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WORKING HEAVY GUNS BY MANUAL, HYDRAULIC, AND STEAM MACHINERY.[1]

By H. J. Butter, Esq., Royal Arsenal, Woolwich.

The vast increase in the weight of ordnance has necessitated a gradual introduction of mechanical appliances in working them: fifteen years ago, common tackle and levers were the only aids to manual labour; now, the gun carriage is a machine requiring the exercise of the highest skill in its design and manufacture, and of intelligence in its use; and whilst the severest bodily labour was then imposed on the gunners, ordnance of eight times the weight are now worked with less physical exertion and with greater precision of movement.

These improvements have engaged the attention of many persons, and the successful results are so numerous, that, obviously, it would be impossible for me to attempt, in one lecture, any description of them all. I propose, therefore, to mainly confine myself to a portion of what has been done in the Royal Carriage Department, and I am led to hope this course will not be unsatisfactory to you, inasmuch as, being members of either the naval or military professions, you will naturally take a lively interest in what, so to speak, emanates from the Service itself; for these improvements are the work of the engineer, guided and influenced by the immediate control of Officers experienced in gunnery, and fully conscious of the peculiar conditions attending the use of machinery in actual warfare; whilst those inventions of the engineer acting outside these influences and military experiences, tend naturally to be of a type more suited to the ordinary workshop than to the fort or vessel of war.

Working heavy guns of from six to twelve tons weight, on the broadside of ships, was the first occasion that initiated the introduction of a higher order of mechanism in gunnery, and was due to the genius of Captain Scott, R.N.

[1] A lecture delivered at the Institution on 1st of March, 1878, Major-General Sir John Adye, K.C.B., R.A., in the chair.

Curved toothed racks were laid on the decks of ships, and by means of a training pinion secured to the slide, and actuated by a train of wheels and winch handles, the gun was laid quickly and accurately by two men; endless chains, formed of flat links riveted together, were placed on suitable wheels inside the slide, which by being attached by nipping gear to the carriage, and worked by spur gearing in the slide, enabled the gun to be run in or out, and thus the two most laborious operations, hitherto calling into play clumsy tackles and large numbers of men, and being after all uncertain and jerky, were placed under the entire control of four men at most.

Owing to the necessarily confined spaces available in ships and forts in which these heavy guns had to be worked, it became, from the first, evident that no corresponding increase in the length of recoil could be permitted; in fact, from the greater length of the guns, the platforms and slides had to be shorter than those hitherto in use with light guns. It was, therefore, essential that some greatly superior form of compressor should be used, and that it should be self-acting, if possible, in order to avoid the risk of the gun, after discharge, going back to the rear with such violence as to produce a break-down, and temporarily, at least, putting it out of action. Captain Scott proposed a modification of Erickson's American compressor, consisting of a large number of sliding surfaces, held in contact by a comparatively light pressure, set up by a lever, or hand wheel, and screw. This proved to be greatly superior to anything else which was tried, and he afterwards modified it into what is now known as the bow compressor, in which the pressure is set up by the weight of the gun when it is thrown off the rollers of the carriage. A more efficient invention, however, for this purpose, was that of the hydraulic buffer now so well known, not only by its general adoption into the British Service, but also, with various modifications, by every other leading nation. Its great merits are its being absolutely self-acting, the unvarying character of its resistance when opposed to the same force, and its extreme simplicity. As considerable misapprehension regarding the nature of its action still exists in the minds of many, I may be permitted a few moments to describe it somewhat in detail.

A section of the buffer is shown in the diagram (Plate I, Fig. 1). It consists of a wrought iron cylinder corresponding in length to that of the full recoil. A piston, having four small holes, works from end to end, by means of a piston-rod, having its outer end attached to the carriage, whilst the cylinder itself is firmly fixed to the platform; in the firing position the piston is drawn to the front end, and during recoil it is forced through a fluid which partially fills the cylinder, to the rear end; during its progress all the fluid must pass through the four small holes, and it is this which gives rise to its resistance to recoil, a resistance proportionate to the velocity of recoil, and to the ratio existing between the area of the piston and that of the holes.

In the 38-ton gun carriage, the ratio of the area of the piston to that of the holes is 40 to 1; therefore the velocity with which the fluid passes through the holes is 40 times greater than that with which the piston moves at any given point; but owing to the contraction of area assumed by any fluid passing rapidly through small orifices, much less really passes than that strictly due to the area of the holes, and from this cause the actual velocity is about 60 times greater. Now the velocity of the gun immediately after recoil begins, is about 10 feet per second, hence the velocity of flow through the holes is at this point $60 \times 10 = 600$.

There is a constant relation between pressure and velocity of fluid, and by the use of a well known formula we can find out what pressure on the piston must exist to produce this velocity; it is about 47 tons, but this enormous pressure acts only at the first moment, for the gun rapidly loses its velocity, and as the resistance varies as the square of the velocity, it is manifest that the resistance rapidly diminishes until, towards the end, it practically ceases altogether.

By a simple modification of the buffer, it was proposed, on its first introduction, to do away with this falling off of the resistance towards the end of the recoil, and to make it either uniform, or greater, at the end, by diminishing the area of the holes as the gun recoiled. This was effected as shown in the diagram (Plate I, Fig. 2), by having large holes, and placing through them conical rods the full length of the cylinder, with the large ends at the rear; thus, as the gun recoiled the apertures were reduced in any required proportion. This form was tried, but the original and simpler form answered better, the recoil being much steadier, and resulting in no upward jump of the front of the platform.

The steadiness, or unsteadiness, results from the action of two forces; when the gun recoils, it sets up an enormous pressure at the buffer, which tends to turn the platform over on its rear rollers; the weight of the gun, acting with a lever due to its distance from the rear rollers, opposes this tendency. Reduction of the resistance, and consequently pressure on the buffer, in proportion as the gun acts with less leverage, is obviously therefore the proper method of keeping the platform steady, and of bringing the gun gradually to rest in place of doing so with a sudden jerk. The simple buffer accomplishes this perfectly; and the use of conical rods, spring valves, or any other contrivances for maintaining the resistance are not only unnecessary complications, but are positively detrimental. This was further illustrated by time-curves taken with each kind of buffer, from which it was proved that the time occupied in recoiling six feet was twice as long when the simple buffer was used, as was the case with the other —all other conditions being the same. While on the subject of the hydraulic buffer, I should like to draw your attention to two special features proposed in 1867 in connection with its use in the Navy, but which, owing to the delay attending its general adoption into that branch of the Service (now I am glad to say at an end), were not introduced.

The one (Plate I, Fig. 2) was the use of a solid piston having no holes, and a side pipe communicating with the front and rear ends of the cylinder, with a valve worked by a lever capable of being set so as to secure any required aperture; the recoil of the gun forced the fluid through the side pipe and the valve, the opening in the latter performing the same office as the holes in the piston; while by working the valve lever the running up of the gun was perfectly controlled.

The other feature was the introduction of a hydraulic pump and cylinder for the purpose of running the gun in or out; thus, in 1867, the Royal Carriage Department initiated the use of hydraulic appliances in gunnery, which, in 1874, expanded into a complete system, under the same direction, in connection with the 35-ton platform. During the interval between these two dates considerable experience in the application of hydraulic machines to gunnery was gained, owing to their introduction for various purposes in naval gun carriages.

Lest I should appear to claim undue credit for the department with which I have been associated for 22 years, I should mention that many of these machines are due to the suggestion of Captain Scott, and their success in a large measure was secured by the able assistance of Mr. Stephen Holman, one of the partners in the celebrated firm of Tangye Brothers and Holman.

The first of these machines was introduced two years after the hydraulic buffer. It consisted of a ram and pumps, and was used for raising and lowering guns in turret carriages to enable the guns to fire out of reduced ports.

In 1870 a different plan for the same purpose was devised at the request of Captain Coles for H.M.S. "Captain;" in that unfortunate ship, which mounted four 25-ton guns, the small port principle was met by placing the rams under the platform, and thus raising the platform carriage and gun—in place of the gun alone as in the former case—to secure the various degrees of elevation.

In the same year (1870) small turn-tables were introduced, upon which, by traversing the rear rollers of the slides on them, and raising the front ends clear of the deck, the guns might be turned from one port to another. To raise the front end of the slide and thus throw the whole weight upon the turn-table, a hydraulic lift was devised; it was secured permanently to the under side of the slide, and, by thrusting downward its ram into a bearing on the turn-table, raised the front end as desired.

Another useful hydraulic appliance, introduced about the same time as the former one, was that of the rear-roller jack. This was for performing an operation in the working of guns of great ingenuity, and, comparatively speaking, of considerable antiquity. It is one of those things which proves that the carriage builders of old knew what they were about. They did not create difficulties in order to overcome them, but chose rather to adopt the simplest means to meet what could not be avoided, and if possible turn it to some useful purpose. When a gun is fired it is forced in an opposite direction to that of the shot, and with an equal force. To hold the gun perfectly still would be to create an enormous difficulty, to allow it to recoil unrestrained on live rollers down a decline would be equally bad, although of the opposite kind. Our old carriage builders did neither, they sought to restrain its recoil within reasonable limits, and provided, by the nature of their precautions, an easy method of getting the gun back into the firing position. They checked the recoil by making the gun ascend an incline, and created frictional resistance by making the weight of the gun act upon the sliding surfaces of the carriage and platform; thus, without the use of compressors, the gun was brought safely to rest in a position suitable for being loaded; they then used the carriage as a lever, and, by raising it on rollers at the rear end, brought into play rollers in the front, which latter sustained more immediately the weight of the gun, which then by gravitation descended into the firing position. We have now, owing to the greater force of recoil and shorter platforms, to adopt means of providing additional resistance in the form of the hydraulic buffer, but this is no reason why we should discard the simple principles of the old gun carriage. For instance, if we keep the carriage always on rollers we lose the frictional resistance afforded by the weight of the gun, and we must make our compressors so much the more powerful. If we fire on a level platform, or on one having a downward slope, we lose the resistance of gravity, or make it positively promote the recoil, while we have to provide gear for forcing the gun into the firing position, and thus create complication unnecessarily, and invite the dangers of a break-down.

All these hydraulic appliances of which I have spoken are of a simple character, portable for the most part, and easily replaced by spare ones, if disabled. The lift for turret carriages, however, having its ram and pumps separated, necessitated the employment of pipes which were liable to damage, and, besides, interfered with their easy removal, therefore, in preparing the small-port carriages of the 18-ton guns for Breakwater Fort, the ram and pumps are combined in one simple portable machine.

After the successful introduction of these various machines, it became a question whether it would not be desirable to extend the use of hydraulic power to training and running the gun in; accordingly, a design was proposed in connection with the 35-ton casemate carriage and platform, which was carried out and successfully tested in 1874. As the first example of the general application of hydraulic power to gunnery, I think it merits a somewhat detailed description.

The hydraulic buffer is modified in its form in order to adapt it to the purpose of running the gun in; a solid piston (Plate I, fig. 3) is used with hydraulic leathers to keep it tight, and on recoil the fluid is forced through an orifice into a tank provided for its reception in the rear of the platform; the orifice is of conical shape, and is enlarged or reduced to offer more or less resistance by means of a conical valve; (Plate I, Fig. 4); a pipe leading from the hand pump communicates with the front end of the compressor cylinder (Plate I, Fig. 6), and conveys water under pressure for running the gun in when required; another water cylinder is placed alongside the hydraulic buffer, and is used for traversing; pipes connect both ends of it with the hand-pump before mentioned, thus allowing of the piston-rod being forced inwards or outwards, according to whether the gun is to be traversed right or left; the motion of the piston-rod is augmented, and conveyed to the rollers of the platform by a chain and pulleys in much the same manner as hydraulic power is utilized in cranes.

Only one pump, and that a small and portable one of simple construction, is used for all these operations, the stream from it being directed by means of a slide valve (Plate I, Fig. 5) into whichever pipe will convey it to perform the required action; this slide valve is worked by a lever, and a dial plate points out the different stations to which it should be moved to "Traverse right," "Traverse "left," or "Run in;" thus, several men (in case of need one man is sufficient) working the pump, and one the lever of the slide valve, perform with ease these laborious operations.

This arrangement was tested at Shoeburyness in the presence of the Duke of Cambridge and other distinguished Officers, in competition with lighter guns worked by spur-gearing; it beat them considerably in time and accuracy, and after more than three years of comparative neglect, it was, when tried a few days since, in good working order.

The complete design embraced the substitution of steam for manual power, the hand pump being retained as an auxiliary in case of steam failing; but a curious accident which befel it in one of the preliminary trials, induced the Heavy Gun Committee to put on one side for the time the consideration of the advisability of adopting, and of wholly depending upon, hydraulic gear on so extensive a scale. The accident was the bursting of one end of the hydraulic buffer and running-in cylinder, and was due to a misuse of the levers.

I have, thus far, alluded only in very general terms to the various kinds of gear used. I must now direct your attention more in detail to the manual, steam, and hydraulic gear devised in the Royal Carriage Department for working the 38-ton gun in casemates. I have adopted this course to suit the time at my disposal, and also because the details of other plans have led up gradually to those of which I shall now speak, and which are for the most part embodied in them.

The first thing was to establish a good and efficient hand-gear, which, having been designed and prepared, was very thoroughly tested. On one occasion, 100 rounds were fired in two days, the gear being worked in a casemate erected at Shoeburyness, and representing one of the worst types as to available space. The whole of the operations were done by manual labour, including loading; two detachments of gunners were told off, one being thoroughly experienced, and the other casually selected from men under instruction; the time occupied by each per round was about the same (two minutes); each one worked twenty minutes continuously, and made excellent shooting. This famous trial was witnessed by a large assemblage of Members of Parliament and Naval and Military Officers, and was completed without a single hitch of any kind, except the break-down of a portable hydraulic jack (the only piece of hydraulic gear used), which, however, was readily replaced by a spare one.

The carriage is of the "low type," introduced into the Navy by Captain Scott; the platform is comparatively short, owing to the confined area of the work, and admits of only six feet recoil (Plate I, Fig. 7); an ordinary hydraulic buffer is used, and fully controls the recoils within this limit; the carriage rests upon the platform with its rollers out of action in the firing position, and on the discharge of the gun ascends a slope of 4°; a portable hydraulic jack attached to the rear-end is used to place the carriage rollers in action, which admits of the gun, after being loaded, running up of itself.

The traversing is effected by means of a toothed rack secured to the floor, into which is geared a strong pinion working in the platform, so that, as the pinion is moved, it forces the platform right or left.

The running-in of the gun is accomplished by means of two endless chains placed along the inside of the platform upon suitable wheels; nipping blocks are fixed to the bottom of the carriage, and, by means of a lever, may be made to secure the carriage to the chains; motion is imparted to the chains by forcing round the toothed wheels upon which they are suspended, and thus the gun may be run in or out. Before firing, the lever working the nipping blocks is released, and the blocks fall clear of the chains by the action of a counterweight provided for the purpose.

Considerable power is required to impart motion to the training pinion, as also to the endless chains, and a combination of toothed wheels and pinions in the nature of a crab is provided for the purpose, the whole being worked by two winch handles placed opposite to eacl other on the rear end of the platform. This series of power-gainin wheels is intended either to traverse or run the gun in, according to whether it acts upon the training pinion or upon the endless chains.

The means for associating the power thus provided for running in or traversing consists in placing on one of the shafts two wheels running loose (Plate I, Fig. 8), that is, not keyed, as the other wheels are, to their respective shafts, but free to stand still while the shaft is revolving; between these two wheels is placed a collar or clutch, consisting of a frustrum of a cone at either end; this clutch is connected with a lever capable of moving it into a corresponding recess in the wheel right or left of it, and it is keyed to the shaft in such a way that, while free to move laterally, it is forced to revolve with the shaft in whatever direction it is turned by the winch handles. Now, suppose men working these winch handles, and setting in motion the train of wheels leading up to this clutch, if it be midway between the two wheels, motion will end in the clutch itself; but if this clutch be forced into the recess of either of the wheels, then, by the friction set up, it will carry round the one with which it is in contact; one of the two is geared with the training pinion, and the other with the chain wheels, and thus, you perceive, this double-friction clutch provides the means of carrying the power accumulated in what I have termed the crab, to either the running-in or traversing operations. While standing midway, both operations cease, even though the crab be kept going.

I have considered this clutch movement in detail, because it has a special feature of great importance when we come to consider the steam-gear. It is this, that by adjusting the taper of the cone clutch, we can make it just sufficiently powerful to set up the requisite friction to overcome the resistance to the legitimate operations, but not so great but what it will revolve in either wheel should the operation be carried too far and meet with unusual resistance; the parts of the gear when running rapidly by steam power are thus saved from fracture.

The whole of the gear is boxed up, so to speak, under the gun, and within the sides and ends of the platform; it is thus protected from any injury short of that which would most probably destroy the efficiency of the gun or platform; it is of simple character, easily understood, and, if damaged, the damage would be readily detected.

As to its efficiency, I may refer to the speed with which 100 rounds were fired; and with regard to its durability and strength, I may state that one set alone has stood the test of over 200 rounds, many of which were experimental, with charges of 180 lbs.—130 lbs. being the service charge when it was prepared—and although the shock with the experimental charge was very severe, owing to the necessarily short recoil causing the front of the platform to be raised several inches, and letting it fall on the steel rails or racers, with immense force, yet not the slightest damage has occurred to any part of it.

I think, therefore, the Heavy Gun Committee may be congratulated on having secured a thoroughly efficient hand gear, of which large numbers have been made, and the next question was to adapt steam power to it, so as to save the labour of working it, and obtain increased speed with less exposure of the gunners.

Although there is much to be hoped for in the employment of steam power, there are some disadvantages to be considered; for while steam affords an enormous concentration of power in a limited space, and is easily manipulated by a few men, yet it involves the use of engines and boilers which are undoubtedly less reliable than the human machine. In whatever way, therefore, its employment might be considered, the contingency of having to resort to a well-tried hand gear, must form a part of the question.

Where steam power can be used under certain favourable conditions, no need exists to anticipate any necessity for resorting to man power. In a factory such favourable conditions exist, thus a pause in the work, owing to a break-down, is not of vital consequence, and is mostly of only short duration, owing to the immediate attention of skilled labour, and the ample supply of means and material; nor is a break-down likely to occur often, as the sole business of all employed is to study the action of the mechanism. The genius, so to speak, of the steam-engine and steam machinery dominates every mind, creates the prevailing thought, and animates every action.

In a fort or a vessel of war, however, all this is changed; a break-down in the gun-gear might turn a victory into a defeat, for its remedy would most likely be indefinitely prolonged, owing to the absence of ample means and sufficient skilled labour, as also to the pressure of great excitement, and the total absence of that prevailing tone of thought, so favourable to the speedy remedy being available in the ordinary workshop.

In short, there are at least two causes operating most powerfully to induce and aggravate accidents to steam machinery when employed for gunnery purposes in forts and ships—namely, excitement and an object other than the mere care of machinery. The records of the trial trips of ships furnish a sad list of accidents, almost wholly due to the effects of excitement alone: it remains for the future to disclose how many of far graver consequence to the nation may arise from both these causes acting in combination with others of less value, if we fail to appreciate the important fact that forts and war ships are not ordinary factories.

Having then secured a good and reliable hand-gear, obviously the wise course was to retain it and to adapt the application of steam, or of steam and hydraulic power combined, to it, in such a way that it should be always in operation whichever power was employed, thus keeping its features always before the gunner, and ensuring that when steam failed, the hand-gear itself should be in good order and available for immediate use.

To have considered first the best nature of steam-gear, and then alter all the usual gunnery operations to suit it, no matter how complicated these operations became, nor how unsuitable for hand-gear, would, of course, be the easier task for the engineer. With ample steam power it does not matter whether we load, for instance, by taking the gun to the shot or the shot to the gun—whether we bring the gun into its firing position by the simple action of gravity, or by the pressure of many tons: if we add to this a disregard of the exposure of our appliances, the task is still simpler for the engineer, but the consequences to the successful operations in actual warfare are most serious; hence, the condition laid down by the Heavy Gun Committee relative to the provision of an efficient hand-gear, is conspicuously wise and soldierlike. No matter what difficulties are created for the engineer, it is his business to overcome them, and to subordinate his plans to the necessary conditions of the service, not to force the conditions to suit his inventions.

It was determined then to retain all the hand-gear which has been so well tried, and to apply steam power to it in such a way that either steam or manual power might be used, according to choice or necessity, by merely turning on the one or the other by the motion of a lever M (Plate II, Fig. 4), and I will now proceed to explain how this has been accomplished.

In the case of the hand-gear, men apply their power to winch handles, which is transmitted through power-gaining wheels and pinions, to the points where the required work is to be done. In that of steam power, the winch handles are removed as being no longer necessary, but the steam power is applied to the same wheel C (Plate II, Fig. 4) upon which the winch handles acted—so that either begins to operate at the same point, and the drill at the gun and platform is identical for both.

There is a considerable choice of means by which steam power can be transmitted to this point, such as compressed air, water, revolving drums with wire ropes running over them, and common shafting—all being good media for the transmission of power from the steam-engine, if well considered in relation to the special circumstances under which they are to be used.

Compressed air is well suited for conveying power considerable distances into mines to do work, or for rock boring in tunnelling, where its liberation, after producing its useful effect, is a positive good in assisting ventilation, not an evil as would be the case with water; but it is a wasteful and troublesome conveyer of power, and being besides of such a nature as to burst vessels containing it explosively, it is unsuitable for gunnery purposes.

Water I shall speak of hereafter, but I may mention here a common fallacy, often expressed, that water is a power in the same sense that steam is a power, and thus we hear of steam *versus* water power. Now, water cannot originate power as steam does, it can only convey it just as a common shaft does, or augment it at the expense of time, as is the case with a screw or a lever. In all applications of water to perform work, it is utterly dependent upon either steam or manual power, and can, in no case, give out a greater amount of work than it originally receives from either of these sources.

Drums working by long stretches of wire rope is a rude contrivance for conveying power to great distances, and would be well adapted for taking steam power from portable engines into trenches in siege operations.

The transmission of steam power by shafting is, however, the one most generally used. It is cheap, simple, and readily understood, and it is not liable to derangement with common care. For these reasons it has been adopted in the first instance, in connection with working the 38-ton gun by steam, although, for special reasons, it is intended also to try water for this purpose.

The power generated in the steam-engine is located in the fly-wheel, and this, being connected by toothed wheels, or by bands to a series of straight iron shafts, laid in passages underground, turns them with a force proportionate to the power generated.

In this diagram (Plate I, Fig. 9) you will see an arrangement of such shafts disposed in the rear of several guns mounted in a circular fort. All these revolve by the power of the engine, and, to enable them to work the gun, means have to be provided for connecting their motion to the gear in the platform. The simplest manner of effecting this would be to carry it on by other shafts to some point in the platform which remains stationary over some other point in the floor, namely, the pivot around which the gun is traversed. This would be easy in the case of a central pivot, but is not so where the pivot is situated in the armour plate, as is the case with broadside slides and casemate platforms; and it is this condition we have to meet. Some convenient point in the floor is selected where the fixed shafting must end, and some special means be devised of connecting this point with the platform which moves to and fro above it.

In the diagram (Plate II, Fig. 1) you will perceive this point is at A, and the platform passes, on being traversed, several feet to the right and left of it. To carry the motion of the steam-engine, which ends at A, into the platform, must therefore be accomplished by means of a shaft, one end of which is in contact with A, while the other end follows the platform; but the end which is free to move describes an arc of a circle of which A is the centre, while any point in the platform describes one of which B is the centre. These arcs recede from each other, and can be made to coincide only on the centre line, unless some compensating movement be devised, by means of which the shaft can lengthen itself, so as to keep its moving end on the arc described by the platform.

This movement is met by making the shaft in two pieces (Plate II, Fig. 2), and sliding one within the other in the same manner as the tubes of a telescope. One has a long feather which fits into a recess in the other, so that as one is forced to revolve by its connection with A, it imparts this motion to the other, whether it is closed up, as it would be on the centre line, or lengthened out, as it is when the gun is traversed right or left.

In this way the power of the steam-engine is taken to a toothed wheel in the platform, and from it to the same wheel *C* upon which the winch handles act when working by manual power. The diagram and model illustrate sufficiently, without further description being needed, the combination of toothed wheels on the ends of the telescopic shaft which are concerned in carrying on the motion from the main shafting. A plate is used having pieces removable to allow access to the bearings, to cover over the triangular space required for the radial movement of the shaft, a groove being cut to accommodate the traverse of the piece of vertical shaft L (Plate II, Fig. 2) which takes up the motion into the platform.

The engine revolves always in one direction, and the first series of shafts does the same, but obviously the power must be provided of controlling the direction of motion, or of stopping altogether the shafting leading to each gun. This is done as shown in the diagram (Plate II, Fig. 3). The shaft in the rear of each gun has a pair of bevel wheels with a friction cone clutch, such as I have already described, between them another wheel fixed to the end of the shaft leading to the gun and ending at A (Plate II, Figs. 1 and 2) is geared with these two; the clutch keeps on revolving in one direction all the time the engine is going, but the wheels remain stationary unless the clutch is forced into one or other of them; if forced into one, it gives motion to the shaft leading to the gun; if forced into the other, it does the same, but imparts motion in a contrary direction. A lever, D (Plate II, Fig. 4), connected with this clutch, gives the man working it power to traverse the gun right or left, to run the gun in or out, and to load or withdraw the rammer according to the signal or word of command given him, precisely the same in effect as when manual power is used the men turn the winch handles in one direction or the other, thus keeping the drill perfectly intact, as the operations at the platform itself are precisely the same whether steam or manual power be used, the heavy labour alone being saved in the former case with fewer men and greater speed.

Of all the operations connected with the service of the gun, by far the most difficult is that of loading, owing to the smallness of the space between the muzzle and the shield, which also causes considerable exposure of the gunners. For a long time, therefore, it has engaged the attention of many minds. So long ago, indeed, as 1862, Mr. Stevens, an American, brought out his steam and hydraulic rammer (Plate II, Fig. 5). It consisted simply of a cylinder and piston placed at an inclination below the deck of a vessel. The gun was depressed to bring its axis in a line with the rammer; the charge and shot were raised by a hydraulic lift to a hole opposite the muzzle, and were then driven home simultaneously by the steam rammer. An ingenious water-squirt was combined with the sponge, by means of which a quantity of water was injected into the bore.

This rammer was originally designed in connection with a fixed gun carriage, placed in a vessel, which gave direction to the gun by being steered. The ship, in fact, was the gun-carriage, an arrangement which eminently suited the rammer, but was scarcely so advantageous to working the ship. It was also claimed to be capable of use in turrets by revolving the guns to the loading hole, and in casemates by turning the guns away from the embrasure to some position suitable for the erection of the rammer.

Although successfully tried, it did not find sufficient favour with the American Government to be adopted, probably because it entailed operations which were inadmissible from a gunnery point of view, such as dealing with the gun in place of the shot, and also placing it in a dangerous position while loading.

The plan adopted for trial with the 38-ton gun (Plate II, Fig. 6) consists of a chain which is flexible in one direction, and admits of being wound round a barrel (Plate II, Fig. 2), but becomes rigid like a bar when unwound. It was devised in the Carriage Department in the year 1873, but was, I believe, independently invented by one, if not two, gentlemen not connected with that department about the same time.

The invention of the chain was one thing, however, and its successful application another, and one of extreme difficulty; indeed, at one time it was altogether despaired of, as its use involved operations which could not be permitted, such as depressing the gun to it, or raising by a distinct process the top bracket in which it worked, to bring the chain to a level with the bore. The invention of a pawl (E, Plate II, Fig. 6) in connection with this latter movement, however, solved the difficulty, and enables the two distinct operations of raising the chain to the muzzle and of driving it up the bore, to be performed by one continuous movement, initiated by putting into gear a cone clutch similar to what I have described. The Diagrams and Model show the nature and working of this chain, and it will be seen that in the absence of steam it can be worked by manual power (F).

As I have already stated, the space in which these heavy guns are mounted is very limited, and when the gun has reached the utmost limit of recoil which in all parts of the work can be allowed, there is no room at the muzzle to use the chain with full advantage, as the cartridge and shot have to be entered into the muzzle before the chain can act. To obviate this difficulty, the gun immediately after discharge is trained opposite one of the openings in the rear, and the recoil, which was arrested at 6 feet, is continued by aid of the steam gear to 9 feet (Plate II, Fig. 4), thus affording ample space for the cartridge and projectile to run down automatically, by means of an overhead circular railway, and to be driven up the bore by the chain without requiring the presence of a single man at the muzzle.

The resistance afforded by the hydraulic buffer, and the friction between the carriage and platform, end as the gun approaches the limit of its ordinary recoil; and at 6 feet from the front the carriage is raised on its rollers, and is also disengaged from the hydraulic buffer, so that no delay occurs in applying the steam gear to run the gun back the additional 3 feet. The carriage remains upon its rollers during loading, being held by a small stop compressor, and runs up of itself to the firing position when the compressor is released. During the running-up the carriage restores its connection with the hydraulic buffer, sinks off its rollers, and releases its attachment to the running-in chains, making all quite safe before the gun can be fired.

By these means the gun is safely loaded with its muzzle pointing to the enemy. Not a single man is required to expose himself at the port, the steam gear is housed under the floor, and every part of the other gear, except the loading chain, is well protected (as it should be) by the gun itself. It is of such a nature as not to be injured by violent concussions or movements resulting from firing, nor from the chances of misuse, to which, from excitement on the part of the gunners, all gun-gear is liable.

I have now to consider the application of water in connection with steam power. The arrangement already tried so successfully with the 35-ton gun in 1874 presented a tempting combination. It could very easily have been associated with steam power by setting up steam-pumps and an accumulator, and by drawing off the water from the accumulator to do the work of the hand-pump, retaining the latter for use with manual labour when requisite; but it would have possessed this great disadvantage—that the hand-gear would have entailed the use of hydraulic gear in place of common spur gearing. Now, it is well known that hydraulic leathers and valves have a disagreeable way of suddenly failing from various causes, and the hand-gear in this case would have been as liable to get out of order as the steam gear, in fact, more so. It was, therefore, resolved to employ water precisely in the same manner as shafting, leaving the common spur gearing for manual labour, thus securing a perfectly safe, simple, and reliable auxiliary, should either steam or the hydraulic gear fail.

The power then conveyed by water from the steam engine has to be applied to the same point at which the winch handles act when manual power is used; to effect this a small water engine, G (Plate II, Fig. 7), is substituted for the winch handle. When the steam and hydraulic gear are in good working order, this engine drives all the gear in the platform. When either is out of order, this engine is thrown out of gear, winch handles are placed on the spindles, and, in a moment, manual labour is called upon to keep the gun continuously in action.

This water engine, which is the invention of Mr. Brotherhood, is a very beautiful machine. It consists of three cylinders placed at equal distances round a fourth one, the interiors of the whole communicating freely with each other; in the fourth,—the centre cylinder,—is placed a crank fixed to a shaft and pinion, which are intended to perform the work of the winch handles—thus, by forcing round this crank the gear of the platform is set in motion to perform the various operations required. Each of the three cylinders is a hydraulic ram having a solid piston, which, by means of a connecting rod, thrusts the crank-pin round one-third of a revolution—thus each, acting in succession, completes a circle of movement and maintains an equable motion in the whole of the gear. A valve, worked by the crank shaft, maintains the proper supply of water under pressure, and also provides for the removal of the water when it has done its work.

For the conveyance of water from the accumulator, pipes are laid to some convenient point in the floor of the casemate,—and from this point it must be conveyed into the platform by means of pipes which will adjust themselves, as in the case of the telescopic shaft, to various lengths. Telescopic tubes might have been used, but tubes jointed at their ends, similarly to ordinary gas brackets, were preferred for trial. A double set of these are placed in the same recess required for the movement of the telescopic shaft,—one set to convey water under pressure, and the other to carry the waste water back to the steam pumps. The pressure water enters a valve box in the rear of the platform I, and is allowed to pass to the engine, or arrested, according to whether the gunnery operations should proceed or not. A lever regulating this valve gives the man working it the control of all the movements. He can train right or left,—run the gun in or out,—load or withdraw the rammer,—just as the man working the clutch lever does with the more direct steam gear I have already described.

I have endeavoured, so far as the time at my disposal would permit, to make you acquainted with the common spur gearing adopted for performing the various gunnery operations. I have shown you that this gearing, while specially designed for manual power, is made the vehicle for steam and hydraulic power—steam acting through common shafting, and steam acting through water. It remains only for me now to point out the relative advantages and disadvantages of these two methods of using steam power.

In the case of shafting, there is the disadvantage of not being able to vary the rate of motion imparted to the gear of the platform. It is, however, one that only applies in the case of laying the gun. In traversing large distances, great speed is required, while, for accurate laying, a slow motion is desirable. If we arrange the gear, therefore, to give high speed, we render the operation of laying the gun with great accuracy somewhat difficult, while, if we arrange the speed to suit the laying, we sacrifice the speed so desirable in traversing over large arcs. A mean has been sought between these, and a little practice in the use of the steam clutch lever has hitherto resulted in giving quick and accurate laying. Under the worst circumstances the steam gear can be disconnected in a moment, and the final laying performed by the hand-gear. By the use of water in place of shafting the speed may be modulated to any extent, and in this respect it is undoubtedly superior to shafting.

With the exception of this one advantage, however, the employment of water cannot compare favourably with shafting. It is liable to fail suddenly, which shafting is not. When it ceases to act, the most expert engineer will often fail for some time to discover which among many parts, all hidden from view, is the one out of order. It involves the use of much delicate machinery, over and above the boiler and steam engine, while shafting only demands the use of these two. For these reasons, I cannot but think the simple shafting, in spite of its one disadvantage, will be the one ultimately preferred by practical gunners.

In conclusion, I should state that the hand-gear has been thoroughly tested, and is adopted into the Service; the steam and hydraulic gear have been partially tried, and are still under consideration. Most probably these latter will in any case only be used in certain favourable localities, as they are by no means necessities, it having been proved that guns up to 38 tons in weight can be perfectly placed under the control and power of manual gear, and fired at a fairly quick speed. I would not, however, be understood to underrate the vast importance of steam power in lessening the labour of the gunner, increasing the speed of firing, and securing better protection. All I would wish to state is, that the employment of steam is not a necessity, and being of a nature to lead to the employment of mechanism which adds immensely to the cost of mounting each gun, and to the difficulty of working it and preserving it in proper order, it is not at all probable that it will be adopted for every 38-ton gun, but rather be confined to such works as the Spithead forts. And even where employed, the simple manual gear must be retained, to ensure the guns being kept in action, should steam or the steam gear fail.

Captain R. A. E. SCOTT, R.N.: I merely wish to say a few words to open this discussion, as Mr. Butter has kindly referred to my plans, which he well knows from our having been so closely connected in carrying them out while I was at the Admiralty. I will, therefore, say what I have not had the opportunity of saying before, that it was mainly due to the loyalty with which the Arsenal developed and carried out my own and other plans, that so large a measure of success in mounting and working heavy guns at sea has been reached. To fully realize the value of this result, we must consider how important is that success to the maintenance of our maritime power; for, however admirable the gun itself may be, and the gun has been admirably manufactured in the Arsenal, unless there are the means of pointing it accurately, the gun can be of very little value in actual warfare. It amounts to this—that if we have not accurate appliances for pointing our heavy guns and for handling them with *certainty*, so that they will not fail us in action—then it is clear, that the vast weight of armour that we put upon the sides of our vessels to protect their ordnance, the top-heaviness thereby caused, and the immense sizes of the vessels constructed to carry this ordnance (which, even in such ships, necessitates a reduction in engine and coal-carrying power, to bear such a mass of thick iron coating), are a *very great mistake*. Granting, however, that the gun dominates all other naval weapons, then it must be a most important point that we should have the very best appliances for working them, and I think, from what Mr. Butter has now shown, that you have such means at hand. I entirely concur in what he has said, and were I to attempt to lecture to-morrow on the same subject, I should commence by saying, let us have the well-tried hand-gear with which our sailors are already familiar. Put upon that any steam or hydraulic power you choose, but let the present hand-gear be the foundation of the system. Mr. Butter has said rightly, that up to guns of 35 tons weight, this hand-gear has worked perfectly, and I do not think that any purely hydraulic power, which has been used afloat, has as yet caused the guns to be worked so quickly as the "Devastation's" guns are now being worked by the usual service appliances, which are actuated by manual labour. The "Devastation's" guns are, however, 35-ton guns, and some of those that are worked by hydraulics are 38-ton guns. I feel very strongly indeed on this subject, having urged that the simple hydraulic gear, which had been already adopted for lifting turret guns from step to step in their carriages, should be extended to working all the gear in the case of the 35-ton guns, being actuated by a steam pump; but I was met by the objection that a line was drawn between the 35-*ton* and the 38-*ton* guns, steam and hydraulic gear being necessary with the 38-ton but not with the 35-ton gun, and there the question has rested. I hope, however, the time is now coming when all jealousy will be put aside, and when Englishmen will go shoulder to shoulder, for unless they do, it is clear there will be great difficulty in maintaining our place in the world. I think, when we see the combinations that are going on around us, that every Englishman with a mechanical mind, and, more especially, every Officer capable of lending assistance, should do so to the utmost of his power, not so much in exposing what is wrong, as in showing how the very best system can be developed and maintained in Her Majesty's service. With respect to naval armaments, my own view is that *all* our turret guns should have simple steam machinery added to their present simple appliances, so that the running in and out and all other laborious operations should be done by steam, and then there would be the hand power always ready to be fallen back upon in case of the steam failing. Were this system carried out, the men would, on having to work the larger guns, such as the 80-ton of the "Inflexible," be enabled to at once handle the gear efficiently, from having become familiarized with similar appliances in working the lighter guns. What we require with respect to the guns themselves, is, I think, to make the *present* weapons more efficient, rather than to gain the required power by adding to the weight of our ordnance. I am aware that stronger or additional gun-carriage appliances are required when you get a higher recoil, but these are easily added; the urgent need for improvement is apparent, when you reflect that our 18-ton gun gives a velocity of only 1,300 feet a second, while two of the German naval guns, one a 50½-ton and the other a 14-ton, give velocities of 1,600 feet a second; the former velocity representing a force of only 17, but the latter a force of 25½. I think, therefore, it is time for us to be putting our shoulder to the wheel, so as to secure that this great mechanical country shall not be behind any nation in the world, either in weapons of offence or defence. Let us, therefore, secure for our Navy the very best tools that can be got. The discussions here are important, from calling attention to our military requirements in this age of progress, and showing the necessity for expenditure. We all must credit our authorities with the earnest desire to have the very best weapons that can be obtained, but these are generally the most costly, and, therefore, one feels the more satisfied to know that the public as well as the Services give some weight to what is elicited here. Although I have already alluded to the assistance rendered to the Navy by the Arsenal departments, I cannot avoid mentioning that the Superintendent of the Carriage Department on one occasion said to me—"Everything must give way to the wants of the Navy, it "is the Navy that we are bound to assist, and the Navy shall be assisted to the "utmost of our power." That was the spirit that then ruled, and which has, I believe, obtained ever since. Mr. Butter has omitted to say how great the efficiency of the naval armaments is due to the co-operation and assistance of the Royal Arsenal; and, but for the Arsenal aid, any man without a factory at his back must have made a complete failure. I, therefore, now wish to say that I am especially indebted to the Superintendents who so kindly assisted me, for the amount of success which my plans have obtained. With respect to these plans, I do not say that our gun-carriages are perfect, for, I believe, if we had continued to work together a little longer, a greater amount of perfection would have been reached. We are, however, in this position, viz., that of being on the right road for working the whole of our guns in a manner not inferior to that of any country in the world; in fact, every other nation has copied from us. If we had made an equal advance in the system of rifling guns, improving projectiles, and in other gunnery matters, I should then say we were far ahead of all the nations in the world. I think you will all see that nothing can be more perfect than the steam appliances shown, and will agree with me that similar fitments should be added to all our turret guns, so as to familiarize their crews with steam and hydraulic machinery. The importance of this training may be seen from the fact that some of our largest vessels mount only four guns, and fancy what the effect would be if one or two of those guns failed, as is not unlikely to happen in a prolonged action. In addition to steam for turret guns, we should apply to all guns an invention which the Arsenal has perfected, and which, I am quite sure, you have heard described with as much pleasure as I have myself; I allude to the plan of loading by the *chain*. By this means, ships that are low in the water could lower their broadside ports, and the men will be able to load protected both from musketry and the wash of the sea. In our turret vessels, where the space is confined, whatever the position the turret is in, while pointing and firing one gun, the crew could be loading the other. I, therefore, look upon the chain loading as a very important invention, and, from the increased facility it affords for working naval ordnance, I trust it will be adopted, so as to give to our soldiers and sailors alike the very best appliances for working the heavy weapons that have been made for them.

Mr. J. Scott Russell, F.R.S.: I should be very sorry if this very valuable paper was not fully discussed by the various professions connected with it. I am very glad we have heard from the sailor what his view on this matter is, and perhaps you would allow me, as an engineer, to speak against my own profession, and to speak against every complicated engineering mechanism in the gunnery of ships, and to say, that for that very reason I highly appreciate this paper. I do so because it puts forward, as the basis of everything, that the guns shall be so arranged as to be efficiently and expeditiously worked by hand. Now I, as an engineer, appreciate that fact more highly than I do any clever little tricks and inventions of my own as an engineer; and I would say that there is this great point, that you will get more out of human beings capable of mechanical power in a short time than you will by mechanical engineering. That is the great advantage of hand power. Then, having first got perfect hand-gear, for which, I believe, we are chiefly indebted to Captain Scott—having first got good hand-gear for our Navy guns, it then becomes the second question, which the writer of this paper has so admirably coped with, how we shall apply mechanical power after that, without interfering with the efficiency of the hand-gear, and the great merit, I think, of his paper and of the inventions he has brought forward is, that he has shown how the hand-gear can be combined, in an extremely simple manner, with steam and hydraulic-gear. I will go to issue with him on one point; I do not think that hydraulic-gear or shafting is a good naval mode of conveying power from the steam-engine of the ship to the guns. I entirely disapprove of them all, from the inconvenience to which they are liable and the derangements to which they are liable, and I differ with him *in toto* upon one point. I think that the simplest mode, the most efficient, least inconvenient, and least derangeable method of conveying mechanical power from the engine, in the engine-room, to assist our sailors in the manipulation of the guns, is condensed air; and I will tell you why. All these mechanisms are liable to derangement, all of them are liable to escapes, and all of them have grave inconveniences when they go wrong, except the air. What happens if an air-pipe goes wrong? Of course you would have a spare air-pipe for every gun. If an air-pipe goes wrong this happens, merely that good, fresh, excellent cool air comes into the compartment where the pipe has burst; therefore, you have there the least possible complication of power and no possible inconvenience arises from derangement; whereas, if one of your hydraulic pipes burst, where are you? "you are inundated." That is a matter on which, I think, you will agree; we may all have a difference of opinion, but, allow me to say, I do not see any inconvenience in the attachment of an air-pump to the engines of the ship, which air-pump pumps into a large reservoir or thing like a boiler, which is in the engine-room along with the other boilers and under the management of the Chief Engineer; and, if from the reservoir a small pipe, like a gas-pipe, goes separately, under water if you like, wherever you think it is best protected, behind the armour, into each gun casemate, there is a perfect engine with the least possible mechanism and hardly any inconvenience, and much simpler than any other. Allow me to say, with regard to the hydraulic buffers, they have been used in every possible way by many of our great gunners and engineers.

I think hydraulic buffers are good, and I will only venture one remark, to say I have used these hydraulic buffers for various important purposes; but that I find the best form is not that form in which there are openings in the pistons, nor the other form in which these openings are varied by taper tubes; but what I have found the best form is this, to take the hydraulic cylinder with its piston, and then, on the outside of that, carry a tube from one end to the other, and upon that tube put a simple stop-cock, and this simple stop-cock, turning round at different angles makes an absolutely perfect regulator, which the gunner can adjust to any purpose he wants at all times, and it utterly avoids any complication in the inside.

Mr. FAUCUS: Mr. Scott Russell has already anticipated much of what I would otherwise have said, and I would simply follow his remarks by suggesting how your traversing may be independent of the gun or gun-carriage. Mr. Butter made many observations with which I entirely agree. The difficulty of traversing I perfectly agree with, and I have, within the last few days, submitted this little apparatus to show a new traversing movement. That is a new application of the old elliptical trammel apparatus for drawing ellipses. Instead of the screws, I substitute bearings travelling on wheels. This arrangement is applicable to the smallest boats or to the largest frigates, for by it you obtain an elliptical movement, enabling your men to follow any rapid sailing craft at which you may be aiming. The same principle will apply to the Gatling guns in the tops or in any other position; and I have now great pleasure in submitting this model for your approval. (A model of a gun-carriage, slide, and platform was exhibited.)

Admiral SELWYN: When Mr. Scott Russell spoke of the point on which he was at issue with the author of the paper, I thought he was going to refer to an invention very little known in England, but considerably practised in America, which is very ingenious, and may possibly, in some cases, aid very much the labours of those who have the working of heavy guns. The Americans have found that the use of steel wire rope supersedes shafting altogether, that you may turn a steel wire rope round any corner you please in any direction, and it communicates the rotary movement perfectly in that new direction. You then do away with all the difficulties and dangers of the breakage of cog-wheels, and it seems to offer every advantage we can ask for, except that you must be careful never to use it in the reversed direction, otherwise you untwist the rope. But that is easily overcome by the frictional arrangement which has been proposed here. I think, if I recollect right, when Colonel Moncrieff was in Waterloo Place, I spoke to him about our chain pump when we were on the question of a flexible rammer, and told him how to stiffen the chain, and how to put it into the bore of the gun. I presume it went to Woolwich, and I am very pleased to see it has been so beautifully perfected, and so successfully adopted.

Mr. BUTTER: I am very much obliged to the gentlemen for their kind remarks. With reference to myself personally I have nothing to say with respect to what Captain Scott has said. He has not joined issue with me on any point in the lecture, therefore there is nothing for me to speak about further than this, that I am very glad that he has such a kindly remembrance of the intercourse which took place between us years ago, and also of what took place between himself and my then superintendent, Colonel Field, whom I am very glad to see present to-day. I may take this opportunity of saying I have not mentioned any of the Officers connected with the Arsenal or the Heavy Gun Committee who have had dealings with these inventions, because I thought it better not to do so; but I have mentioned some gentlemen who are not connected with the Arsenal, such as Captain Scott and Mr. Holman, to whom, as being outside the official circle, it was due that I should mention their names.

With respect to the remarks made by Mr. Scott Russell as to the use of air, I stated in the paper why I thought air was not a suitable agent for carrying on the steam power. I mentioned, as he did, that there was this advantage, that when the air escaped it promoted ventilation, and that it was also a most convenient way of carrying power to great distances; but still it has this disadvantage, that it is rather a difficult agent to deal with, and that it is almost impossible to keep the tubes perfectly tight. Air is very insidious, and escapes from joints in a manner that we can hardly control, except by means which are apt to get deranged by the rapid and violent concussions caused by the discharge of the gun. There is also a great loss of power. Over 60 per cent. of the steam-engine power is lost in its transmission, and that is a very serious matter. The loss varies with different pressures. According to experiments that have been carried out the loss is, as I have stated, 60 per cent. with two atmospheres of pressure: with the higher rates of pressure the loss becomes greater than that, and with smaller pressure the loss becomes less, therefore the higher you condense air, the more is lost through its subsequent expansion.

Mr. Scott Russell: That loss is not of the least value.

Mr. Butter: No. Of course it may be compensated by having higher engine power.

Mr. Scott Russell: It is only a loss of two pennyworth of coal.

Mr. Butter: Then there is the disadvantage of the air reservoir bursting explosively, and that is not the case with water or shafting. If the shaft becomes deranged it produces no evil effects: it does not give out anything offensive. Of course, if a steam pipe were to burst it would be offensive, but a shaft becoming deranged would not be so in the least degree, and by disconnecting the gear from the steam-gear you can at once resort to your manual power just as if an air pipe burst. There will be no more inconvenience in the one than in the other.

With respect to the bursting explosively that is a serious matter. I believe there is a gentleman present who used air in his works for some time in place of steam, and I think he had several accidents. There were several explosive burstings, and they resulted in great injury to the men. The air, therefore, was abandoned, and water substituted for it. We know also that we have had one of the torpedo vessels burst at Woolwich, and we know that air does burst explosively in the same way as gunpowder and steam, and produces very destructive results. Another great disadvantage in the employment of air is that you must increase your complication. You must have another engine at the gun to develop the power which the air or water receives from the steam-engine. With shafting that is not the case. You carry on the power and take it off by a simple toothed-wheel. You must have a very delicate and complicated machine indeed at the gun for the purpose of re-developing the power of the air. With regard to the hydraulic buffer I may mention that the hydraulic buffer that he first mentioned is one that we have had in use for a great number of years at Woolwich, and it is a very admirable form of buffer; it was one which was proposed specially for use in the Navy, and of which I have shown you a diagram. It was proposed in 1867. It has the side pipe and the valve, and gives, besides the power of controlling the running in and out of the gun, that of regulating the aperture to accommodate itself to any recoil. But the one with the four small holes is so remarkably simple in its form, and has answered so admirably, that it is retained in preference to any other.

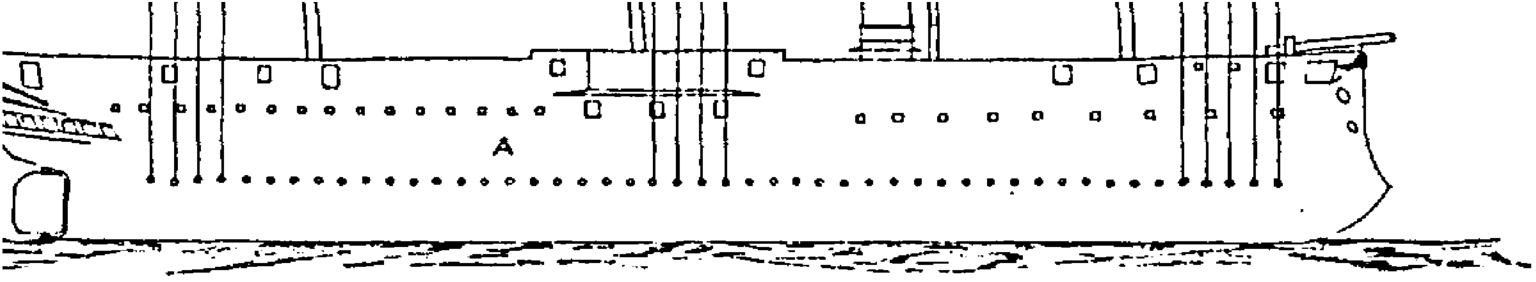
With respect to the traversing arrangement of Mr. Faucus it is a very ingenious application, but I do not think it bears upon my lecture, and therefore it does not fall within my province to criticise it in any way.

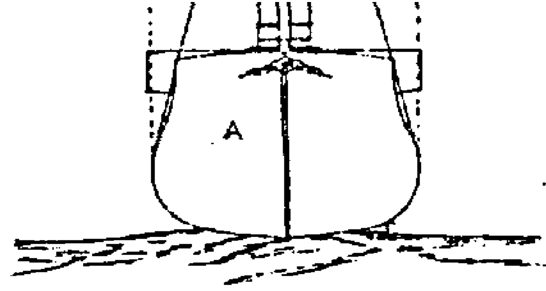
With regard to the wire rope mentioned by Admiral Selwyn, I think I named that it was one means which might be adopted for the purpose of conveying power from the steam-engine to the gun. I also named that it is a very admirable contrivance for carrying power from a portable steam-engine into trenches where there is plenty of space for large pulleys, but it is not so well adapted for carrying the power into a fort, when there are only small spaces to work in, and only a certain limited depth in which to construct the passages under the floor; it is the same way with regard to ships. The shaft, on the other hand, gives the power of carrying along the power in a very small passage indeed—only three or four inches deep. You could not carry a long rope in so small a passage as that.

Admiral Selwyn: The steel rope is merely used by twisting for the purpose of imparting motion.

Mr. Butter: I misunderstood you. I am very glad of your correction. Then it comes to this, that it is really flexible shafting. This is in use in the Arsenal, and it is a very useful contrivance for carrying on a small amount of power, but it is restricted in length. It is introduced for the purpose of drilling holes up to one inch in diameter, but you cannot use such a shaft more than about eight feet long. Of course, if you only want a small amount of power it answers the purpose, but it becomes useless when you have to get such enormous pressure as you require for the purpose of working heavy guns. They are in use both in the Gun Factory and in the Carriage Department, and the result was such that it naturally suggested itself to us as being advisable to employ a shaft of that description; but on going over the matter carefully we found it would not carry enough power for the lengths which would be required, and the telescopic shaft does convey the power very admirably, and does not give rise to any inconvenience whatever. I have only to thank you for the attention you have given me, and to add that I should have been glad to have made the paper more interesting; but we have lately been so very busy that it has been only under great difficulties that I have been able to complete the paper at all.

The CHAIRMAN: I feel sure I shall only be fulfilling your wishes in offering to Mr. Butter our acknowledgements for his kindness in giving us this interesting lecture on a difficult subject, one of great interest to naval and artillery men—and especially for his coming under the circumstances he has just mentioned—that the Carriage Department at the present moment is so fully engaged that it was with difficulty he has been able to prepare his lecture. We should probably have been much surprised if we had been told ten or even five years ago that we should be sitting here to discuss the best application of steam machinery to the working of our heavy ordnance. The fact is, it is one of the results of that great revolution which has been going on with regard to ordnance during the last twenty years, and which does not at present show signs of abatement, our ordnance, their carriages, appliances, and projectiles, are becoming so large, and the weights so enormous, that we are as it were almost forced into some system of supplementing manual labour. No doubt, as Mr. Butter has pointed out, it is essential that we should retain the means of fighting our guns by manual labour, but there are great apparent advantages in the use either of steam or hydraulic machinery. One advantage is that less men are required for manning the gun; another, that fewer men are exposed in the casemates during an action. That is important, because you know perfectly well what confusion and loss would arise from a projectile bursting in a contracted casemate. There is, however, another advantage, perhaps more important than all, that we hope, by means of steam machinery, to obtain greater rapidity of fire. Now, rapidity of fire with a field-gun is not a matter, perhaps, of much moment, but it is otherwise with heavy guns, because the object fired at will generally be a moving one; and it is evident that if an ironclad or other ship is rapidly moving across your front, it is of the highest importance to be able to strike quickly. Therefore, one of the great elements of advantage we hope to gain from this application of steam or hydraulic machinery, is that we shall get rapidity of fire. I wish to say one word about muzzle-loading rifled ordnance. That system has the great advantage of enabling us, even without the application of steam machinery, to fire faster than with guns constructed on a breech-loading system. There are so many operations to be performed in loading the latter, and they require so much care, that the firing is much slower. Mr. Butter has told you that our 38-ton gun has fired ten rounds in twenty minutes, or about one round in two minutes without steam machinery. I am not aware that any gun of a foreign Power of that calibre and weight, made on the breech-loading system, has been fired with anything like the same rapidity. But I must go further and point out that the application of steam machinery seems more simple when applied to a muzzle-loading gun than to a breech-loader. Therefore, I think we are not only right in studying the question of steam machinery, but that the system we have adopted for our guns is well adapted for its application. I was glad to hear the remarks of Captain Scott with regard to the Officers in the Arsenal, and feel quite sure that they have no petty jealousies, but that they are anxious to obtain the assistance not only of brother Officers, but of others from whose efforts we have already received so much advantage. I would name Captain Scott himself, and Major Moncrieff, and also Sir William Armstrong, and Mr. Rendel, by whom two guns have been fitted up in one of the forts at Spithead for the very purpose of developing a system of working by steam machinery. In the prosecution of our studies in this difficult matter we cordially invite the assistance of those who may not be in the department. I have only to conclude by thanking Mr. Butter for his kindness in coming here to-day, and giving us this excellent lecture on such an important subject.





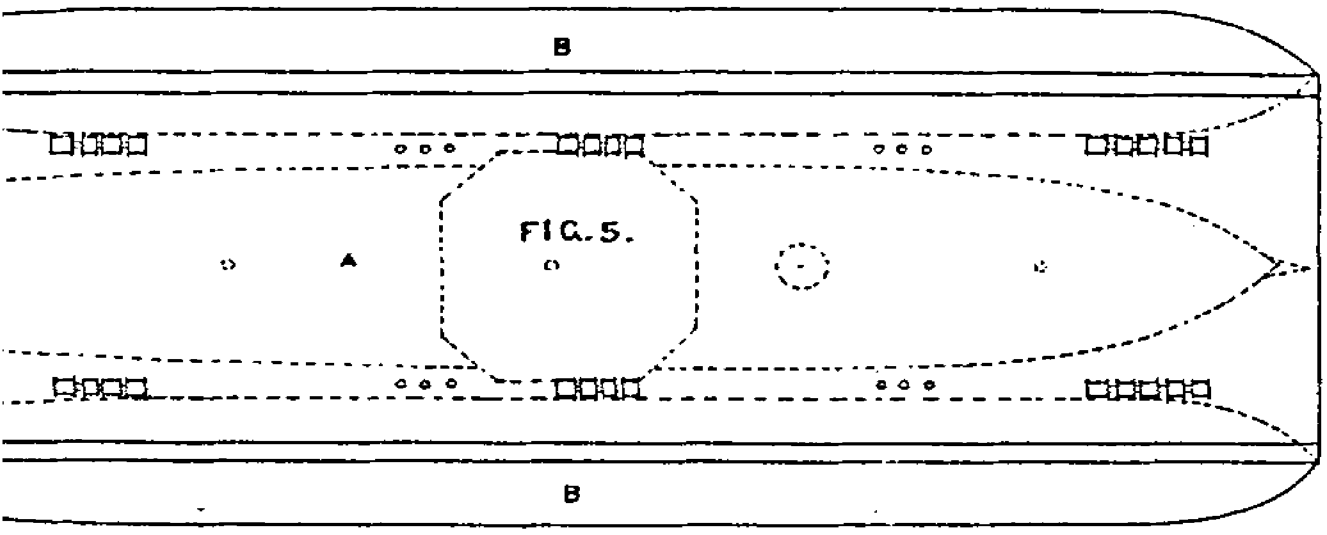


FIG. 5.

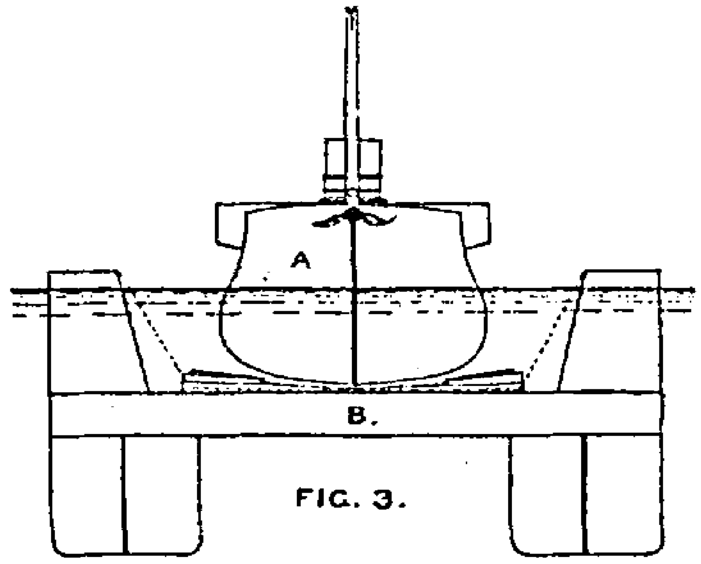


FIG. 3.

FIG. 10.

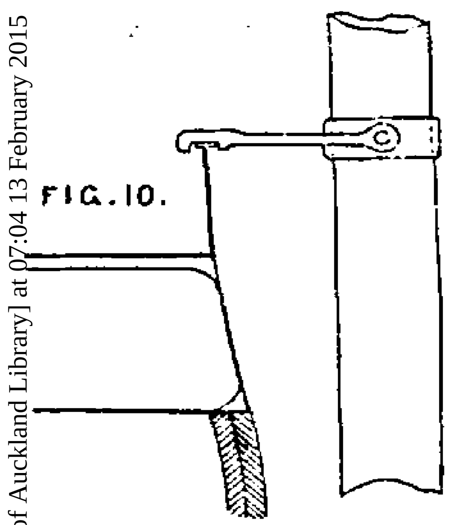
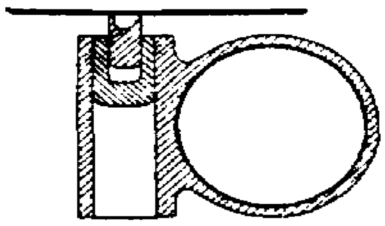


FIG. 11.



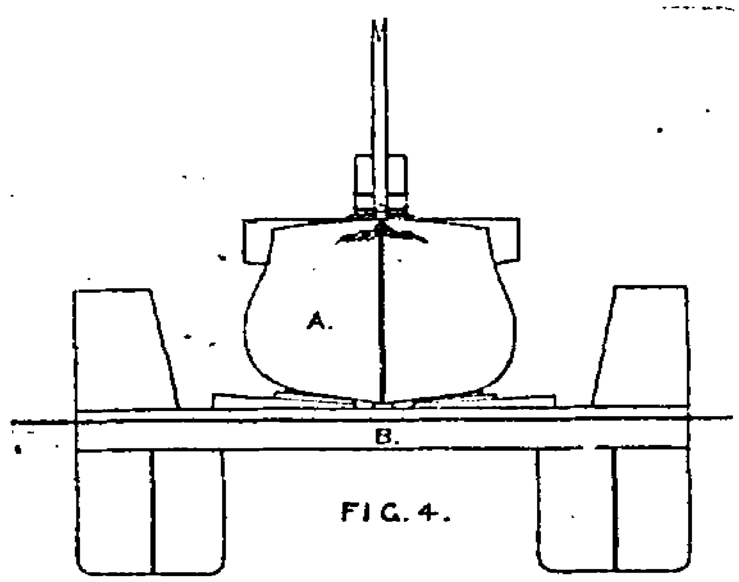
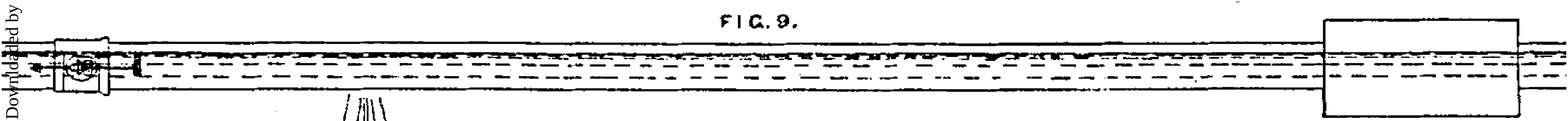


FIG. 4.

FIG. 9.



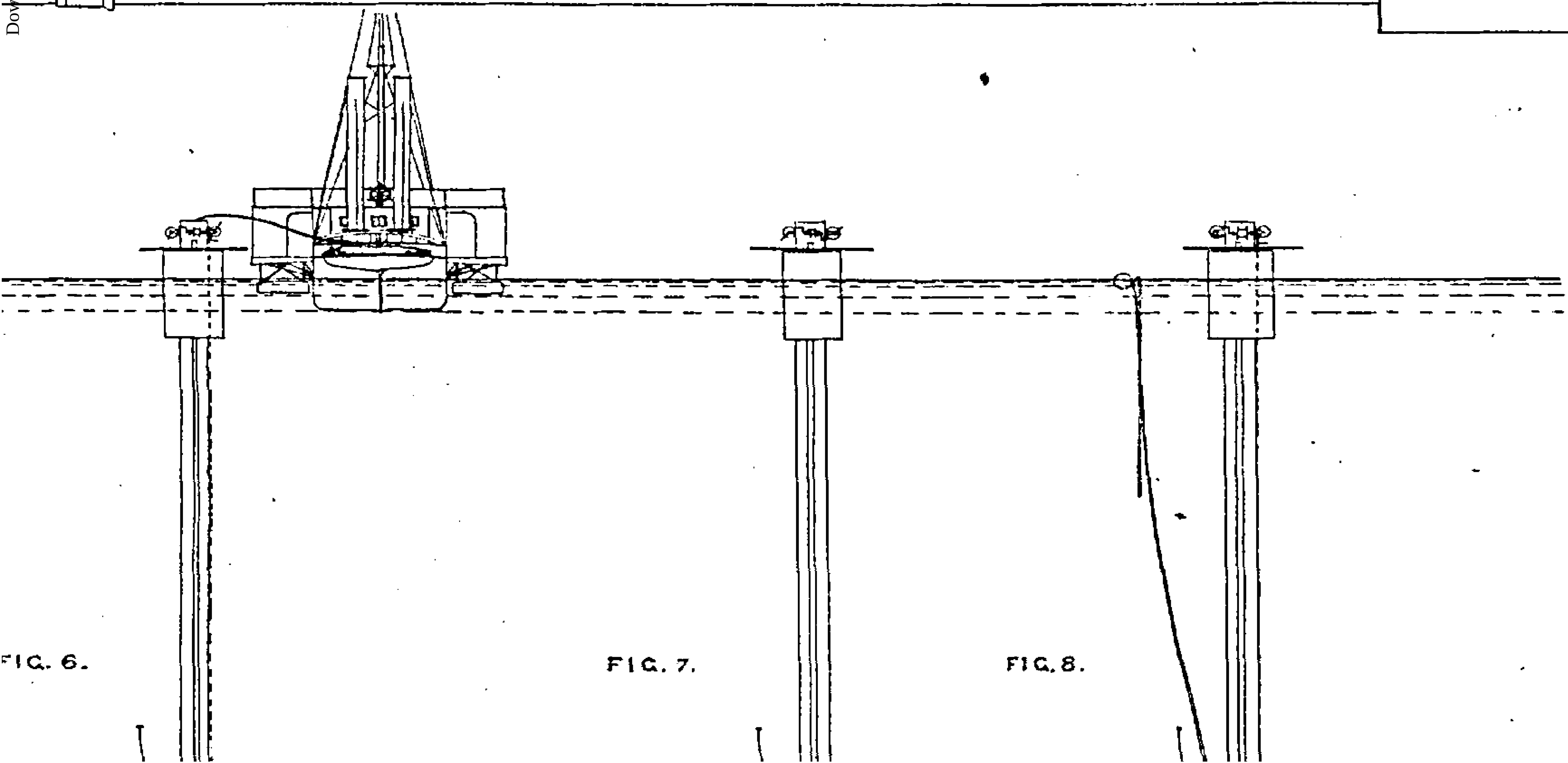


FIG. 6.

FIG. 7.

FIG. 8.