Recoil Delicately Checked and Utilised

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Ebening Meeting.

Monday, February 1st, 1869.

ADMIRAL SIR HENRY J. CODRINGTON, K.C.B., in the Chair.

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ANNUAL.

Acton, E. W. F., Capt. 1st Roy. Cheshire Mil. 1l.	Innes, J. M. McLeod, U.C., Major Roy. Engrs., Bengal. 1l.
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	Scriven, Horace W., Capt. 25th K. O. Borderers.

RECOIL DELICATELY CHECKED AND UTILISED.

By Lieutenant-General W. N. HUTCHINSON.

Read by Captain ROBERT SCOTT, R.N.

THE increasing power of resistance constantly added to defensive armour gives a proportionately increasing importance to ordnance throwing heavy charges, and bespeaks a careful consideration of any proposed improvement in the principle of checking recoil, for it is well known that the range and efficiency of powerful guns are much diminished from the inability to fire as large charges of powder from them as would be practicable, were it not for the evils arising from the great recoil occasioned by large charges. In August, 1863, the Ordnance Select Committee reported "that wrought iron guns might

"be made lighter than they are, or be used with heavier charges, if "the recoil could be more effectually checked." The present proposition for more efficiently checking recoil is by the use of the most elastic and inexpensive cushion known, viz., the common atmosphere, which can be employed in the most delicate, yet effective manner, and to any amount.

The application is by the use of a closed cylinder, with a piston and rod working in it, having much air on one side of the piston, and very little on the other (see Plate v, figs. 1 and 2).

When recoil takes place, the piston is forced into the part containing the greater body of air, which is thereby compressed, while at the same time the air on the other side of the piston is proportionably rarefied. The increasing resistance of the air thus gradually and quietly receives and absorbs the force of the blow from recoil. This smooth absorption of recoil allows of the employment of a gun much lighter than the ordinary gun, supposing the weight of powder and shot to be the measure of the similarity in both.

To utilise the rebound that would instantly occur from the elasticity of the highly-compressed air, a self-acting catch (or other contrivance) retains the gun (with carriage) in its back position until loaded; then, when the catch is released, the pressure of the compressed air against the piston most usefully assists in running out the gun to firing position.

With very light guns (which are particularly desirable on turntables) when very heavy charges are fired, the air will be more compressed by recoil than is required to return the gun to firing position. This stored-up-force can be smoothly eased off by means of a light hand-rope rove through double-sheaved pullies, or be controlled by means of a friction band, &c. But were all precautions neglected little inconvenience could arise; for the air that had been rarefied at one end of the cylinder, becoming in its turn gradually compressed as the gun resumes its firing position, would act as a soft cushion, and prevent mischief at the termination of the rebound.

Fig. 3.—When a gun is mounted on an ordinary carriage, the cylinder, constructed as shown in Fig. 3, is attached to the carriage below the gun, not far from the trunnions. The piston-rod lies nearly horizontal in a vertical plane with the axis of the bore, the exterior end of the rod being towards the muzzle. This end of the rod plays freely in a ring (or circular staple, or eye) fixed below the sole of the embrasure or port-hole. Thus the free training of the gun is not in the least impeded. When the gun recoils, it carries the cylinder with it, compressing the air in front of the almost stationary piston. All the force of the recoil is thus absorbed without friction, and without causing the least jar or strain to any part of the carriage or platform, for it is obvious that all the horizontal strain is borne by the ring.

For the sake of security this ring might play in the angular part of two strong iron bars joined together in the form of a letter V, running for many feet horizontally through the parapet. To the extremity of these bars would be attached large flat bars or beams, fixed crosswise and vertically in the body of the parapet.

SKETCHES.

Fig. 1.

Fig. 2.

Fig. 5.

Fig. 6.

Fig. 3.

Fig. 4.

Fig. 8.

Fig. 7.

Section through a Mortar Head.

In applying the cylinder, made according to Fig. 1, as a substitute for the weight in Moncrieff's carriages, it would be firmly attached to the after-part of the traversing platform.

A flexible rope (passing over a pulley, fixed vertically, in the front and lower part of the platform), would be attached to the exterior end of the piston-rod, and would connect it with the centre of the horizontal cross-bar which unites the front extremities of the toothed segments constituting the sides of the carriage. The rope intervening between this cross-bar and the end of the piston-rod would be about the length of the rod, which would be the measure of the limit of recoil.

Recoil would cause the trunnion-ends of the segments to roll inwards with the gun, and sink below the crest of the parapet,—the too sudden elevation of the other ends being, soon after starting, gradually more and more resisted by the gradually increasing density given to the air by the rope pulling forward the piston.

The cylinder, if sufficiently increased in diameter (therefore in power), need only be half the described length, were the rope, when fastened to the front of the traversing platform, to be passed through a pulley fixed at the exterior end of the piston-rod before it passed over the other pulley.*

By a little alteration of the disposition of the parts which connect the sides of most gun-carriages, ample space would be found for the proper adjustment of the cylinder.

Marks on the rod would show at all times the exact position of the piston within the cylinder.

C, C, C, C, are air-cocks occasionally turned to allow the entrance or escape of air, and thus regulate to the greatest nicety the resistance to be given by the compressed air, and the length of the stroke of the piston. It is clear that the less the air is admitted into the vacuum-end of the cylinder the greater will be the resistance of the compressed air, and consequently the less will be the length of stroke, and the less the length of recoil. This principle of checking it, gives such absolute control over the gun, that all rapidity of recoil might be prevented *ab initio*. By bringing the piston home to the head of the cylinder there would be practically a perfect vacuum at that end, when the gun's starting to recoil would be resisted by a pressure exceeding 14 lbs. per square inch of every inch of the piston's area, even should the cylinder be only charged with air of natural density.

Were there any advantage in the arrangement (which is doubtful), any greater resistance at starting could be made uniform during the whole of the recoil by means of a safety-valve placed at the end of the cylinder, whose spring would more and more yield to the escape of air as its pressure increased. It must be obvious that were the end quite open, the pressure might always be 14 lbs. to the square inch, both for resisting recoil and for running out the gun.

* When cramped for space, instead of the compressed-air end of the cylinder being closed in the usual manner by having a globulous reservoir attached to the sides near the end, and the lowest part of the sides thus encased pierced with holes communicating with the reservoir, the piston might be driven home the full length of the cylinder.—W.N.H.

It has been suggested that there would be danger of leakage of air were the gun retained for hours in the loading position,—but manufacturers will assure you that with careful workmanship, there need be no apprehension on that score. The motion of the piston is slow. The pressure of the condensed air, unlike that in a steam-cylinder, is always on one and the same side of the piston, therefore the compressed air is constantly forcing the soft, well-greased packing into any crevice that might otherwise exist between the uppermost plate of the piston and the side of the cylinder. Moreover, the collar round the piston-rod being always in the air of greatest density (inside the cylinder, Fig. 1, outside the cylinder, Fig. 2), is always pressed against the piston-rod, which prevents any escape in that part,—but were there even a slight escape, it could readily be replaced by the air-pump.

In the two foregoing instances of recoil being checked, it was resisted by the piston-rod being partly drawn out of the cylinder, but in the case of wall-pieces and all arms fired from the shoulder, the force of recoil could be met by the piston-rods being driven into the cylinders (see Fig. 2).

The stocks of such pieces would be in two parts. To the shoulder-plate a small cylinder made on the principle shown in Fig. 2, is fixed within the stock. The part *A* slides within the part *B*, see Fig. 5. The two parts are usually together, as shown in Fig. 6. Recoil drives *A* (say an inch, or inch and half) close to the shoulder-plate, the force of the blow being received on the piston; then *A* returns, by the force of the rebound, to its usual position. Rifled wall-pieces with steel pointed projectiles were much employed by the Americans in their last war, and from their range, precision, and penetration, are likely to be frequently used in future to resist approaches by sap, &c., especially as the adoption of the cylinder would allow of pieces of increased power being manufactured. Only sap gabions of unheard-of diameter could resist penetration from such pieces.

The decks of iron-clads being their most vulnerable point, many think that mortars will be much used in future. It is clear that any arrangement which would admit of their recoiling, would greatly augment their power by allowing larger charges of powder being employed than can now be used. It is believed that no attempt has as yet been made to attain this desirable end, but endeavours have been made, by supporting the beds of mortars on vulcanized india-rubber, to lessen the injurious strain given to a ship on their being fired. These attempts failed, principally from the constant weight of the mortars destroying the elasticity of the india-rubber.

It is now proposed (see Fig. 7), where a traversing platform may not be required, that the carriage shall be somewhat in the form of a wedge,—that on the mortar being fired, it shall recoil or slide downwards (towards the fixed cylinder *E*, and from the fixed cylinder *D*) on a wooden platform lying at such an inclination that the carriage will not slip down, but remain in the highest position until the mortar is fired,—that, after recoil, the carriage, with mortar, shall be retained by a catch in the lowest position (where the gunners will be sheltered) until it be re-loaded,—and that on being released by freeing the catch,

the force of the compressed air shall aid the gunners in making it re-ascend. Of course the wheels of the carriage will always self-lock during the descent. Few easier plans could be adopted for effecting this lock than the falling weight on a cogged wheel, as employed in a ship's windlass.

Where it would be inconvenient to place cylinders of such a size that air in its natural state would give sufficient resistance, the power of both the cylinders might be increased by their being charged by an air-pump (attached to the air-cock), with air of the requisite density, as indicated by a gauge.

As there would always be ample space for D cylinder, it could be made of whatever size and power* might be required.

It is hoped that Fig. 8 will give a sufficient general idea of the arrangement proposed when it is necessary that the recoiling-mortar should stand on a revolving platform. In a mortar-boat, a circular hole (say 7 feet in diameter) is cut in the upper deck, also in the lower. The inclined beams that support the carriage and mortar rest on a revolving frame standing on wheels, which travel in a circular groove attached to the bottom of the boat. A projection (terminating in a wheel) from the upper part of the revolving frame prevents its lifting or receding when the mortar is fired. That wheel plays in a circular groove fixed underneath the upper deck, near the edge of the hole cut in it. Against the edge of the lower deck (through which the revolving frame passes to the bottom of the boat) is also a racer in which work horizontal wheels to further steady the frame in a sea or during firing. The skids (or rails) on which the carriage glides are curved upwards towards their lower termination, to assist in checking recoil.

In pits on shore, or wherever additional weight would not be disadvantageous, a counterbalancing weight to the mortar might be substituted for the cylinder.

Some naval men think that the adoption of a few mortars in our iron-clads would much add to their efficiency. If the shells projected, were made to rotate rapidly in the plane of their progress, they would gain in precision and penetration. This, it is believed, could be effected on the principle shown in the wooden model of a 32-pounder disc-gun, now in this Institution, and which was fully described in a paper read here on the 4th of February, 1867.†

The shot on starting is tripped, as it were, by a fixed steel catch, which fits into a notch, or small hole cut on the surface of the shot. This causes the shot actually to spin during its flight, and when alighting on level ground to roll rapidly for a long time in the direc-

* Of any power. The undersigned took out a patent, dated 1st February, 1864, for "Improvements in the construction of Cylinders of Hydraulic Machines, applicable also to the construction of ordnance and other articles, or vessels subject to "pressure from within." It explained how in a cylinder composed of many consecutive tubes, each tube could be made to do as much useful duty as the innermost, in resisting a bursting strain, by a calculated pressure given to the mercury (or any fluid) that slightly separated the several tubes.—W.N.H.

† Printed in No. 43 of the R. U. S. I. Journal, vol. xi.

tion of aim. On striking an object, the force of the blow received is the resultant of the horizontal trajectory and of the velocity imparted to the surface of the shot by the spin. None of the force of the powder is expended in overcoming the resistance to the shot's progress in the barrel (therefore to its initial velocity) caused by rifling.

All these cylinders, which are so simple in their application, would be durable and not expensive, while the certainty and uniformity of their action without the risk of wrong manipulation (for they are really self-acting), promises to give them an advantage over every kind of check from friction, however ingeniously applied; and the fact of the recoil, instead of continuing a detriment, being made to aid the efficiency of the gun by the condensed air serving to run it out after it is loaded, thereby rendering but few gunners necessary, argues strongly in favour of substituting cylinders for compressors on board ship.

It is thought that the employment of them to check the recoil of heavy guns, besides adding to their efficiency in permitting large charges to be used, would, from the entire transference of the usual strain on pivots, racers, and carriages, to the immovable parapet or ship's side, effect a considerable saving in the construction of all that pertains to platforms, as well as a general saving in wear and tear from the absence of all jar and friction. It is further thought that it would effect a saving in the manufacture and alteration of ordnance, for it would diminish the amount of metal hitherto considered necessary to be given to each piece in order to assist in resisting recoil.

A convenient length being agreed upon for the recoil of the gun, what diameter should be given to the piston starting from a state of rest in air of a known density, could be computed in the following manner:—

Let—

a = area of cylinder in square inches.

p = pressure per square inch on piston at commencement of stroke.

s = length of cylinder in feet. Much determined by the pressure it can innocuously sustain.*

l = length of stroke of piston in feet. The length the gun recoils.

Then,

$\frac{s}{s-l} a p$ = pressure on piston at termination of first length of stroke, and therefore the greatest pressure.

$\therefore a p \sqrt{\frac{s}{s-l}} l$ = mean pressure during stroke.

$\therefore a p \sqrt{\frac{s}{s-l}} l$ = total units of work done in first length of stroke in bringing the gun to a stand-still.

* That pressure per square inch on cylinder will equal $2p$ if $l = \frac{s}{2}$

“ “ “ “ “ $3p$ if $l = \frac{s}{3}$

“ “ “ “ “ $4p$ if $l = \frac{s}{4}$

and so on.

Again, weight of gun with its carriage, and of the shot and its initial velocity being known,

If W = weight of gun and carriage in lbs.

w = weight of shot in lbs.

V = initial velocity of recoil.

v = initial velocity of shot.

Then by the Artillery rule,

$$\frac{V}{v} = \frac{w}{W} \therefore V = \frac{w}{W} v.$$

$\therefore$ The total number of units of work accumulated in gun and carriage during recoil = $\frac{W}{2g} \left(\frac{w}{W} v \right)^2 = \frac{w^2 v^2}{2gW}$

But this accumulated work is overcome by the work done by the cylinder in bringing the gun to rest.

$$\therefore a p \sqrt{\frac{s}{s-l}} l = \frac{w^2 v^2}{2gW}$$

$$\therefore a = \frac{w^2 v^2}{2gW} \times \frac{1}{p l} \sqrt{\frac{s-l}{s}}.$$

From this equation the area of the piston becomes known, hence its diameter.

The CHAIRMAN: If any gentleman has any remarks to offer we shall be glad to hear them. It is a very interesting subject, new to most of us, I daresay; as for myself there are one or two points that I should like to ask a question about, if Captain Scott is in a position to clear them up. First of all, when the mortar (Fig. 8) has recoiled to the position in which we see it, I do not see how it is to be loaded. Next, there seems to me to be a weak point in connection with the wear and tear of the rope round the pivots. The next is a point that I should think would be only determined by actual trial, viz., that in the case of the compression of the air, heat would be eliminated on one side, the compressed air, and cold on the other side, the rarefied air. These are points I think that can only be settled by actual trial. We know that the compression of air, very strongly and very suddenly effected, would liberate a great deal of caloric on one side. The other point that struck me at the time it was mentioned, is the escape of air round the piston. I fancy that would require trial to prove whether it would be so or not. Those appear to me to be the weak points in that system. If any gentleman, who has thought on the subject, would be kind enough to give us his opinions, we should be happy to hear them.

Captain BECKLE, R.N.: May I ask what there is to prevent the head of the cylinder coming out by the effect of the recoil? How is that controlled?

Captain MONCRIEFF: I should like to ask whether the recoil would be in the direction of the piston, or if it would be lateral?

Captain SCOTT: As to heat and cold, or changes of temperature, I do not think that practically they would be found to exercise any material effect; I do not think they would be found to be difficulties. The wearing of the rope is a very great difficulty, there can be no doubt of it; there is always a tendency to break at a nip. However, a rope may be made of almost any strength, and with the turret wheels, tackles and chains have been found to resist recoil; you have only to make them large enough and heavy enough, and then you can get them to stand; it is mainly a question of weight. A wire rope would have stood but for the nip

over the roller, which is certainly awkward. Therefore, you could only use a chain, and a chain of a particular character, viz., a pitch chain coiling over a drum, and I have no doubt that in that way you would get over the difficulty. As to loading, I take this to be rather a fancy sketch than the position in which a mortar would ever be placed. Of course it would not turn up in that way, for it would come down gradually in this line, and then you could load; but in the other case unless you had a platform across you could not load. As to the head of the cylinder going, on the piston being pulled forward, the air acts as a cushion, compressed in the way it is shown, and the air being a cushion would never allow the piston to come close against the head of the cylinder, and strike it, there would always be an amount of compressed air which would act as a cushion to prevent any damage to the head of the cylinder. I do not think there would be any practical difficulty. With regard to another question, the recoil would be in the direction of the piston, which, in this case, would correspond exactly with the water-buffer piston.

Captain MONCRIEFF: Would that be the case with the mortar?

Captain SCOTT: Yes, certainly it would, because if it were laid in the way shown, it would keep as indicated, you could not alter the line, it must really move in it. You have only to get the axis of the cylinder parallel with the line in which the piston is moving; there would be no practical difficulty in that, and then the packing would keep it steady. I confess it is a subject in which we have not many experiments to guide us, and the limits between success and failure are extremely narrow. I do not think the plan should be set aside without very careful experiment. I am sorry that General Hutchinson is not here, because he has gone thoroughly into the matter, and could explain it far better than I can. But granting that it succeeded, it would have a very great advantage over water, which is now being tried. Water, as we all know, is incompressible, and when water is set in motion by the recoil, the great check is at the first instant, and it becomes gradually less. Now, that is a wrong principle; you want the gun to recoil at first as easily as you can, and then to be brought up more and more gradually. If the air would do that, you would have a perfect compressor; therefore, if it can be successfully worked out, it be good plan.

Captain MONCRIEFF: I should not have made any remarks, only General Hutchinson has employed as an illustration a form of carriage which I have introduced, and I think I ought to say a few words about his very interesting programme. The question of absorption of recoil and of utilising the recoil of guns is a problem which has attracted the minds of several mechanical men lately; it is one which possesses very great fascination. There is no doubt whatever that the idea of using an elastic medium so perfect as air to absorb, that recoil, is a very pretty one. I may state to this meeting that four years ago I myself made designs for applying it to the carriage which bears my name. From the drawings, which of course are mere sketches, I am afraid General Hutchinson has not arrived at that stage in the process in which the real difficulties are discovered. The mere idea of applying air is a good one, but there are difficulties lying between the idea and the application of it. I noticed in the remarks which Captain Scott made that he took credit not only for the advantages of the compressed air upon one side, but for the advantages on the other side, which would have been derived from the weight of the atmosphere. Of course, if you use the one, you cannot use the other to the same extent as when the vacuum exists. I would prefer not to criticise the use of ropes passing over pulleys, and the other arrangements which I see depicted there; they evidently represent the investigation at an early stage. I think the subject is one in which there is a great deal to be done, and I hope myself to be able to describe at this Institution, some other methods of applying the same power. With regard to the mortar, it occurs to me that an elastic medium of a more solid character would be better suited for the purpose, and would make the traversing arrangements less unwieldy than those which are there depicted.

Captain SCOTT: If you would allow me to add one more remark, I would say that General Hutchinson only intended to put forward designs, not finished models; he has merely shown the way in which his system can be applied. And after all, if it

can be applied in these ways, you have really the back-bone of the system. Although there are great difficulties to be met, as we all know well there are with every invention, because the limit between success and failure is so exceedingly narrow, still I think they may be fairly taken as well worth very full consideration. With respect to the traversing arrangement, General Hutchinson, I suppose, merely put that in, not thinking that he would be treading upon any person's toes. I think there is nothing more than that in it, for many arrangements can be made to traverse the gun without a rack and pinion, which is perhaps the simplest plan. I think, however, that the discussion of this subject should be directed rather as to whether air cannot be usefully employed, than to any particular details, and this seems to be the object that General Hutchinson has in view.

Major-General BOILEAU, F.R.S.: I should wish to say a word before the subject closes, merely to give a general opinion upon the project, because it is simply a project at present. The question of utilising recoil has for some time occupied the attention of the authorities, and that some method of this kind is desirable, it occurs to me, is proved by the fact of the water-buffer, or the application of water for the same purpose as this, which is now being experimented upon at Shoeburyness. Captain Scott has very clearly pointed out that the great objection to water is, that it checks the recoil too suddenly at first, and that the action of water then becomes gradually diminished, until at the time when it is most wanted it ceases to act altogether. I think the introduction of air in a perfectly air-tight cylinder, such as I suppose these are to be, and which is not a matter of difficulty in practice, is, as a first idea, worthy of all consideration by the authorities. If water has been applied successfully to check the recoil of guns, it is my opinion that air may be applied more successfully to the same purpose, because it better fulfils the conditions which are required than water does. Without entering into the detail of the principles, and of the proportions necessary for that air cylinder to meet the recoil of large guns, I think the design is one which exhibits great ingenuity, and which, if it can be successfully applied, will be likely to produce great and useful practical results. And should such results occur, it will only be one more added to the many instances of useful national inventions, tending to place our country in its present advanced position in regard to artillery, which have been brought forward in this Institution.

The CHAIRMAN: I am sure we all feel very much obliged to General Hutchinson, whose unavoidable absence we regret, for having given us this paper. I must concur in the remarks that General Boileau has made, indeed in all the remarks that have fallen from gentlemen; they give a good summary of the subject. It is but fair to say of this man, that though I and others might criticise the ropes and other details, we should remember that the illustrations are simply sketches and nothing more, intended to convey an idea, which idea would be worked out practically to a good and sound conclusion as soon as we know the forces we have to deal with better than we do now. For instance, I would not take that rough sketch as a representation of what the invention is likely to come to hereafter, any more than I would take that sketch of a human figure as a representative and model of the beauty of a sailor. Still it serves to convey to our eyes the idea of a sailor. So this sketch gives us an idea of what the invention may be hereafter. The idea is the thing we have to deal with now, the practical working out is to be done by-and-by. There are difficulties no doubt to be encountered, but I believe those difficulties will be got over by the talent of mechanicians in this country. We are very much obliged to General Hutchinson for his paper, and we are equally obliged to Captain Scott for the way in which he has read it. I have now the pleasure to introduce to you Mr. Stone, of the 77th Regiment, who will exhibit models illustrative of his new gun platform.