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THOMAS E. HARRISON, President,  
in the Chair.

No. 1,385.—“Gun-Carriages and Mechanical Appliances for working Heavy Ordnance.” By GEORGE WIGHTWICK RENDEL, M. Inst. C.E.<sup>1</sup>

A few years ago gun-carriages were of the simplest character, and, though well-adapted to their purpose, were scarcely worthy the attention of the Civil Engineer. But of late, owing to the increase in the size and power of ordnance since the introduction of armour, gun-carriages have gradually become elaborate machines, and the appliances for working the monster ordnance now in contemplation will tax all the resources of mechanical science. The subject is of the greatest importance. It deserves and claims discussion in an Institution whose members have the widest possible experience of engineering appliances, and such a discussion cannot fail to be attended with public advantage.

The common form of garrison and ship gun-carriage (Plate 24, Fig. 1) in use fifteen years ago is well known. It ran in and out upon small wheels or trucks having disproportionately large axles, designed to create friction for the absorption of recoil; or the rear trucks were dispensed with, and a block of wood, called the rear chock, was substituted for them, the recoil being further arrested by the slope of the platform, or by a rope breeching. Elevation was given to the gun by raising the breech with hand spikes, and propping it with a loose quoin, or by a simple elevating screw under the breech. Training was effected by prising the carriage bodily sideways with levers, or by hauling it with tackles. The adoption of slides (Plate 24, Fig. 2), and traversing platforms for gun-carriages to run on, had been a great improvement; but levers and tackles, and, for ship use, breechings continued to form essential parts of the apparatus for working ordnance, and the carriages were most imperfect machines when great improvements in guns had been realised.

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<sup>1</sup> The discussion upon this Paper extended over portions of three evenings, but an abstract of the whole is given consecutively.

The first difficulty experienced in mounting wrought-iron rifled guns arose from the much greater violence of their recoil as compared with that of the old cast-iron guns; a disadvantage mainly resulting from their superiority in lightness, strength for strength. Serious objection was made to the new guns on this account. The service compressors first introduced with improved ordnance were found inadequate and unsuitable, and it became essential to devise an efficient break for arresting recoil. The conditions to be fulfilled in a mechanical break were:—First, to provide ample surface and pressure to give the requisite frictional resistance. Secondly, to cause the break to be self-acting, so as to remove the risk of accident. Thirdly, to make it capable of adjustment to meet the alterations in the force of recoil due to different charges and other changing conditions. Fourthly, to render it sufficiently elastic to meet variations of gauge of the rubbing surfaces. And, finally, to add as few parts as possible to the carriage, and those compact, strong, and accessible.

The first break or compressor, designed at Elswick to meet these requirements (Plate 24, Fig. 3), was tried in the year 1864, by the Ordnance Select Committee, on a 70-pounder timber carriage. In this compressor elasticity is obtained by a bow piece which spans the slide beam, and is capable of springing to any probable variation of the gauge of the beam, without sensible alteration of the pressure and consequent friction on the beam. Adjustment of the frictional resistance is provided for by the screw (A), which can be turned and set to any zero by means of the notched wheel (B) held by the catch (C). The compressor is rendered self-acting as follows: a lever (D) is attached to a quick pitched screw (E) passing through the bow piece opposite the adjusting screw, and runs at its outer end between stops or in a swivel-eye on the gun-carriage, so as to act on the screw whenever the carriage moves, but the rest of the compressor is disconnected with the carriage, and is free to the extent of the play it has between the transoms. It therefore does not move, when the motion of the carriage is reversed, until the transom behind reaches it and carries it forward, by which time the lever (D), having described a sufficient arc, has either clamped or freed the compressor, according as the motion is in or out. It will be obvious that, as the compressor is set up by the action of recoil itself, there can be no difficulty in employing any desired pressure on the rubbing surfaces, and that, as the pressure simply compresses the slide beams, it causes no distortion or straining of the slide structure. This compressor was afterwards adapted for iron carriages, by substituting iron boxes filled with wood for the friction-

plates (Plate 24, Fig. 4); and it has been extensively used for naval and land service with guns not exceeding 7 tons in weight.

The liability of timber to change of form and to rapid deterioration renders it a very unsuitable material for gun-carriages, and the great superiority of wrought iron, in unchangeability, durability, and strength, soon became apparent as gun-carriages were adapted to keep pace with the improvement in guns. A strong prejudice, however, long existed against the use of iron for gun-carriages, under the belief that shot would produce more numerous and dangerous splinters on striking an iron structure than on striking a timber one: but although this may be true of cast iron, it proved not to be so of wrought iron. In 1865 experiments were made at Shoeburyness, by firing against wrought-iron and timber carriages, and noting the effect on dummies set up to represent the guns' crew. Contrary to expectation, it was found that the splinters from the wood were more destructive than those from the iron gun-carriage, and the wooden carriage was disabled in a less number of rounds than the iron one. Similar experiments were subsequently made with field carriages of wood and iron, and with like results. It might be questioned whether one or two experiments could be considered conclusive of a question so much affected by chance; but it is evident that a timber carriage for one of the present heavy rifled guns, would be so cumbrous, and so full of iron-work in fittings and bolts, that it could not be struck by shot without forming numerous fragments of iron as well as of wood; and even were it superior to an iron carriage in this respect, its disadvantages in others would more than counterbalance that superiority. The use of iron is now thoroughly established, and a return to timber would be as impossible for heavy gun-carriages as it would be for the huge ships, which, through the adoption of iron-plate construction, are now built without difficulty.

In 1865 Sir W. G. Armstrong and Co. designed and constructed a 70-pounder wrought-iron naval carriage and slide (Plate 24, Fig. 5), in which they introduced an improved "compressor" made entirely of wrought iron. This carriage was tried in the same year on a gunboat at Spithead by Vice-Admiral Sir Cooper Key, whose approval of it, and whose advocacy of wrought iron as the material for future naval carriages, led to an order being at once given for a 12½-ton gun-carriage on the same system, subsequently tried and adopted by the Admiralty. The compressor (Plate 24, Figs. 6), in both these carriages, consists of a number of short plates on the carriage interlacing long plates or bars on the slide, in such a manner that when both are clamped together by the vice action

of the compressor jaws and the carriage is set in motion, the frictional resistance produced is that due to the pressure applied, multiplied by the number of sliding surfaces, *i.e.*, by twice the number of the fixed plates; so that the power of the compressor can be increased by merely adding plates without increasing the pressure applied through the vice jaws. The compressor is tightened by a quarter turn of the lever (A). The toe projects so as to catch a tripper (B), which turns it in the event of its being forgotten, and thus renders it self-acting. A second lever (C), fixed in any position on a notched arc, turns the screw nut (D) and adjusts the pressure applied, by altering the zero point from which compression commences. The rocking levers (F F) are sufficiently elastic to meet the slight variations of gauge to be expected in the bundle of bars throughout their length. The adoption of thin iron bars enables the friction to be so multiplied, by repetition of surface, that a moderate pressure suffices, and practically the compressor can be applied by hand with great power, with hardly an effort and in a moment. Perfect control is thus obtained over the motion of a gun on its slide in a sea-way, so that this compressor is superior to the one previously described, which only resists motion of the gun backwards or in the direction of recoil, and does not check its running out. The principle of increasing the frictional resistance due to any given pressure, by multiplying the sliding surfaces subject to that pressure, instead of increasing the pressure itself, was first applied to gun-carriage compressors in America. But although this important principle is common to both, the Elswick compressor differs from the American form in several essential particulars. As it is self-acting no accident can happen from its being forgotten. It is capable of easy adjustment, so as to regulate the recoil to any required extent under different conditions. It is applied instantly by a quarter turn of a lever, thus affording the means of perfectly controlling the motion of a gun on its slide in a sea-way. Finally, the adoption of thin iron bars in place of timber planks gives a great extension to the power of multiplying surfaces, and consequently of increasing the resistance of the compressor, while at the same time it renders it durable, and prevents the irregularity and uncertainty of action experienced with the American compressor. Contrary to general expectation, the iron rubbing surfaces have answered well, and are free from liability to seize, the amount of surface always being made ample. They want no attention, and may be allowed to rust freely. This compressor has been adopted almost universally for naval use, and to a large extent for land service also,

having been manufactured at Elswick for nearly every Power in the world.

Some of the leading types of carriages made at the Elswick Works will now be described. Plate 24, Fig. 7, represents a naval broadside wrought-iron carriage and slide for the 9-inch 12½-ton Armstrong gun. A section of the carriage is shown in Fig. 6. The cheeks are of double plates riveted on each side of a frame of iron. They are connected by a horizontal base plate and by vertical diaphragms, secured and stiffened by angle irons. The slide is formed of two rolled H beams, bent round and riveted together at the front, and braced by diagonal bars. This construction is simple, strong, and convenient, and has been followed generally in wrought-iron carriages. The self-acting plate compressor checks recoil, and controls the motion of the gun on the slide. An inclination forward is given to the slide, so that, as a rule, the gun will run out by itself into firing position whenever the compressor is eased; but it can also be run in or out when necessary by a pair of endless chains, set in motion by crank handles acting through toothed gear, or cupped wheels engaging the links of the chains. The chains pass through guides on the carriage, so formed as to seize them, when a hooked bar is dropped over an eccentric pin on the shaft by which the carriage is raised upon its wheels for running in or out. Thus the chains can be seized or not at will, in the act of throwing the carriage on its wheels, and yet run freely through the guides on recoil, or when not required for running in or out. The slide is trained about a front pivot, by a pinion gearing into a toothed arc secured on the deck, as first used by Captain Scott, R.N., the pinion being driven by the same crank handles as the chain gear, through a clutch worked by a foot lever. The training gear is locked by a notched wheel and pawl (Fig. 8), to prevent the gun breaking away under the influence of the motion of the ship. Another form of apparatus for running the gun in and out is the rope winch gear, introduced by Mr. Cunningham, of Gosport (Fig. 9). In this case the traction is effected by a rope laid over and biting in a groove of V section on a wheel driven by the winch. The same rope led round a conveyance-sheave to a ring-bolt in the deck serves to train the slide. This apparatus works well with guns of moderate weight, and has the merit of simplicity with the attendant advantage, so important in all war material, of small liability to derangement. Elevation is given to the guns by a pinion and toothed arc, and is easily effected, since the guns are now made without the breech preponderance formerly considered essential. The guns

are fixed at any elevation by a lever, which clamps the elevating pinion to the carriage cheek. Figs. 10 and 11 represent an 18-ton gun naval wrought-iron carriage and slide, of similar construction to that of the 12½-ton gun-carriage, but capable of revolving about a rear pivot as well as a front one, so that the gun may be shifted from one port to another adjoining, and be used in both. The racks and radius plates required on the deck for two corner ports of a battery under this arrangement are shown in Fig. 12. The special feature of the plan is the pivoting of a portion of the rack, by which means it is easily moved out of the track of the slide wheels during the shifting of the gun from one port to the other, and at the same time is available for training the gun in both ports. The pivoted rack is fixed in either position by a drop bolt, which, with the screw pivot, securely holds it in place. This renders unnecessary the turn-table used for the same purpose in several English ships. The slide or platform of a gun-carriage may be regarded as in itself a turn-table, and the addition of a second turn-table below is obviously undesirable. Such an addition is especially objectionable in a ship, for a large hole must be made in the deck, the deck beams must be cut and space occupied below, besides which a serious and costly complication in the structure of the vessel is introduced.

Figs. 13 and 14 represent a wrought-iron carriage and slide for land service, for a 15-ton gun. The two points of novelty, to which attention may be directed, are the method of training the platform, and the substitution for the usual tripping rollers under the carriage of a number of grooved rollers, permanently running on the slide, and sufficient to bear the shock of recoil. The training is effected by gear connecting the platform trucks, on the front and rear rails, in such a way as to drive them at a speed proportioned to the respective radii of the rails. The result is that the platform moves truly about the centre of both rail circles, and requires no actual pivot and pivot bars. The excessive difficulty often experienced in training heavy garrison carriages without actual pivots is due to the binding of the truck flanges against the sides of the rails, from a want of coincidence between the direction of the pressure applied to give the motion and of the resistance, causing the front or the rear to lag, and the platform to cease to move in a true circle. The coupling of a fore and aft wheel with proportionate gear removes this difficulty, and enables the platform to be trained with ease by the traction of the wheels alone, and without fixed fulcrums such as the toothed arc required for naval service.

All British service gun-carriages are at present mounted on

their slides in such a manner as to recoil on a dead bearing, but to run out on wheels thrown into action by eccentrics or cranks. By placing the carriage permanently on wheels, and trusting more to the compressor to arrest recoil, the operation of "tripping" the carriage, *i.e.*, of throwing the wheels into action for running out, is avoided. In an earthwork or a barbette battery the men who do this are frequently much exposed; and in all cases "tripping" a heavy gun-carriage involves labour and time. By this alteration the gun may be worked more quickly, with fewer men, and in many cases with less exposure of the men. The power of the plate compressor is ample for the purpose of controlling the recoil and motion of the gun on its slide, at sea as well as on land, and the value of the natural friction between the carriage and slide, small in comparison with the artificial friction of the compressor, is dearly bought at the cost of an operation which occupies a large portion of the time and labour of working heavy ordnance, and involves other serious disadvantages.

The loading of heavy guns has not hitherto been facilitated by the introduction of mechanical aids to the same extent as the work to be done in running the gun in and out, and in elevating and training it to deliver its fire. Winches are used for hoisting the shot to the muzzle, with cranes or runners in some cases, and several forms of shot-bearers have been devised for different circumstances; but the ramming home of the shot, and the sponging of the bore, are still done by ramrods, which are rapidly attaining dimensions totally unmanageable. The ring shot-bearer (exhibited) was designed especially for use in turrets, where the shot has to be brought up vertically through small apertures. It carries the shot by locking itself on the front row of studs, and lifts it so that it may be turned to a horizontal position at the muzzle, and enter the bore of the gun with the studs opposite the grooves. The vice shot-bearer (also shown) is more adapted for deck use. It is intended to be hooked on to the muzzle of the gun, where it forms at once a shelf and guide corresponding in diameter and in the position of its grooves to those of the bore, so that the shot may be pushed at once into the bore. The vice jaws hold the shot so firmly, that the shot cannot slip off the bearer while being conveyed to the gun, until the handles are let go. A rope or canvas sling is, however, found to answer for naval broadside use, with the service form of projectile, and has the merit of lightness and simplicity.

The result of the adoption of these mechanical arrangements for the application of manual power to the working of ordnance, has

been that guns up to 25 tons weight are now worked with more ease, safety, and rapidity than guns of one-fifth that weight were formerly.

The size of ordnance continues, however, to increase by rapid strides. There are already many rifled guns in existence of 36 tons or 38 tons weight, throwing 700-lb. shot. Guns of nearly double that weight are actually being made, and there is no manufacturing obstacle to the construction of still larger artillery. It is difficult, indeed, to place a limit to the size of gun that can be produced on a system, like that of Sir Wm. Armstrong, under which it is built up of concentric cylinders superposed in layers, whose number may be increased so as to form an immense total thickness, without involving any one piece of unmanageable dimensions. The powder pressure attained with large charges would, possibly, first impose a limit on the size of guns; but recent experiments and investigations give ground for the belief, that even with charges vastly exceeding any yet used, the powder pressure may be regulated and kept within prescribed bounds. Hence, then, the adoption of some inanimate power, in the place of mere hand-labour, for loading and working heavy ordnance, desirable as it already is for existing guns, will become an absolute necessity for guns of the immediate future. Instead of complicating mechanism, the abandonment of manual labour will tend to simplify it, because the number of men employed cannot be much further increased; and the train of mechanism required to apply the constant and limited power of men, to the forces to be exerted in loading and working heavy guns, becomes larger and more complicated as the weight of the guns is increased.

Adopting the steam engine as the most ready and convenient source of power, it is believed that that power will be best applied through the medium of water under pressure. The simplicity and compactness of hydraulic machinery, the circumstance of its direct action rendering toothed gear unnecessary, and the perfect control it gives over the motion of heavy weights, especially adapt it for the purpose. Power sufficient for the heaviest gun may be transmitted by water through a very small pipe, for long distances and by intricate ways; so that a steam pumping engine may be placed in a fort or ship, in such a position as to be absolutely secure, and supply power, by this means, for working many guns.

The drawings and the working models illustrate some of the arrangements experimented with, or now in progress at, the Elswick Works, for loading and working guns by hydraulic machinery.

The cylinder or press (Plate 25, Fig. 15) performs the double



office of checking recoil and moving the gun in or out along the slide. The gun on recoil drives back the piston and is arrested by the resistance which the valve (D) offers to the escape of the water from the cylinder. The valve is loaded with a spring, which may be adjusted to give any required resistance, and so meet the variations of the force of recoil. It is also partly balanced, to lessen the load required upon it. The area of the piston-rod is one half that of the piston, and the gun is run out by admitting the water pressure to both sides at once. For running the gun in, the pressure is admitted to the front of the piston only, the exhaust being at the same time opened to the rear. Clack valves in connection with a waste-water tank are used to insure the cylinder being always full, and there is a relief valve on the front for preventing any excessive strain. On the rear the recoil valve acts as a relief valve upon occasion. It will happen in some cases that the pressure required on the valve (D) to arrest recoil falls short of that necessary for running the gun in or out, in which case the water admitted to the cylinder for the purpose would lift the valve and escape to waste. This is provided for by making the act of opening the cylinder-inlet valve (A) place an additional load on the recoil valve (D), retaining it there so long as the inlet valve remains open. Fig. 15 shows one method of placing the extra load on the recoil valve, viz., by a small inverted press having in its normal condition an open communication with the waste-water tank, which communication is closed, and the press charged with water under pressure, by the first movement of the lever employed to open the inlet valve (A) of the recoil cylinder.

Experiments, made at Elswick with a recoil press of the nature described, gave very satisfactory results. It was found that the recoil could be regulated with precision, and that the most perfect control could be exercised over the movement of the gun on its slide. The same arrangement of recoil press may be used independently of the application of hydraulic power, to check recoil and to control the movements of gun-carriages on their slides. The loaded valve not only serves to arrest recoil, but as a working valve to govern at will the passage of the water from one side of the piston to the other, and, by thus controlling the motion of the piston, to govern that of the carriage to which it is attached through the piston-rod. The press is therefore as available for sea service, where the motion of the ship makes perfect control essential, as for land service, and for carriages running permanently on wheels on inclined platforms as for those arranged to be tripped. The hydraulic, or, as it would more correctly be

called, the hydro-pneumatic buffer, introduced some years ago by General Clerk, R.A., late the Superintendent of the Royal Carriage Department, for existing garrison carriages, is not applicable in either of these two cases. Like the recoil press, already described, it consists of a cylinder fixed on the slide, and fitted with a piston attached to the carriage by a piston-rod. The piston is perforated with small holes, and when recoil takes place the water is compelled to pass through these holes from one side to the other, the friction thus caused arresting the recoil. The apertures being constant, while the velocity of recoil varies from 15 feet or 16 feet per second at the commencement to zero, the resistance varies excessively throughout the stroke, and the maximum strain, for which the strength of the parts must be calculated, is greatly above the mean. An air space is provided to lessen the violence of the first action, and to allow, by compression, for the displacement of the piston-rod entering the cylinder; but the buffer will not, of course, retain the carriage in any position on an inclined slide, nor will it restrain the movement of the carriage and gun within safe limits of speed under the influence of the motion of a ship; so that it cannot be used for sea service, except in conjunction with a frictional break of sufficient power to control the gun when being run out or in on its slide.

In the turret arrangement shown in Plate 25, Fig. 16, the carriage is placed upon permanent rollers, in view of the advantages of rapidity and ease of working already previously shown to result from dispensing with the operation of "tripping." In the same carriage the gun is made partially muzzle-pivoting, by hinging the slide at the rear horizontally, and raising and lowering the front end upon a press to three or more positions, in which it can be chocked by turning under it the bracketed supports. In 1867 and 1868 a partial muzzle-pivoting carriage was made at Elswick for an 18-ton gun, in accordance with the proposals of Colonel Inglis, R.E., who adopted the plan of raising and lowering the trunnion bearings of the gun in vertical grooves formed in the carriage. Captain Scott, R.N., has modified the arrangement, by the substitution of hydraulic jacks, in combination with chocks, for the screw-lifting gear used by Colonel Inglis, and by the application of the jacks to act from fixed positions in the slide or turret floor on a bow piece carrying the trunnions. In this form the system has been applied for heavy turret guns in the Royal navy. It makes the carriage, however, high and top-heavy, a disadvantage for naval service, which would become more serious with every increase in the weight of guns.

The object of "muzzle pivoting," or, more correctly, of "port pivoting," is the reduction of the size of the port. This object would be obtained sufficiently for most cases if the trunnions could be placed on the gun very close to the port, and the part of the gun which projects outside the port be lowered as the gun recoils. The arrangement shown in Fig. 17, and illustrated by the working model, is designed to effect this. At the same time, to enable exceptionally heavy guns to be carried with perfect security in a turret under any circumstances of weather and motion of the vessel, a carriage is dispensed with, and the gun is supported on three points, viz., on a pair of trunnions placed well forward, where the diameter of the gun is less than at the breech, and on a saddle under the breech itself. The trunnion arms rest in two sliding blocks, which run in guides on fixed beams, built on the floor of the turret. Immediately behind each block, in the direct line of recoil, are two hydraulic cylinders, for checking recoil and running the gun in or out. The cylinders are connected by a pipe, and have a common recoil valve, so that the two pistons must act in unison; and the guides on the breech of the gun running between the slide beams further insure the simultaneous movement of the pistons, by preventing any horizontal rotation of the gun with reference to the slide. The saddle which supports the breech slides along a beam or table beneath it. The front of the beam can be raised or lowered by an hydraulic press to give any desired elevation, but the rear is pivoted at a point corresponding to the horizontal position of the gun; consequently the gun returns always to the horizontal position as it recoils, whatever elevation it may be fired with, and clears the port in coming back. A curve is given to the beam or table to ease the shock which would come upon it when the gun is fired at elevation. A lifting press under the rear of the elevating table is required to depress the gun to the loading position in the arrangement described, but it is not an essential part of the system, and is dispensed with in the loading arrangement shown in Fig. 17. The waste of power due to sliding the gun, instead of running it on wheels, is wholly unimportant where steam power is available, and ample bearing surface can be obtained to obviate the risk of the rubbing surfaces seizing.

Upon the system of mechanical loading, adopted at Elswick for guns mounted in turrets, the gun is revolved and depressed to a fixed loading position, where it is sponged and the charge rammed home by hydraulic power. The shot is brought up to the loading place on a small railway truck, controlled by a friction plate,

which clamps it to the rails whenever the truck handle is lowered. It is then run on to a hoist, which rises between guides against stops, and brings the shot opposite the gun muzzle ready for being rammed home.

The hydraulic tube rammer (Fig. 18) consists of a parallel tube in which runs a piston and tubular piston-rod. The head forms a sponge for cleansing the bore, and contains a self-acting valve which opens when pushed against the end of the bore, and discharges a strong jet of water within the gun. In ramming home the shot, this valve does not act, because it does not then come in contact with the shot, owing to the form of the rammer head. Nor does the valve open in ramming home the cartridge, the resistance being sufficient to bear the pressure against the bag without yielding. The same form of rammer has been made telescopic, to reduce the length, and has been found to answer well.

The jointed rammer shown by Fig. 19 is designed for positions where there is not sufficient space for the tube rammer. It consists of a flat link chain, on each joint of which is a wooden roller of a size to fit the bore of the gun. The joint pins project and engage notches in a double disc wheel or drum, the turning of which sets the rammer in motion. The disc wheel may be driven by a crank handle, or by a chain from an hydraulic cylinder, or in various other ways. A flexible tube may be employed to enter the gun with the rammer and drench the bore with water, or a pipe nozzle may be arranged to throw a jet of water into the gun when brought into the loading position. A wad pushed home with the shot in either case prevents the latter from running forward when the rammer is withdrawn.

By the arrangements described the following advantages are obtained: The loading operation is transferred from a confined space and exposed position in the port of the turret to a roomy and convenient place on the main deck, where the apparatus is completely protected;—the dimensions of the turret are greatly reduced, the minimum size that will inclose the guns being all that is necessary;—one man in the turret and one outside may direct and control all the movements of a pair of the heaviest guns, and may load and fire them without other help than that involved in bringing up the ammunition;—and finally, far greater rapidity of fire is attainable than would be possible by manual power. A popular objection to this plan is the alleged liability to premature explosions in loading, and the risk of self-destruction to which it is said the ship is thus exposed. Now the gun need not be depressed for loading to such an extent as to aim a shot below the water line, and

a hole made in the side armour in the line of the axis of the bore would enable the shot to pass clear out, without endangering the vessel, in the event of the accident occurring; but the fact is, that although premature explosions occasionally occur in firing blank charges in saluting, they are hardly known with shotted guns. An inquiry recently made by the English Admiralty has only elicited one case, and that a doubtful one, out of 250,000 rounds fired during a period of seven years. A risk so minute, and furthermore provided for by a special arrangement for drenching the bore of the gun with water in sponging, can hardly be considered an objection. Such as it is, however, it is entirely removed by the arrangement shown in Fig. 17, in which the loading gear is placed under cover of a gallery or hood slightly raised above the upper deck, and the gun is so little depressed when in loading position that a shot fired from it then would pass clear out, and glance from the upper surface of the armoured deck.

The time required to turn a turret from firing to loading position would be very short. The turret of the 'Devastation' makes a full turn in forty-five seconds, and this speed might easily be increased if desired. A dial and indicator hand may be placed near the lever controlling the engine which turns the turret, to enable the attendant to mark its position, and a stop similar to that shown in Fig. 20 will arrest and lock it without undue strain. A railway swing bridge over the Ouse, constructed at the Elswick Works, under the direction of Mr. Harrison, President, of 800 tons weight, and measuring 250 feet over all, is turned, brought up, and fixed in proper line, with great ease and rapidity by the adoption of very similar means. The gun may be placed in loading position on the slide while the turret is revolving, and since a fresh charge and shot can be brought up immediately one has been pushed home, and while the gun is being laid and fired, no time is lost. As a matter of fact, the whole operation of bringing to loading position, sponging, loading, and placing again in firing position a 9-inch 250-pounder turret gun, mounted experimentally on this plan, at the Elswick Works, has been effected in twenty-three seconds; and there is no reason why that time should be much exceeded even if the shot and gun were five times as heavy. Two or three loading positions may be provided round a turret as reserves, and to enable that one to be selected which will keep the turret port out of the line of the enemy's fire.

Fig. 21 represents a loading arrangement similar to that previously described, but adapted for a gun mounted "en barbette" behind an earthwork or iron parapet. Here the platform revolves

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in place of the turret, and the loading gear and men working it stand in any convenient position in the rear, on a lower level than the gun platform, and completely protected by the parapet.

Fig. 19 shows the jointed rammer applied on a garrison platform in a manner in which it has been tried with success at the Elswick Works. In this case, as the rammer is fixed on the platform, there is no necessity for turning the gun to a definite loading position. The men engaged in loading remain under cover of the parapet, which may be of sufficient height completely to protect them as well as the loading gear; or the gun may be made to revolve sufficiently to allow of the loading being carried on, as in the last case, from a lower level within the parapet. On the present method of loading barbette guns by hand, the men have to mount upon the platform in full view of an enemy, and besides being exposed to shell fire, they become the targets for a rifle fire, which, owing to the precision and range now attained with rifles, will render it difficult to keep guns in effective action under such circumstances.

A plan suggested for the application of the hydraulic tube rammer to guns mounted in ironclad casemate forts, such as those at Spithead and at Plymouth, is shown in Fig. 22. Here the tube is overhead, and gives motion to a guided bar which passes out of the port, carrying at its end an ordinary rammer attached to it by a hinged stay. When done with, the rammer is thrown up over a hook above the gun, ready again for immediate use. In this case the gun is run in and trained to a fixed loading position, where the shot is raised on a hoist to the muzzle. The application of hydraulic power would enable these movements of the gun to be performed with ease and rapidity.

There is, however, no doubt more difficulty in the adoption of mechanical loading in existing casemate forts than in turrets or open earthworks. The size of artillery has so outgrown that of the existing forts, during the long time necessarily expended in their construction, that 38-ton guns have now to be mounted, if possible, in batteries originally intended for 12½-ton guns. But this fact renders it more imperative to dispense with manual power, because the heavier guns, while they further restrict the already limited space, require larger crews. The service by large numbers of men, of heavy guns closely ranged in confined casemates, tier upon tier, may tend to serious confusion in the heat of action; and the necessity of crowding men in time of war in isolated forts is of itself a grave evil. By substituting hydraulic for manual power for working the guns, nine-tenths of the men may be dispensed with, and the work may be done more coolly, more

rapidly, and more efficiently. Rapidity of fire is nowhere of greater importance than in the case of guns designed to prevent the passage of swift steamers past fixed batteries; and economy of men is a vital consideration in the defence of a coast so extended as that of the United Kingdom. It is said that already far more guns are mounted than can be manned. Modern artillery can only be worked by highly trained men, whom it would be impossible to produce upon short notice. Nor could a small force be made effective by activity in shifting to threatened points, for the attacks of steam fleets will be sudden and unexpected, and can only be met by preparation at all points.

The introduction of mechanical loading has an important bearing upon the question of the comparative merits of breech and muzzle-loaders. One of the chief advantages claimed for breech-loaders is that any length of bore can be given without increasing the difficulty of loading, and that, therefore, a higher duty can be obtained from the powder in a breech-loader than in a muzzle-loader of a length necessarily limited by the consideration of convenience of loading. It is also argued that men when loading the breech-loader are partly covered by the gun instead of being exposed at an open port as when loading the muzzle-loader. The mechanical methods described for loading at the muzzle neutralise these advantages, for it is evident that the stroke of the machine rammer may be increased without difficulty to meet any desired length of bore, and the loading gear together with the men working it are completely protected by the armour or parapet which protects the gun, whereas the shelter afforded behind a breech-loader by the gun itself is partial and inadequate. On the other hand, the breech mechanism of a heavy breech-loader involves complication both in construction and use, and the opening and closing of the breech requires considerable time, as may be inferred from the fact that the strain to be borne by the movable breech block of a 15-inch gun on Mr. Krupp's plan, assuming the powder pressure not to exceed 20 tons per inch, would be about 4,000 tons, and the weight of the block itself about 3 tons. Nor must it be assumed that the space required for loading a heavy breech-loader is inconsiderable. Room is wanted for the charge and rammer behind the gun and for the loading mechanism. In designing at Elswick a turret for two 70-ton breech-loaders of 15 inches calibre and 22 calibres in length, to compare with one for two muzzle-loaders of the same size, it has been found that whereas an internal diameter of 26 feet suffices for the two muzzle-loaders, a diameter of not less than 32 feet is

required for the breech-loaders. Fig. 23 shows the plan upon which the breech-loaders are arranged in this case, and it will be seen that space has been economised by making the rammer telescopic, and fixing it in such a manner as to be swung aside out of the way of the gun on recoil. The corresponding arrangement of the two muzzle-loaders is shown in Fig. 17.

The principle of sinking guns entirely under cover from horizontal fire behind any sufficient parapet, and raising them only to deliver their fire, possesses the great advantage of making earthwork defences available. Whatever thickness of armour be used, it may be predicted that it will in time become obsolete. All defences must yield to continued attack; an iron fort seriously injured could scarcely be made good before the end of a war, and only then at great cost. It is the especial merit of earthwork that it may be easily strengthened and adapted to new circumstances, and that it may be repaired almost as fast as it is destroyed. Two forms of gun-carriage, adapted for this system of protection, have been proposed by Major Moncrieff, M. Inst. C.E., the principle of both being the storing and utilisation of recoil. In the carriage (Fig. 24) tried and adopted by the English government, the gun on delivering fire and sinking raises a counterweight, the fall of which again lifts the gun when required. In the later invention the same object is sought to be attained by substituting for the counterweight the elastic force of air compressed by the recoil through the medium of water. Messrs. Sir W. G. Armstrong and Co. have endeavoured to carry out this later proposal for a 9-inch 12½-ton gun, mounted on a gun-boat of the *Staunch* type. The model will give an idea of the mechanical part of the apparatus. The air vessels, not shown, stand immediately in rear of the lifting cylinders. Careful investigation and calculations were made to adapt the volume and pressure of the air to the work to be done throughout the rise of the gun, and all unnecessary friction was studiously avoided. Fig. 25 shows the calculated work, and the corresponding air pressure at every point of the gun's motion. Notwithstanding every precaution, however, to avoid loss of power, it was found that the force of recoil was not efficient for the purpose. The principle was therefore abandoned, and steam pumps were employed for raising the gun, in combination with an arrangement for checking its recoil and descent, similar to that already described in reference to the hydraulic apparatus of slide carriages.

The economical value of utilisation of recoil is insignificant where steam power is available. Less than 1 lb. of coal is ex-



pended in raising the 12½-ton gun into firing position in the gun-boat, and 6 HP. enables it to maintain a continuous fire of one round per minute. The main object to be attained by the utilisation of recoil is to make of each gun-carriage a machine complete in itself, and independent of any connection with other machinery for producing the required power. In a system, however, of hydraulic gun-carriages, supplied with power from steam pumps, the connection between the carriage and the source of power is of the simplest kind, consisting only of a small pipe, which may be furnished with a stop-valve, and thus enable the power to be turned on or off, with nearly as much facility as a jet of gas. As there is no limit to the amount of power that may be conveyed, so there is no restriction of the height of cover obtainable—an important point in the employment of earthwork as a protection for guns, since the crest of the parapet may easily be cut down. Fig. 26 represents a design for mounting a gun of 12½ tons weight to be raised to firing position by hydraulic power. It will be seen that it lies a long way below the crest of the parapet, and protected from all shot whose angle of descent does not exceed 25°. A line in the drawing indicates the path of a shot entering the battery at that angle.

It is a question how far the principle of a disappearing gun is applicable to ships of war. In vessels of low freeboard, liable to have their decks frequently swept by the waves, an open barbette battery could not be worked in a rough sea. A proposition has been made that the gun should rise and fall through an aperture in the deck closed by sliding or hinged doors, to be opened only for the protrusion of the gun. Such devices may be objected to as being liable to be disabled in action, in which case the ship would incur great danger of sinking by the admission of water through the opening. Another plan has been suggested by Mr. Barnaby, viz., to inclose the gun in a thin plate turret, supported on and revolving with the gun platform, and carried up through the deck sufficiently high to allow the gun to rise under it, and deliver its fire through a port, as in an ordinary armoured turret. For vessels, however, like the 'Devastation' and the 'Fury,' carrying their guns low—as all first-class ironclads may probably continue to do to admit of the limitation of their surface and consequent weight of their armour—the turret appears still to afford the best means of carrying the guns. Where sail power cannot be dispensed with, as in a vessel, like the 'Temeraire,' designed for cruising, and a high deck is consequently a necessity, the case is different. Mr. Barnaby has designed for the 'Temeraire'

a barbette battery composed of a detached belt of armour supported at the level of the upper deck by a thin iron skin, which may be freely perforated by shot without losing its power of supporting the battery. In this case the battery, though open, is so high above the water level that a sea could scarcely enter it, and the advantage of all-round fire is realised in a situation in which a turret could not be used. The model represents a 38-ton gun designed for such a situation, to be worked on the disappearing principle by hydraulic machinery upon the methods already described, the water power being conveyed into the battery by a small pipe carried up from a pumping engine below through the armoured shaft which gives access to the battery. The jointed rammer is used for the purpose of sponging and of ramming home the charge, which is brought up the armoured shaft from below to the muzzle of the gun by a hydraulic hoist. The movable cover and deck are added to illustrate the adaptation of the system to vessels of low freeboard.

In the earlier applications of Sir W. G. Armstrong's hydraulic system, instead of the weighted "accumulator" now generally adopted, air vessels were used as accumulators, and they are still retained in some special cases, including those in which hydraulic machinery is employed afloat, when, from the motion of the vessel, the ordinary weighted accumulator would be inconvenient. It may be desirable to retain the weighted accumulator as part of the hydraulic system for land service; but in applying the system to sea service an accumulator can be dispensed with. Steam power unlimited in comparison with that required for working the guns is always available in modern ships of war, and the main engine boilers are reservoirs and accumulators of power so greatly exceeding what is required for the hydraulic machinery, that they may be drawn upon practically to any desired extent without affecting the main engines. An air vessel is undesirable on several grounds. It renders air-pumps necessary, and otherwise adds complication in construction and use. The regulation of the volume and pressure of the air requires constant attention, and it is apt occasionally to collect in pipes, and by its elastic action interfere with the control over the motions of the gun. It also renders the breaking of a pipe a more serious accident. On all these grounds it is contemplated to dispense with accumulators for hydraulic apparatus on board ship, and to pump direct upon the machinery, employing small steam engines of a form specially adapted to run when required at very high speeds, and so upon small dimensions to develop a very high power during the short periods in which it is required.

In conclusion, the Author desires to point out that this Paper is to be regarded as a *résumé* of the experience and practice of the Elswick firm, and not as a history of the subject. The labours of others in the same field are in some cases not even mentioned, and in others only very partially noticed. The names of Captain Scott, R.N., in particular; of General Clerk, R.A.; of Colonel Inglis, R.E.; of Colonel Shaw, R.A., and of Mr. Cunningham, as well as that of Major Moncrieff, are inseparably associated with the development of the mechanical appliances for working heavy ordnance, although the Author has not taken upon himself to define their respective shares in that development.

The Paper is illustrated by a series of drawings and diagrams, from which Plates 24 and 25 have been compiled.

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[The Rev. J. WHITE, M.A.]

GUN CARRIAGES  
AND MECHANICAL ARRANGEMENTS FOR WORKING HEAVY ORDNANCE.

PLATE 24.



