-ninth	one-tenth	one-tenth
PRESSURE.—Weight of Powder ℔ square inch of area, (Col. L.) .lb	.51 or $8\frac{1}{6}$-oz.	.28 or $4\frac{1}{2}$oz.	.156 or $2\frac{1}{2}$ oz.	.395 or $6\frac{3}{8}$ oz.
RESISTANCE.—Weight of ℔ square inch of area (Col. M) lbs	5.1 or 81 oz.	2.54 or 41 oz.	1.56 or 25 oz.	3.95 or 63 oz.
EXPANSION of Charge in length of Gun (Col. O)	... 9.4 ...	... 19.4 ...	... 23 ...	... 20
VELOCITY at muzzle, (Col. F) ft. per sec.	... 1117 ...	... 1220 ...	... 1213 ...	... 1213
VIS VIVA of Projectile at Muzzle ℔ lb of Powder, (Col. I) Thsds ft-lbs	... 194 ...	... 208.2 ...	... 272.6 ...	... 228.8

But it may be urged with perfect fairness that it is not alone the force with which the projectile leaves the gun that has to be considered. We must find out what its power would probably be at effective distances; and also what the *punching* power of such large shot would be.

For the reasons given at pages 83-4, we may get at a tolerably accurate idea of the range it would command from the figures in Col: M, by which it may be inferred that from the weight of this large 700-lb. projectile, in proportion to its area of section, it would have as nearly as possibl the same power of *maintaining its velocity* when penetrating the air, at the same speed, as the long 250-lb. shot which is fired from the 9-inch gun, (No. 7.) Although the large projectile which I have represented is a capacious shell of less than $1\frac{3}{4}$ diameters in length, it contains in its great mass as much carrying power as the other, which is so much longer in proportion to its area; the actual weight to area being, in fact rather higher, 3.95 as compared with 3.93 that of the long 9-inch bolt.

With regard to the effect of such large projectiles upon iron defences, it must be borne in mind that although absolute penetration may not in some instances be effected, mischief as great might be produced if the blow was sufficient to buckle the plates, destroy their fastenings, and shake the whole fabric to pieces. The question is whether the greater force which is to be gained by exploding the charge against a larger area in the shot is more than counterbalanced by the power of the defence against it. The larger shot would strike with far more force, but having to make a bigger hole it would have so much more work to do. If it did get through, or by other means break up so much of the defensive armour, the destruction would of course be more extensive.

As I have before stated, (*Vide p.* 86-87,) the punching power of projectiles is usually estimated as their vis viva in proportion to their circumference, (Col: Q. ;) and for ***short ranges***, the figures given may, in a general way, be taken as near the truth in each example. Here it is seen that the punching power of the 700-lb. 15-inch projectile, if it left the gun at the velocity stated, would be very little inferior to that of the 600-pounder 12-inch shot; one being as 344.6, the other as 340.1. But the question of ***depth*** of penetration has also to be considered, or what would be the power of each shot to ***continue*** to penetrate, and overcome the resistance they respectively meet with. I think this is fairly shewn in Col: S. The long 600-pounder bolt is heavier than the other in proportion to its circumference, as 15.9 is to 14.9; therefore it would probably penetrate somewhat deeper, although its smashing force would be so much less. But let it be remembered what guns are here compared. One costs about £2000; the other may be made for between £500 and £600, in fact about the same as our 7-inch guns made wholly of wrought-iron.

But this is far from all. The wrought-iron guns require such a vast amount of labour and machine work, only to be done with such a plant as we have in the Royal Gun Factories, that each one takes about three months to complete, as each machine can only deal with one at a time, The other kind being chiefly composed of cast metal, which may be produced in many foundries, could be constructed in quantities without any delay.*

If greater penetrative power is required than this 15-inch gun appears to have, similar guns can be made if need be of twice the size: there is scarcely any limit to this that I can see, except from the weight that the guns must have in order to save recoil, and how many tons could practically be worked by our gunners.

* I have authority for stating that at the Low Moor Iron Works from 20 to 30 such Castings might be made *weekly*.

No enemy would dare to despise the power of the 15-inch American cast-iron guns even as they are; they would have a wide berth given them, and be attacked only from a distance. But such guns if improved to the same extent as the 32-pounder gun is improved by being rifled, so that the effective range shall cease to be inferior, as is shewn in the comparison of actual results given in the general table, and particularly compared with wrought-iron guns at page 23;—with such guns mounted on our coast defences, we need fear but little from any iron-clad vessels. There is a limit to the weight of armour which any ships will float with, but ***there is scarcely a limit to the power to be obtained with weapons of this construction.***

However opposed the idea of making such guns may be to those notions which have worked their way into official favor, and been adopted as the correct thing, I must still claim for the ***facts which relate to the question*** a calm and impartial consideration. We have ***assumed*** that the small bore and high pressure system is sound, for we have never tried to make a large bored powerful gun; yet let the figures which I have brought together be examined and tested in every way that can be suggested, and the conclusions will, I believe, be found inevitable, that this cheap large bored compound gun would prove a ***more powerful weapon*** within any distance at which artillery is practically available THAN ANY GUN WHICH WE AT PRESENT POSSESS, ***with the exception of the last huge monster which swallows up*** 120-***lbs. of powder at every round.***

Its shot would strike with more force than our 600-pr. up to 3000 yards; and, as the weight of the 700-lb. projectile, in proportion to its circumference, is greater than that of the 10-inch 400-pounder, as 14.9 is to 12.7, (Col: S,) it is beyond a doubt that with equal velocity it would penetrate deeper than that shot, but at the same time it would make a larger hole and accomplish more destruction. It might fire a common shell with a *bursting charge of from* 40 *to* 50-*lbs. of powder*, or even considerably more if desirable.

Why this gun should be more powerful is fully explained. It is a simple application of principles of economy. It turns to good account all the force that it employs; ample strength is provided in it where strength is wanted: and the needful weight to absorb recoil, and also full capacity for expansion of the charge is obtained without a wasteful employment of expensive material, or a waste of powder that destroys the gun.

The projectiles for such guns might be either short solid cylinders, or, what would be far better, strong capacious shells of about one diameter and a half or 24 inches long. The shell which I have represented in the sketch is on the expanding principle; but it might of course be on the copper stud plan if experience proved that it was preferable. It appears to me that even a *shell* with such a thickness of metal at the sides as might, in these large projectiles, be retained, would, from the direction of the lines and disposition of the matter, be less likely to break in penetrating iron plates than the *solid* round shot which were tried from the American gun, and which broke up without penetrating very deep, because the matter has not that support in its coherence which it has when arranged in longer columns striking end on.

Whether or not it might be desirable to employ expanding projectiles for guns of the largest kind is a question not to be determined without a proper trial, but I see no reason against it as far as my knowledge extends. At first sight there might appear to be an objection to the use of the lead or pewter envelope, for shot of very great weight, from an apprehension that it might prove liable to injury; but I think that an impartial consideration of the method of construction which is shewn in the sketch at page 58 would remove any such impression. It will be seen that the lead or soft pewter which is intended to be upset and expanded by the pressure of the charge, *is not exposed as it is in the* ARMSTRONG *projectiles*, but lies within a zone, *entirely protected by iron at both extremities.* Formerly I employed a sabot of wood as shewn in the drawing. This was more or less successful, but it was an additional expense and complication, and occasionally was found to be detrimental, as the wood sometimes did not entirely separate from the shot, and must have somewhat interfered with its flight. The plan I now adopt does away with this difficulty.

Imbedded in the soft metal, and *secured to it by the same means as the soft metal is secured to the body of the projectile*, I have an iron shoe-piece which forms an integral part of the shot, and which will never separate from it. This will fulfil all the duty which the wood performed in assisting to bulge out the soft metal around it when pressed by the gas, and at the same time it will form a perfect protection to the edge of the soft metal in which it is imbedded and secured. The soft metal being thus protected, would, as it seems to me, be less liable to become seriously damaged in transport, than the copper studs now used, which stand out prominently all round the shot. And there is difference. The studs are made and required to *fit* the grooves as accurately as possible; if then they became bruised by the rolling or pitching of a ship, the jarring and jumping of land carriage, or other causes, the studs might not be found to go readily into the grooves without being filed up into form again: but the soft metal is *not required to fit the gun or grooves when loading*; if by any rough treatment it did become bruised or indented, this would not be of the slightest consequence, for when it was fired the expansion would bring everything right.

There are advantages appertaining to projectiles of this character which are not to be overlooked.—

1.—They are *cheaper to make*, if proper means are employed. The shape is produced by casting in suitable moulds, and it is not necessary for them ever to go into a lathe to be turned; external niceties of finish are of no value whatever. They can therefore be produced in any quantities without requiring to occupy expensive machinery. There are no holes to be drilled out and undercut; no studs to be first cast, each one then to be turned, then fitted into its place, and afterwards shaped with great care so as to fit the grooves they are to work in.

2.—By preventing an unnecessary escape of gas they would *save consumption of powder*, and at the same time diminish the evils of so much pressure and scour, which it is admitted would be calculated to "prolong the life of the guns."

3.—They would *pack so much closer* in consequence of the absence of studs or projections upon them.

4.—In loading there is no necessity for adjusting particular parts into particular places as with the others.

5.—*The wear of the guns would be less* as the metal of the shot which comes in contact with the grooves is softer, and there is no blow given to the edges of the rifling on the reversal of side at starting. (*Vide page* 34.)

6.—And probably beyond all these in importance there is another advantage.—When, after continued firing, the guns begin to wear, and "gutterings" in the bore occur, in which studs or projections might catch and override the rifling, *the yielding metal of the expanding* *shot would simply give way*, and immediately after passing the inequalities of the bore, it would again be pressed up into its proper form and be in no way affected by it. (*Vide page* 33.) THE RIFLING COULD NOT CAUSE EXCESSIVE STRAIN.

I am well aware that at the present moment lead coated shot are out of favor here in high quarters, and it is not altogether unnatural that it should be so considering the experience we have had with them, and how we have been betrayed through them. But probably it is not the shot we have to blame for this. Similar projectiles have played an important part in the war just brought to a close; and, at least we may say that the Prussian Artillery which used such projectiles proved itself in no way inferior to the *French pattern which we have imitated.* To object to such an application of soft metal which is shewn in the sketch which I have given, because the *Armstrong* shot are not liked, might be called an *excuse*, but by no logical process could it be shewn to be a *reason.* They are entirely of a different character.

I have been speaking of *large* rifled guns; weapons designed for the special purpose of acting against iron defences or armoured ships, and such weapons as this country must depend upon for its *first and principal line of defence*—our coasts and harbours. These guns have properly formed the chief object of our care, for there can be no doubt that the progress of science as applied to the instruments and the art of war, has materially weakened the security this country has hitherto enjoyed from its insular position, rendering it the more essential that British maritime ascendancy should be maintained. The difficulties which stood in the way of the Spanish Armada, and the French Flotilla at Boulogne, were far greater than would now exist, when with the aid of railways and steam transports, with orders conveyed by lightning messages, invading forces in any number might be organised in many places, and within a few hours be concentrated on any one point, or descend simultaneously on several, convoyed by swift invulnerable floating fortresses armed with weapons of irresistible power, and moving independently of winds or tides. "The real strength of the citadel is only as the strength of its weakest part." If then our "first line of defence" is to be chiefly relied upon, we must protect *all* its salient points with suitable weapons, and we must have them in requisite numbers.

But there are other guns besides these monster weapons needed, and needed in infinitely larger numbers still.—Have we them?

Once more turning to the pages of Lord ELCHO's return, presented to Parliament by the War Office, and therefore admitting of no suspicion of inaccuracy, it is to be noted that in order to complete the *new* fortifications as they are designed, *one thousand and sixty one* guns of 95-cwt. or under are demanded, besides large rifled guns. They are wanted for the land faces of these works, and the sea fronts where no iron-clads could swim, and where ponderous plate-punching guns would only be unwieldy incumbrances. What have we to spare for this? We must not be misled by seeing a good show *at Woolwich*. What are there elsewhere?

According to the same return we had just 1013 *Armstrong* long and short 40-pounder breech-loaders, 323 *Armstrong* 20-pounder breech-loaders, firing $2\frac{1}{2}$-lb. charges, and 155 *Palliser* converted 64-pounder guns; since that date we have, I believe, added about 200 more of the latter kind. These are really *all the rifled guns of this class that can now be said to exist in the British service*, and they are nearly all of them of a pattern which has virtually received *official condemnation.*

If then our *eight* new fortified stations were properly furnished, as designed, we should have left only about ***seven hundred*** rifled guns of various sizes, less than the heavy special guns, to arm all our *old* fortresses throughout the Empire, at home and abroad, as well as to complete the armament of all our fleet—iron-clads, wooden frigates, and gun-boats.

Now with this important fact before us let us turn for a moment to some of the lessons which, if we are wise, we may gather from the great conflict which has just been terminated on the continent. In the invasion of France by the German armies, we see the sort of fighting which we should have to encounter if either in England or elsewhere our "first line of defence" was ever turned, and a landing was effected. Where are our weapons?

Although both combatants in the recent war possess a considerable number of very large guns, like ourselves, it is I believe a fact that not half-a-dozen pieces of ordnance were fired during the whole struggle which could have produced the smallest effect upon iron defences of even moderate thickness. There were no iron plates to attack, and therefore they were not required; yet it was pre-eminently a war of artillery. The guns which were used happen to have all been of that class in which we are most deficient.

I need scarcely speak of field guns. The accounts of Sedan and many other bloody battle fields are too fresh in our memories to need a word as to the part such artillery played in them.

What weapons of this kind Great Britain possesses the official list informs us. We have 701 of the *Armstrong* 12-pounder breech-loaders, and 266 of the 9-pounders of similar nature. This is the national stock. As regards actual numbers it may or may not be sufficient; professional men only can judge of this. A few years since we looked upon these guns as absolutely perfect arms. Have we confidence in them now? On the contrary, we are told they are not what they ought to be. The authorities who so lately were loud in their praises have changed their views, and now as strongly condemn them as formerly they lauded them; the decree has consequently gone forth that they are to be all replaced with others which are considered to be simpler, and better for the rough use they have to bear.

But however indispensible a proper supply of field guns may be to us, they can hardly be deemed of so much importance to this country as that middle class of moderate sized ordnance which comes in between the field gun and the modern monsters,—guns not too ponderous to be moved easily and served readily, yet powerful enough for any purpose where no iron defences exist, which guns, as we have already seen, are absolutely indispensible as auxiliaries to the giants of the first class either in sea fortresses or afloat.

If we try to find out what weapons of this class were used in the late war, one fact of primary importance is noticeable. With hardly any exceptions, none but *rifled* guns were used on either side. There were several descriptions employed, but the smooth bore was obselete, and yet there was no lack of weapons.

In the *Times* of the 3rd March, there is a full description furnished by the very able and accurate English military correspondent, of the guns which the German forces brought to bear against the forts on the south side of Paris. From this we learn not only what weapons were selected, but also how they were used by what may be truly considered as the *most experienced and most successful authorities in the world upon modern artillery.*

To operate against Fort Rouge, Fort Issy, and Fort Montrouge, and the minor works about Billancourt and Boulogne, as well as to threaten a portion of Paris itself, the Germans constructed in the neighbourhood of Châtillon and Meudon 23 batteries. In these there were altogether eighty-two 60-pounder guns, (nominally called 24-pounders, that being their calibre if the ordinary round shot had been used,) forty-two 30-pounders, (or nominally 12-pounders,) two 18-pounders, (nominally 6-pounders,) 4 rifled 8-inch mortars, and four 11-inch smooth bore mortars. From these guns a total of 55,000 projectiles were fired, the whole of them I believe being shells.

With the exception of 4 mortars, all were rifled, and all were long range weapons. Now we have heard so much about the value of long range that it is important to note what practical use was made of it, for here, if anywhere, it might be expected that advantage would be taken of it. The Germans however did, what no doubt British artillerymen would always do, declined to waste their powder in firing at distances too great for the eye to command.

With the exception of two batteries in which the guns were sometimes fired at an elevation sufficient to reach a part of the city at less than 4,500 yards, all the rest were fired at objects no farther off than from 900 up to 3,100 yards. The greatest number being used at 2,500 to 2,700 yards.

Most of the guns were of steel, a few being of bronze They were breech-loaders, and fired lead rifling shells. But there were two batteries in which were twelve guns of a different kind, and to these the *Times* correspondent refers specially in the following words.

"The chief feature of its armament (Battery 19) was the four, " (later six) short 60-pounders, which it contained, and which threw

" their long shells, longer by three inches than the ordinary 60-
" prs., so carefully, and so well timed to their curved flight, that
" they cut the escarp of Fort Issy, forming all the grooves in the
" masonry laid down in the schools as proper for the formation of a
" regular breach. But the difference is that the schools teach that
" *the guns should be on the very glacis of the place, whereas the short*
" *60-pounders were* 1,950 *yards from the curtain of Fort Issy. They*
" *were neither of steel nor of bronze, but of* CAST-IRON; *for the small*
" *charges used bring no danger of bursting, and* CAST-IRON IS CHEAP.
" The six short 60-pounders fired 2000 shells." Battery 21 also
" contained six of the *new* cast-iron short 60-pounders, which were
" laid upon the curtain of Fort Vauves at 1600 yards distance.
" From it were fired 1,880 long shells."

I am informed that these twelve guns were in fact nothing less than so many of the *cast-iron service guns, rifled without being strengthened.*

In Belgium such rifled guns may be seen in every fort. Whether these had been copied, or whether a few Belgian guns had been purchased and sent to Paris, is a point which cannot perhaps be traced. It will be noticed that the dimensions of the projectiles were not similar to those of the Prussian arms.

By converting the old service guns into breech-loaders, they necessarily have to be considerably shortened; and this would not improve their efficiency nor add to their strength, because an open tube must be weaker than one with a solid closed end. But it seems from the report that they did their work well. As then this is the first time that any such guns have actually been used in real warfare in Europe, I call special attention to the fact, because for *seventeen years* I have been doing all in my power to prove to our authorities in England that such weapons might be used.

Should these pages ever be seen by the officer who penned the above words, I would call his attention to the figures I have given in the earlier part of this enquiry. He will there see that in this country cast-iron rifled service guns have been tried as successfully as those he saw before Paris. He will see also that English cast-iron unstrengthened rifled guns have proved themselves capable of commanding with accuracy (if ever it might be necessary,) some thirteen hundred yards *greater range* than any distance he mentions in his report to the *Times*. He may also observe that not *one English rifled service gun that has been tried under proper conditions as regards charge and system of projectile has ever yet failed*: and that the only gun which was tested for endurance with service charges under these conditions, is still in existence at Woolwich, and has fired as many rounds as all *six guns* in either of the batteries whose performances he witnessed. He will also see by the comparison at page 23 that English cast-iron rifled service guns are not necessarily inferior in power to breech loading guns of stronger metal; and that when they are not called upon to bear excessive strain from hard metal studs or projections liable to override the rifling and become partially or wholly wedged within the bore, there is no danger to be apprehended of their bursting. They did not burst in France, when the rifling was only acting on yielding lead, neither do they burst in Belgium, nor in Prussia, nor in Russia, nor other places where they are used. *And they did not burst in England during eight years of experiments*, although other guns did which were tried with other shot. (*Vide page* 30.)

How very remarkable then is the present position of this country in regard to arms. We have hardly any garrison guns to use, and yet we possess them in multitudes. They have been accumulating at home and foreign stations for the last hundred and fifty years; and to quote the words of the late Ordnance Select Committee they are "as fit to be rifled now as when they were first made."*

From a thousand to fifteen hundred good serviceable guns may at this moment be found at Malta; probably as many at Gibraltar; and nearly as many at several other stations of the first class; besides considerable numbers at other places of less importance. Who can count them in the batteries all over England, Ireland, and Scotland? At Woolwich they may be seen in the store yards completely covering many acres of land. *As they are*, it is admitted they are little better than so many dummies; *what they might be*, if only a few hours labour were spent upon each of them, the facts and figures I have here placed on record will explain.

But it may be said that we *are* turning our cast-iron guns into rifled guns. It is so. And I believe the *Palliser* guns to be deserving of the good opinion that has been formed of them; but—

On turning once again to Lord Elcho's valuable return, it will be seen at page 15 of the parliamentary paper that the 64-pounders are converted at a *contract price of* £125 *each;* and this is not too much for the work that has to be done to them, and the machinery and time required. Still it is *twice as much as the guns originally cost.*

The converted guns are stated in the return to weigh 71-cwt., and they fire projectiles of 64-lbs. My 56-cwt. and 58-cwt. guns fired shells of 50-lbs, and those of 95-cwt., shells of about 90-lbs. The power with which they do this is compared at page 23, nothing is gained. But instead of costing £125, and occupying much time and labor, the work involved in the alteration I proposed may be judged of by the following extract from page 4 of the report of the late Ordnance Select Committee on this subject

"The rifling could be applied to smooth bore guns on a

* It is a well-known fact that Iron which is kept for many years after being cast, becomes much improved in quality. Our *oldest* guns are admitted to be the best in the service.

"large scale at a cost of not more than 10*s.* per gun, by "extending the machinery of the Royal Gun Factories. It "is stated by MR. ANDERSON that the system of MR. "BASHLEY BRITTEN would be the least expensive. THEY "WOULD RANGE FROM 7*s.* 6*d.* TO 10*s.* PER GUN."

It may be admitted that the guns are stronger for being lined, but if they are strong enough without it, what is the good of lining them? They never failed when using the destructive powder which even the wrought-iron guns were found to suffer from severely, why should they be distrusted when we can use the new pebble powder for them, and get more out of them with absolutely *half the strain?* It cannot be worth while to have the cast-iron guns converted at a cost of £125 each merely that they may be fired with a somewhat excessive charge of bad and destructive powder such as no other state will use.

If Foreign soldiers are not afraid to use cast-iron rifled guns, why should British artillerymen hesitate, and talk of danger? The prejudices which have been created against them by unfortunate experiments with ill-considered schemes would speedily pass away with experience, and in a very short time the country might become thoroughly armed. But if these prejudices are to be suffered to rule, and wel established facts are to be ignored, when shall we get arms, and what shall we have to pay for them?

I conclude my observations by suggesting a point well worth consideration, which lies at the foundation of the matter under discussion.—

As the power which can be employed in heavy guns is practically limited by the amount of recoil which can be controlled; and as we must therefore have *weight* in the weapons *proportionate to their power;* is there not to be found *sufficient strength in so much weight of good*

CAST-IRON as need be provided, when in future we shall cease to use powder needlessly violent in its action.

Entirely opposed as this idea may be to the generally received opinions of the present day, there are facts which are indisputable tending to give it strength.

In the comprehensive comparison I have instituted in the table at page 58, it will be observed in the last column that *even with our "poudre brutale," weight for weight, we get no more force out of expensive iron than out of the cheaper material;* and there are the remarkable facts which the invaluable experiments of the Woolwich Gunpowder Committee have brought to light, (*vide page* 111) demonstrating that the powder we have always used is twice as destructive as it need be.

If we could employ for guns material of *infinite* strength, *we could use no more power than their weight permits.*

If, by a stroke of magic we could "convert" all our cast iron guns into steel, we could then get no more work out of them than we may now, *because of their weight and their recoil*; only let us abandon the use of *bad* powder, and not fire projectiles which are simply badly-fitting screws, necessitating much extra strength in the gun as a provision against their fastening themselves in the thread they have be driven through at enormous speed. For a screw to work smoothly in a thread which does not match it is a mechanical impossibility.