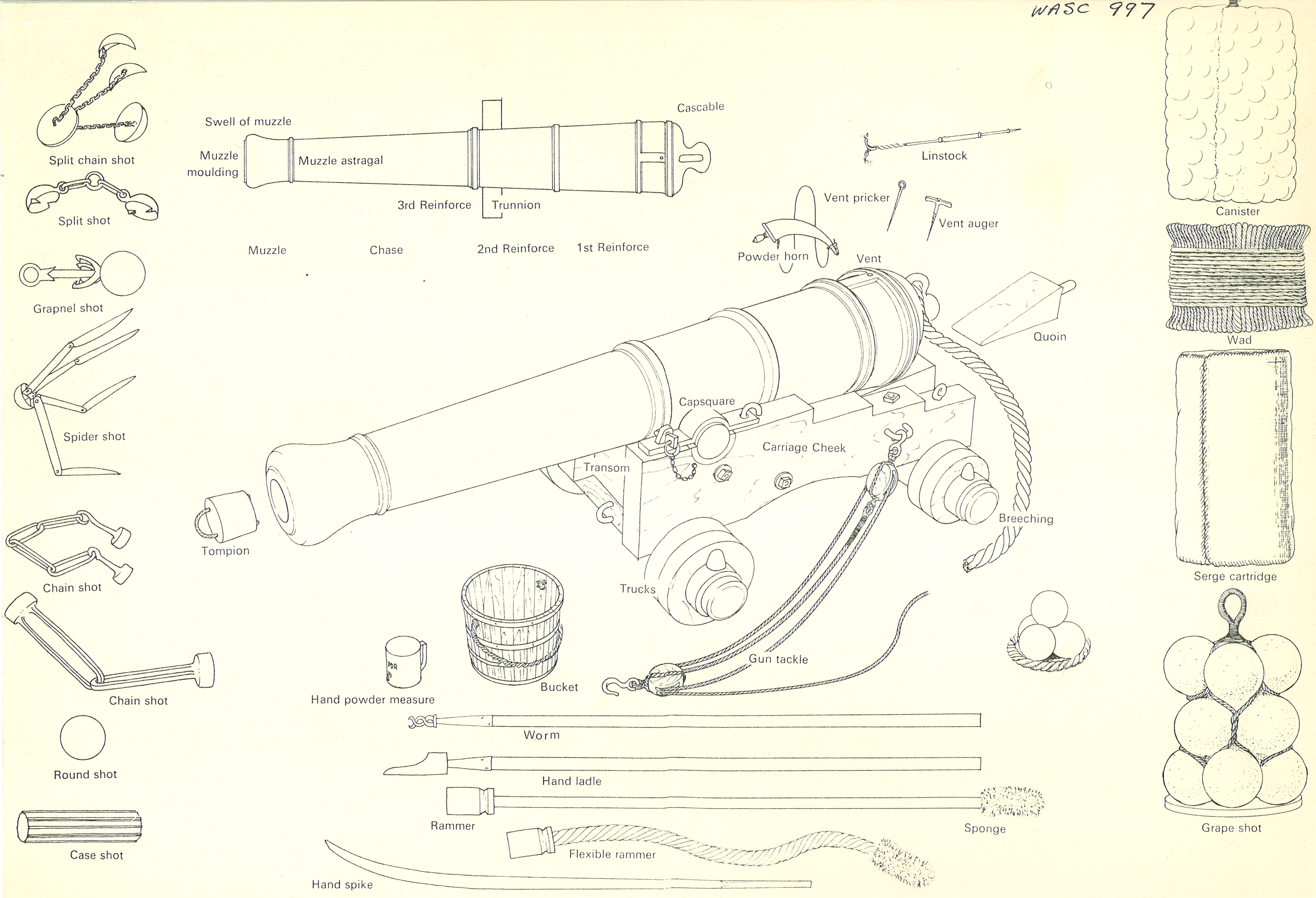
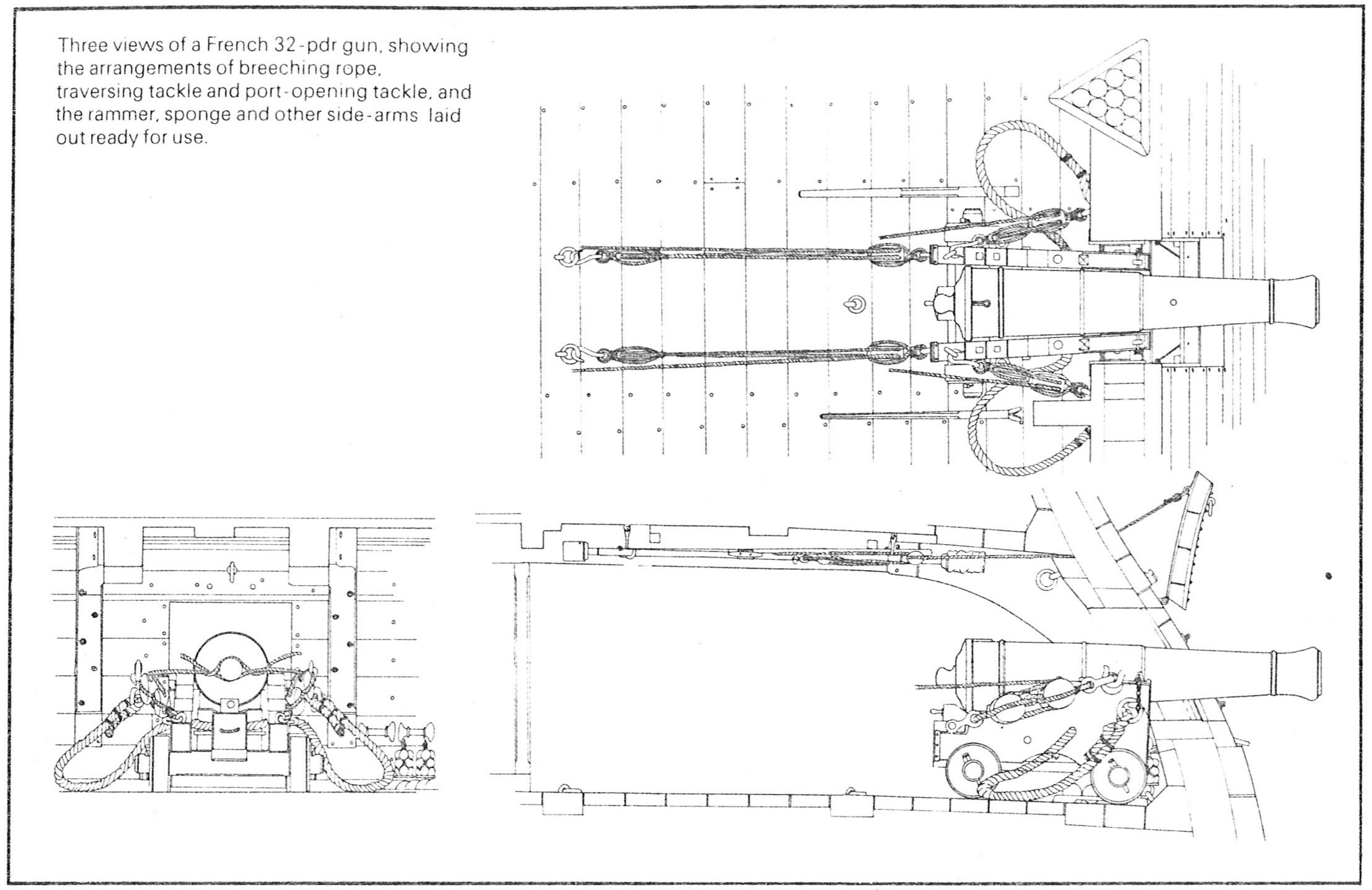

Split chain shot
Split shot
Grapnel shot
Spider shot
Chain shot
Chain shot
Round shot
Case shot
Swell of muzzle
Muzzle moulding
Muzzle astragal
Cascable
3rd Reinforce
Trunnion
Muzzle
Chase
2nd Reinforce
1st Reinforce
Linstock
Vent pricker
Vent auger
Powder horn
Vent
Quoin
Capsquare
Carriage Cheek
Transom
Tompion
Breeching
Trucks
Gun tackle
Bucket
Hand powder measure
Worm
Hand ladle
Rammer
Sponge
Flexible rammer
Hand spike
Canister
Wad
Serge cartridge
Grape shot

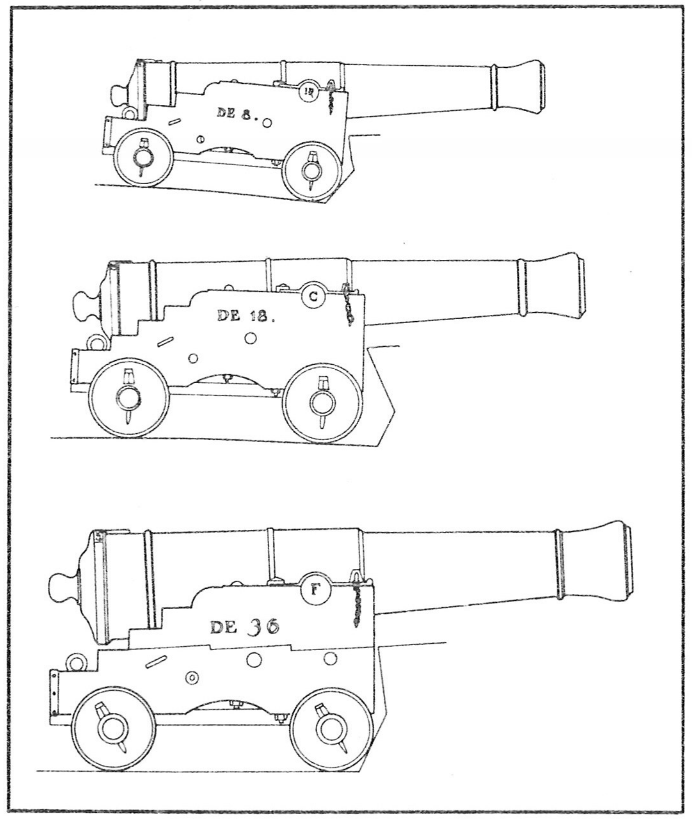


Three views of a French 32-pdr gun, showing the arrangements of breeching rope, traversing tackle and port-opening tackle, and the rammer, sponge and other side-arms laid out ready for use.

seventeenth century the lists of ship ordnance still showed a variety of weapon, but it was not so divergent as it had been at the time of the Armada. Charles I's great *Sovereign of the Seas*, launched in 1637, carried twenty 'cannon-drakes' on the lowest broadside tier, thirty culverins above, and thirty demi-culverins on the open deck. The cannon-drake was a lightened form of full-calibre cannon.

By this time though, there had been a slight change in tactics, Instead of opening fire at extreme range so as to keep the enemy away, the aim now became to close to 'point-blank' range and then fire the entire battery in one salvo; this produced an enormous moral effect at the target and, since 'point blank' was no more than about 250 yards, the shot were delivered with sufficient remaining velocity to smash the timbers of the target ship and envelop the enemy crew in a cloud of jagged splinters, inflicting frightful wounds. The only difficulty with this system was that the enemy, of course, had similar views, which led to the spectacle of two ships, some two hundred yards apart, blasting each other with broadsides until one or other had sustained so much damage that the fight came to an end. This called for the highest possible discipline from the gun's crews, to withstand the enemy shot, load and serve their own guns, and be ready to discharge their broadside when the time came.

While this may have been a satisfactory tactic for those days of 'wooden ships and iron men', it could hardly be said to have advanced the cause of scientific gunnery. 'Point Blank' can best be defined as that range at which the strike of the ball is in prolongation of the gun's axis, before gravity has begun to have much effect, and thus is never more than one or two hundred yards. Using this as



Comparison of French 8-pdr, 18-pdr and 36-pdr sea service cannon of the seventeenth century, mounted upon truck carriages.

the standard engagement range – and some authorities laid down even lesser ranges – meant that little in the way of refinements of sighting or ballistics might be expected, since the worst cannon could hardly fail to miss or to do damage, and little in the way of skill was called for on the part of the gunner.

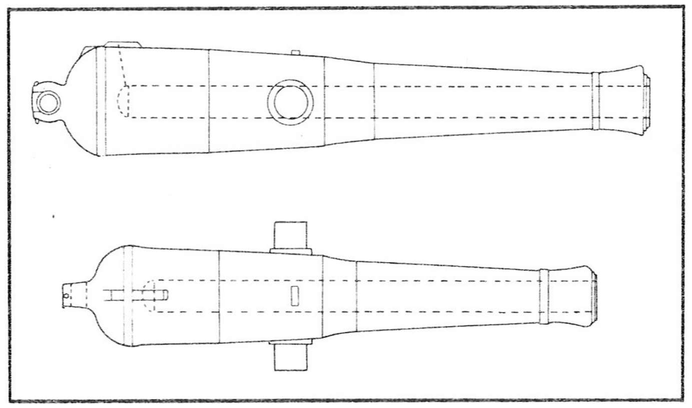
However, there were sufficient people interested in scientific gunnery to ensure that the matter did not entirely die. In 1707 Benjamin Robins was born of a Quaker family in Bath and became a teacher of mathematics. This led him to consideration of the motion of bodies through the air, and from this he progressed to a close examination of gunnery. At that time, gunnery was entirely an empiric art; some text-books had been written, it is true, but for the most part they were theoretical papers based on little more than hearsay and speculation. Some practical gunners had published guides which explained that certain measures were necessary – that, for example, if one carriage wheel was higher than the other then the gun had to be 'aimed off' to compensate – but they never attempted to explain the reasons for their recommendations. Those who did attempt to advance reasons were usually basing their arguments on precedent texts, without having actually performed any practical firings to bear out their claims. The basic theory was that a shot travelled in a parabola from the muzzle to the target and that the resistance of the air could be neglected.

Robins set out to prove or disprove these theories by actually firing guns; since it appeared impossible to actually measure the performance of a cannon shot in a direct manner, he reasoned that if it were possible to transfer the energy of the shot to something more amenable to measurement, much would be thereby discovered. He therefore invented the 'Ballistic Pendulum', a framework in which was suspended a pendulum bearing a heavy baulk of timber at its free end. Attached to the bottom of the pendulum was a measuring tape running past a marker. A cannon was set up at a distance from the pendulum and fired so that the ball struck the baulk of timber and thus transferred its energy, causing the pendulum to swing and the tape to be moved past the index. Since the weight and length of the pendulum were known, knowledge of the distance it had moved enabled Robins to calculate the striking velocity and energy of the ball. By performing the experiment at various ranges, he was then able to determine the loss of velocity as the range was increased and from this to derive a formula which took into account both the resistance of the air and the effect of gravity. He went on to determine the differences in velocity which came from varying charges and gun lengths, and, most remarkable of all, he pointed out 'a most extraordinary and astonishing increase in the resistance of the air which occurs when the velocity comes to be that of between eleven and twelve hundred feet a second.' He had, of course, discovered the sonic barrier, and he was astute enough to correlate this velocity with the speed of sound, though he lacked the instruments to take his surmise any further.

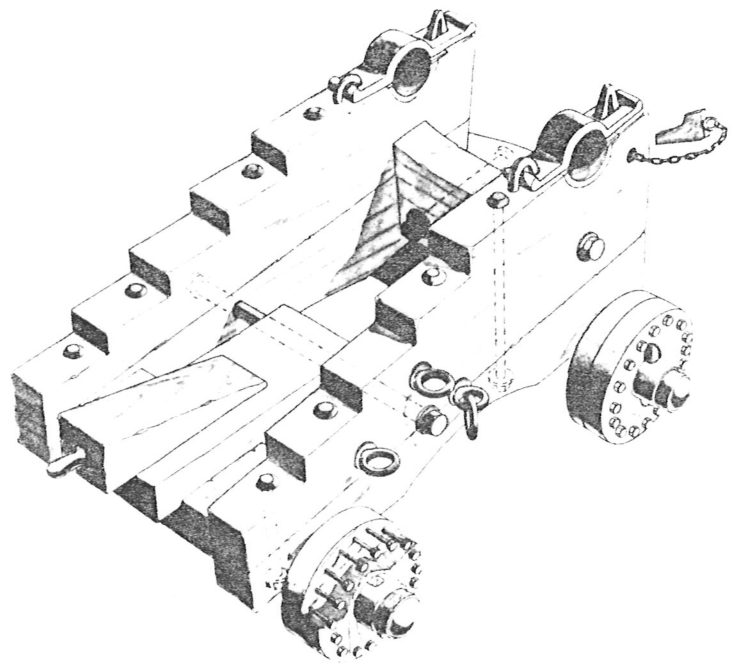
In 1743 he read his paper 'New Principles of Gunnery' before the Royal Society and revealed the results of his labours. It provoked considerable discussion among the learned, but it would be fulsome to say that it revolutionised gunnery overnight. Nevertheless, it at least made people begin to think, Robins as much as the rest, and in 1747 he published 'A Proposal for increasing the strength of the British Navy by changing all guns from 18-pounders downwards into others of equal weight but of a greater bore'. Here, he was asking for a reappraisal of the traditional methods of designing ordnance or, in his words, 'a better redistribution of the metal'; in other words, to take the same amount of metal but use it to make a gun in which the thickness of the barrel walls was worked out according to the strain to be placed upon them. A result of this would be to lower what we know today as the 'factor of safety' to a more practical figure and thus, for a given weight of metal, finish up with a gun of greater calibre. In urging this upon the Navy, Robins pointed out that a larger and heavier shot would range further, and have a better striking force, would make a bigger hole and would have better powers of penetration. By his plan of 'redistributing the metal' the ship would carry the same deadweight but would have more efficient artillery.

This paper got a more receptive hearing from the Royal Navy, largely because a recently captured French ship had yielded papers which indicated that the French seemed to be thinking on much the same lines. But apart from some experiments to confirm Robins' theories and conclusions, little more was done, since the French seemed to be afflicted with the same lethargy.

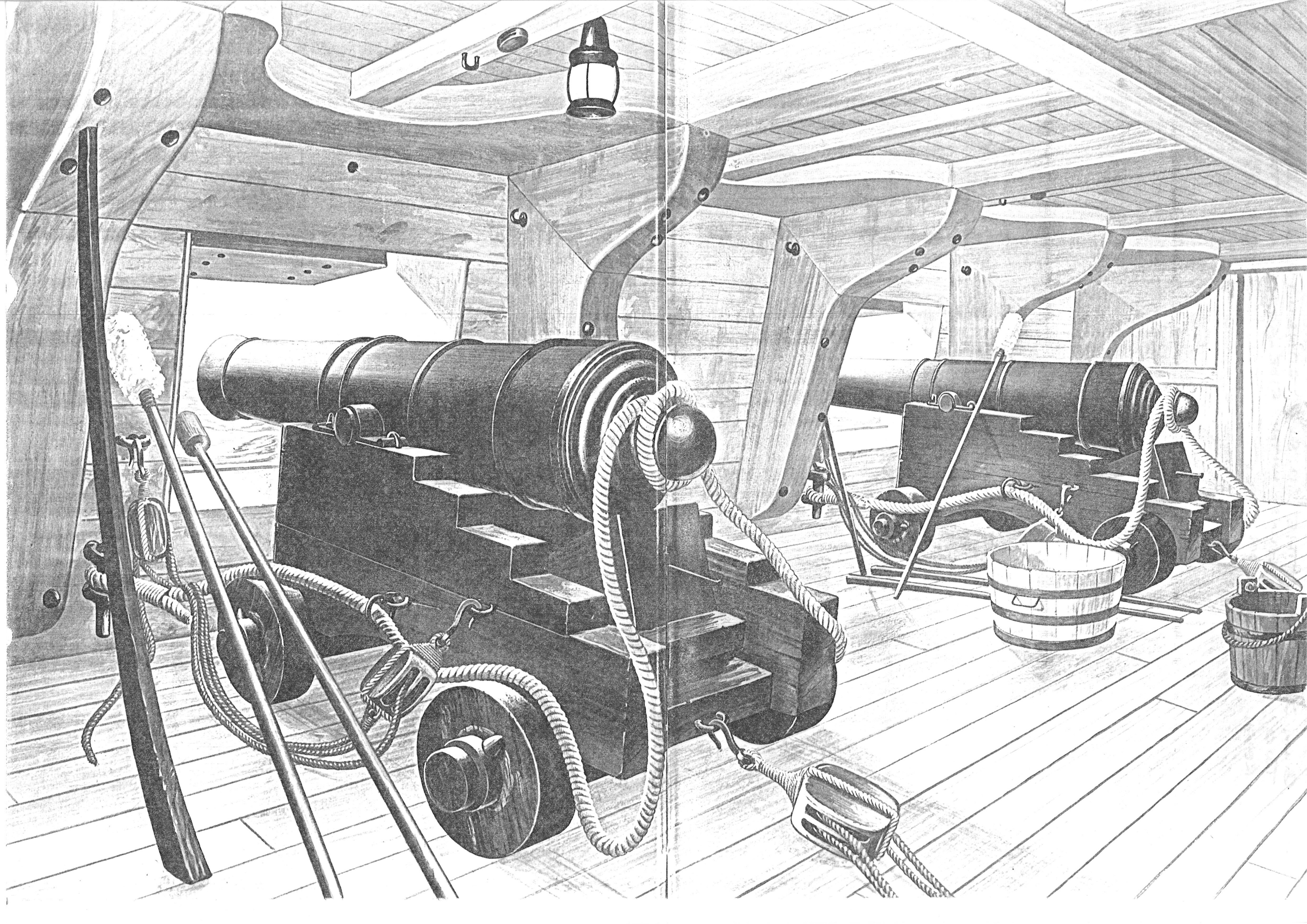
It remained to a private individual to make the first step away from the now-traditional cannon. In 1778 the Carron Company, a Scottish ironworks which owned a small fleet



Drawings of the English 32-pdr of 42 cwt (*top view*) and of 57 cwt (*side view*) showing the bore outline, vent, and positioning of the trunnions.



Standard truck carriage, showing the method of construction.



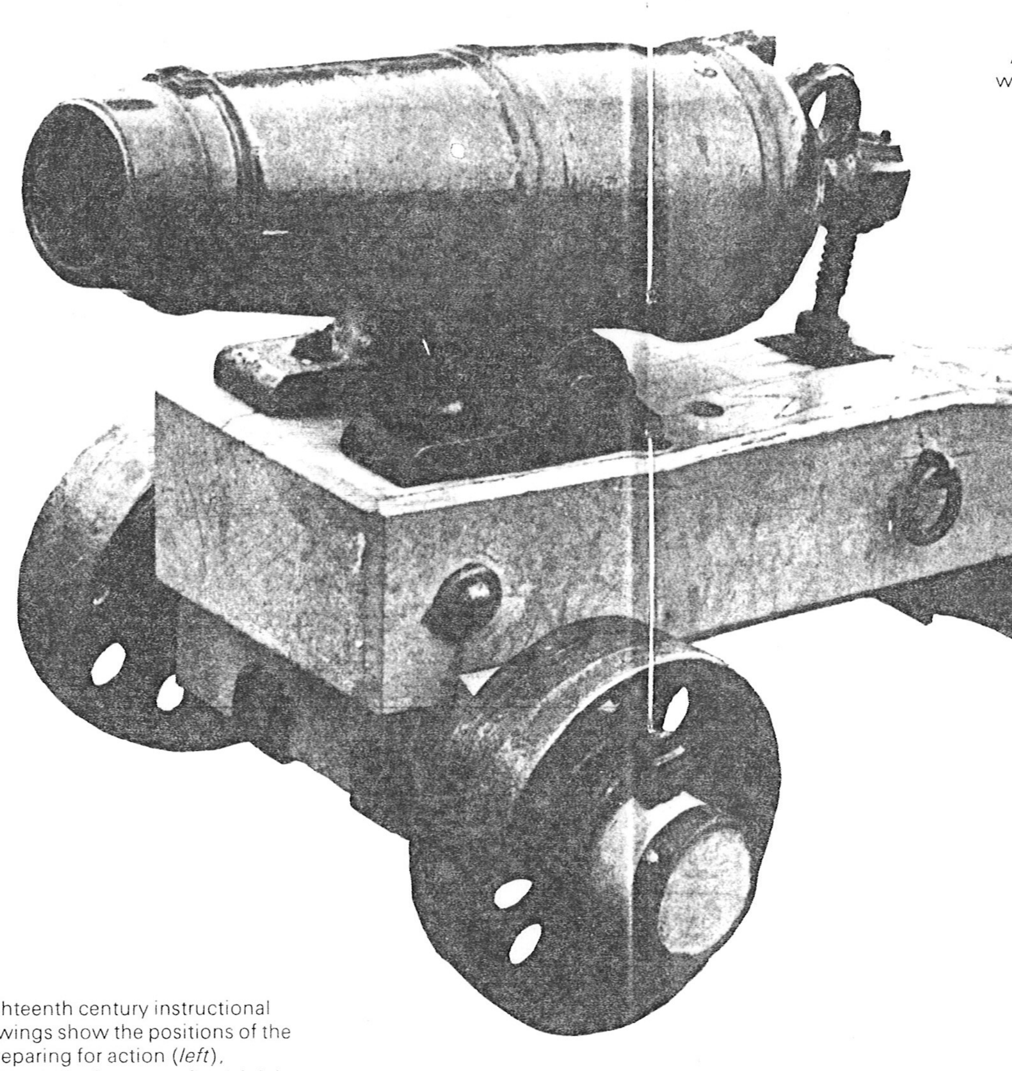
GUN DECK OF THE "U.S.S. CONSTITUTION" SHOWING TWO 24-PDR GUNS WITH SIDE-ARMS AND TACKLE READY FOR ACTION fact remains that it was completely ignored in official tables of armament; one reason for this was that to tamper with the listed armament of a ship was to cause it to be re-classified as to its 'rate', and this led to all sorts of complicated adjustments to the crew strength and equipment of the ship. It was far easier to keep to the 'approved armament' of long guns when calculating rates, and let the carronades, as it were, take care of themselves.

The mounting of the carronade also broke new ground. Instead of the standard ship carriage, except for one or two of the first-made, the carronades were not given trunnions, but had a lug cast in the lower part of the barrel which was anchored to a 'top carriage', a simple sled of wood which was free to slide across the top of a truncated truck carriage firmly bolted to the ship's side. The rearward movement of the top carriage across the lower carriage was restricted by breeching ropes attached to the front of the lower carriage and roved through the 'cascable', the ring-and-knob formed at the rear end of the gun. The carronade was prevented from jumping free by a vertical bolt passed through the top carriage and engaging in a slot in the lower carriage; unfortunately, if the breeching rope was not properly adjusted, or stretched during an action, this bolt was driven hard against the rear of its slot and usually broke, rendering the equipment useless until it could be repaired.

The carronade had some spectacular successes in its early days. In 1782 the *Rainbow* was officially armed with a variety of carronades up to 8-inch calibre by order of the Navy Board and by way of trial. In the course of a cruise she came up with a French frigate, the *Hébe*, which was armed with conventional long cannon and which could, had its captain known better, have stood off and battered the *Rainbow* into submission. But *Rainbow* decoyed *Hébe* into close range and then fired a broadside of carronade, ending the action almost before it had begun. *Hébe* surrendered, and the carronade grew in popularity.

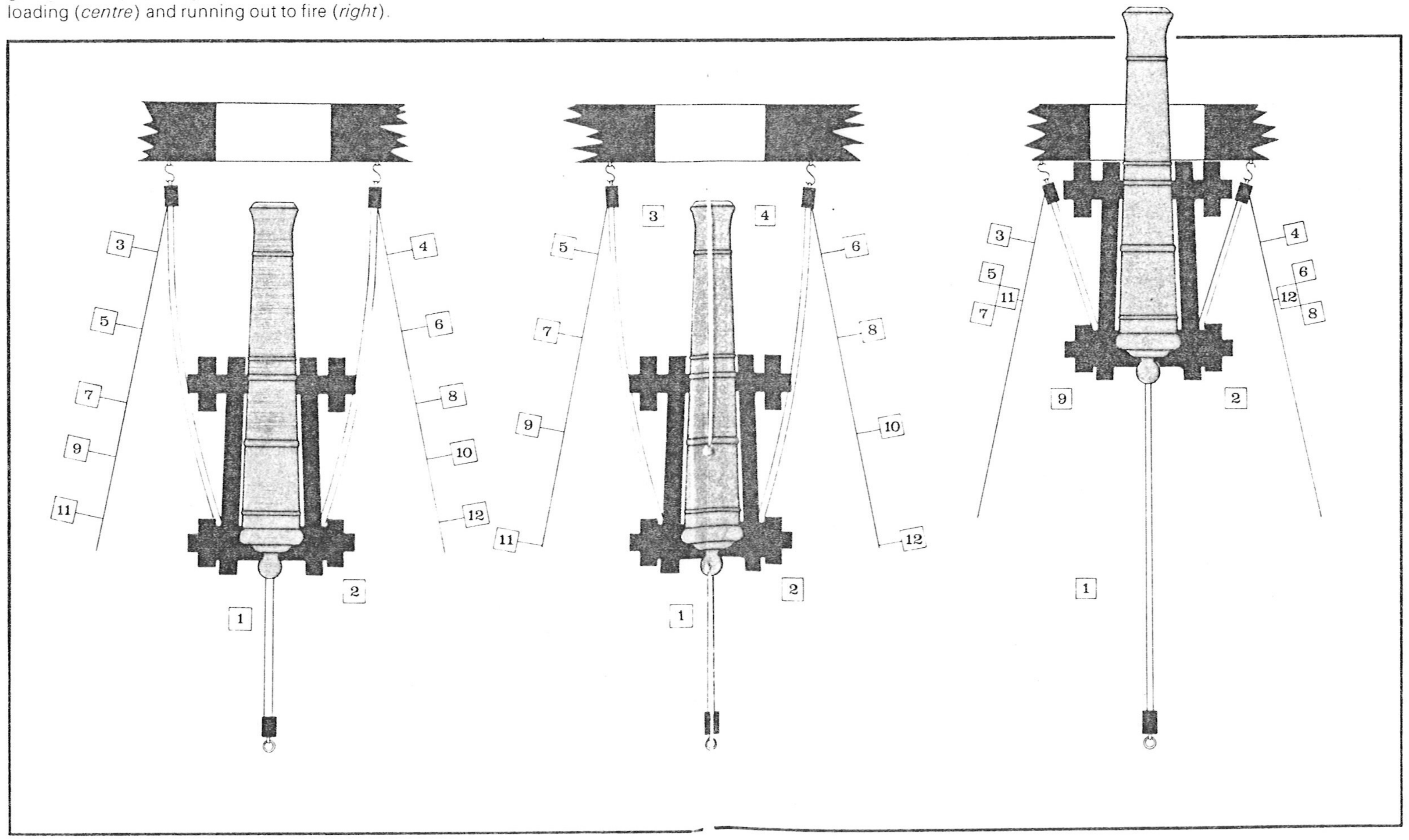
One drawback of a smoothbored gun firing a spherical shot was that the weight of the shot was constant for a given material, and in an endeavour to obtain the highest possible velocity from the short carronade, hollow shot were developed. These, being lighter than solid shot, attained a greater velocity and thus a greater striking force over the short ranges used. It is remarkable that, except for some minor experiments performed in the early carronade days by Melville, there seems to have been no suggestion of taking the projectile a step further and developing an explosive shell. Remarkable because the explosive shell was no mystery by this time. As early as 1682 the French developed a special vessel to fire explosive shells against land defences, the 'bomb-ketch'.

In the seventeenth century the chances of a ship, armed with shot-firing cannon, doing much damage to a land fort with granite walls, was relatively small. So when Admiral Du Quesne took a fleet to bombard the pirates of Algiers in 1682 he sailed with a number of 'galiotes à bombes' designed by an inventive Basque called d'Elicagaray. The ship was specially strengthened and broad in the beam, and was provided with only two masts, in the centre and stern. The forward section was left clear for the mounting of one or more mortars; these were short-barrelled, high-angle muzzle-loaders, borrowed from land



A carronade mounted on an unusual carriage which resembles the 'Marsilly' pattern in being supported at the rear end by a block.

Based on an eighteenth century instructional book, these drawings show the positions of the gun's crew in preparing for action (*left*), loading (*centre*) and running out to fire (*right*).



service where they were commonly used in siege warfare. The bomb weighed over 200 lb and, since recoil is proportional to the weight of the projectile, the downward thrust, or deck blow, when the mortar fired, was considerable. To alleviate this and avoid excessive damage to the vessel, the deck was strongly reinforced with beams, and the space beneath the mortar was packed tightly with old rope so as to give an elastic cushion to the blow.

Algiers was devastated by the new weapon; over 700 were killed, the town set ablaze, and the pirate forts destroyed. Delighted by this, Louis XIV ordered the fleet to Genoa in order to deal out retribution for their aiding the Spanish fleet against the French, and 14,000 bombs duly ruined Genoa. Possession of these bomb ketches gave the French Navy complete mastery of the Mediterranean area, and as the news spread, so other navies took up the idea, and they proved to be particularly useful in the Baltic in later years.

With this corpus of experience with explosive shells, it is thus the more surprising that the shell and the carronade were never brought together, since it would seem a short step from having a hollow shot and boring a hole in it to allow the insertion of powder and a fuse. It would seem, though, that the trouble lay not in ballistics but in simple housekeeping; the bomb-ketch was a specialist vessel, in which more-than-ordinary care could be taken of the bombs. A ship of the line carried more men, more guns and more stores and, proportionally, had less space available to set aside as a magazine. The chances, therefore, of accident befalling a ship of the line with a stock of explosive shells on board was considered to be far too great to justify the tactical advantages which might accrue from their availability in a fight.

Another argument advanced was that the explosive shell was really only suited to the attack of land defences and was not a useful seagoing projectile. This was refuted fairly easily by pointing to the activities of Sir Samuel Bentham and the Russian fleet; Bentham had been a shipwright at Deptford and then went to Russia to organise the Tsar's navy. He later returned to England to become Civil Architect and Engineer to the Navy and be knighted, but during his Russian days he equipped a flotilla of small boats for an attack on the Turks in 1788. The armament was brass cannon and mortars, and the projectiles were explosive shells and 'carcasses', lightweight spheres filled with incendiary material. In the Sea of Azov, Bentham's small fleet of insignificant boats attacked a much larger Turkish array and tore them to pieces, the explosive shells blasting holes in the Turkish ships and the carcasses igniting the wood and pitch of the hulls with spectacular effect.

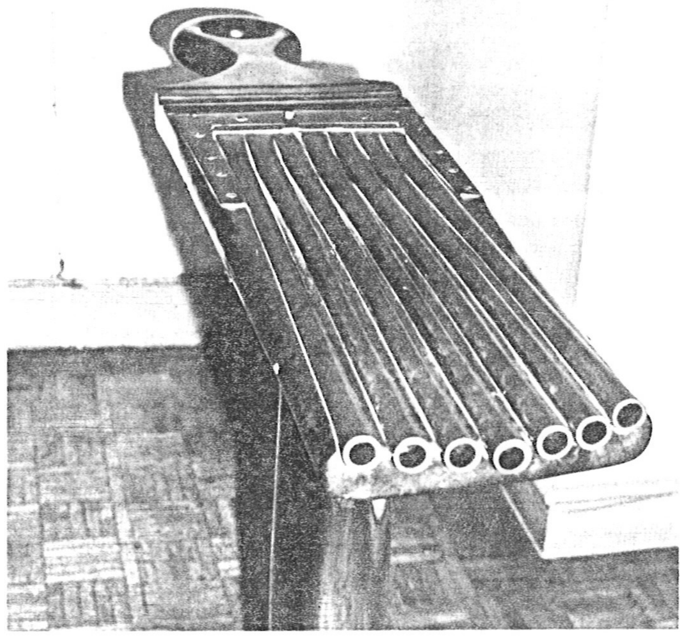
In spite of this outstanding victory, the shell idea was slow to permeate among the naval minds of the time, but it eventually took root in the French Navy. The Napoleonic Wars were a bad time for the French at sea; while their ships were acknowledged to be among the best afloat, the English fleet had a superiority of artillery, both in *matériel* and handling, which outweighed any advantage possible from manoeuvre, and the French were therefore casting about for some technical improvement which might be employed to their advantage. The English for their part were anxious to preserve the status quo; as one historian, writing in 1837, observed: 'So long as foreign powers did not innovate by improving their guns, by extending the use of carronades, and, above all, by projecting shells horizontally from ships; so long it was our interest not to set the example of any improvement in naval ordnance . . .'

In 1795, therefore, the French Navy began making experiments with shells fired from cannon, firstly at wooden butt targets at the Toulon naval base, and later, at Meudon at a target built to represent a British ship of the line. The 18-, 24- and 36-pounder shells were fired at ranges of 400 and 600 yards, and the results were sufficiently encouraging to justify provision of 36-pounder shells for the principal French ships. At the same time incendiary carcasses and hand grenades were developed, the latter to be furnished to the men in the fighting tops in order that they should throw them down on to the enemy's deck when the ships were at close quarters.

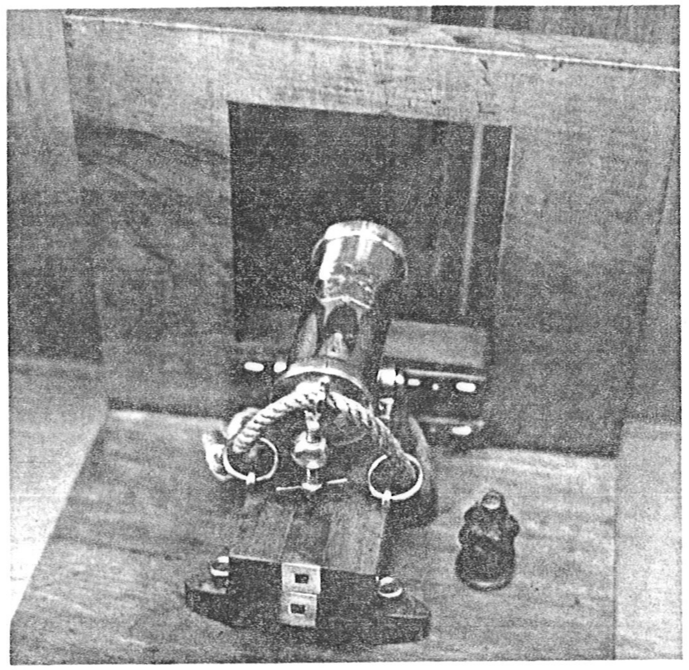
The results tended to strengthen the arguments of the more conservative English captains; as one historian has written 'The history of [the French] navy in these wars is lit up from time to time with the conflagration of their finest ships . . .' When they were not being set afire by spontaneous combustion or accident, then any damage inflicted 'legitimately' in the course of battle could soon be escalated into a major disaster when the flames found the stores of combustible and explosive projectiles; one of the most famous instances of this was the destruction of the French flagship *Orient* at the battle of the Nile.

The French, however, persisted with their researches after the war had ended, spurred on by the unfortunate result of the war and the hope of, at some time or other, neutralising the British supremacy at sea. Much of the work was done by a soldier, General Paixhans, who put forward some unusual but compelling arguments. In the early 1800s the steam engine had been applied to the propulsion of ships, with varying degrees of success, and Paixhans was acute enough to see that the prospects of a steam warship held out special attractions to the French nation. England had a large seagoing population and a tradition of the sea which was of advantage to them in time of war; France, on the other hand, was predominantly agricultural and had no comparable sea-going tradition. Sailors could be and were provided in time of war, but, said Paixhans, they did not have that mysterious affinity for the sea possessed by the English, and they therefore demanded more training and never attained the same proficiency in handling ships. The steamship, however, required none of this mystique of wind and waves; it was an engineer's ship and could be competently handled without having to rely on something as intangible as tradition. Possession of a steam navy would therefore place the French, if not at an advantage, then certainly on a par with any other nation.

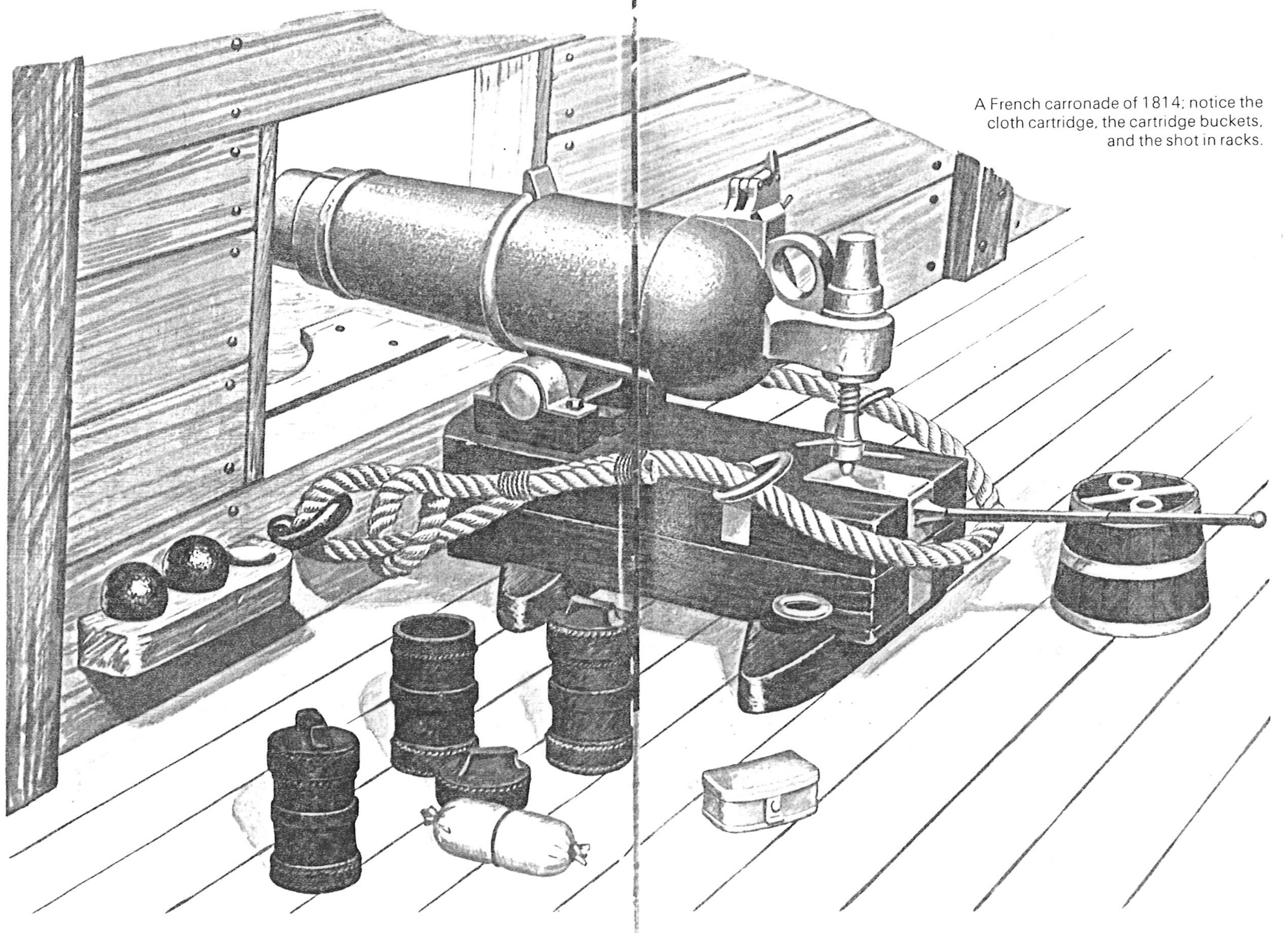
Given this as a foundation, the next obvious step was to make an equally significant improvement in armament so that the combination of steam and armament would give the French a total advantage over the English fleet. And since Paixhans appreciated that the day of the all-steam fleet was still some way off, he urged that, at least, his ideas on armament be adopted so that the system would have been tested and perfected by the time the steamship was ready for it. And his solution to the armament prob-



A seven-barrelled 'organ gun' which could be touched off to give a seven-shot salute to boarders from its position on the fore or after castles.



A model of a French 'Canon Obusier de 36' mounted on a modified carronade carriage and arranged for broadside firing.



A French carronade of 1814; notice the cloth cartridge, the cartridge buckets, and the shot in racks.

lem was the adoption of shell-firing ordnance, allied to a rationalisation of calibres.

For some years there had been a tendency to increase the armament of ships by developing guns of greater calibre; as the ships became larger, so heavier weapons could be carried and, obviously, the heavier the gun the better effect it had on the enemy. On the other hand, it meant a multiplicity of calibres on board any one ship, which in turn led to supply problems and questions of apportioning the magazine space between the various forms of armament. Paixhans proposed adopting the same calibre throughout a ship's entire armament, but varying the weight and power of the guns. Thus, for example, 8 inches might be taken as the standard calibre; the main battery would be heavy 8-inch guns firing powerful charges, while the lesser batteries would be provided with shorter or lighter guns firing lighter charges. Only one calibre of ammunition need be carried, so that there was no fear of the main deck battery running out of ammunition and having to rely on lighter weapons to fight the battle, and since the 'rationalised' calibre was to be the largest calibre, the total firepower of the ship, expressed as shot weight, became much greater than before.

The adoption of such a plan with shot-firing guns was not entirely commendable, since the lighter weapons would have had to fire their shot at such low velocities as to lose much of the range and penetration capability which was so desirable with solid projectiles. But, said Paixhans, if the guns were to fire explosive shells . . . He then went on to explain that penetrative power was not necessary with this type of projectile; provided it was discharged with sufficient force to lodge into the timber of the enemy, its subsequent explosion would do far more damage than could a plain shot, and without demanding powerful ordnance, heavy charges and uncontrollable recoil. Since recoil was less, and the charges lighter, re-loading would be quicker and a faster rate of fire would be attained, leading to a greater volume of shell being poured into the unfortunate enemy.

One last proposal came from Paixhans' nimble pen; that one tier of guns should be sacrificed from the side of the ship and the side protected with iron plates, thus rendering it impervious to the enemy. Here, Paixhans had over-reached himself, for by armouring a ship armed solely with shell guns he had thrown away the advantage; if the enemy chose to armour his ships in similar fashion, and then arm them with powerful shot-firing guns, France would be back to 'square one', since the shells would not hurt the enemy's armour, but the enemy's shot would pierce the French plate.

Paixhans published all his proposals, backed up by cogent arguments, in two books, *Nouvelle Force Maritime et Artillerie* in 1822 and *Expériences faites sur une Arme Nouvelle* in 1825. It caused a certain amount of commotion in naval circles, but in general his propositions were just too revolutionary to be taken in one dose. The only section which appears to have gained acceptance was his proposal for rationalisation of calibre, and the French Navy adopted this idea almost immediately. The 30-pounder gun of 6-inch calibre was selected as the standard, and in 1829 a selection of 6-inch guns of varying weights entered service.

twentieth century, though by that time a number of anomalies had crept in.

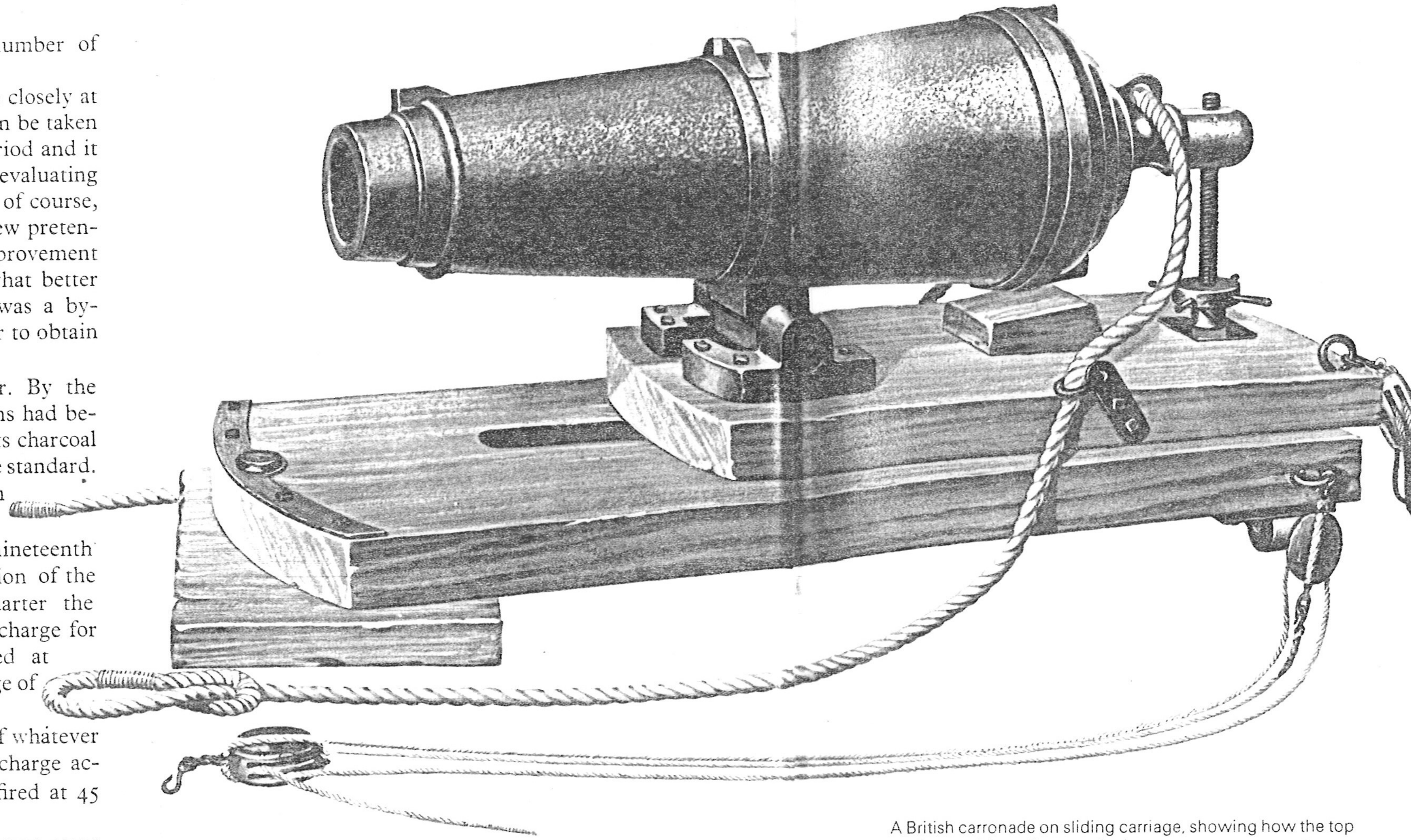
It might be as well at this stage to look more closely at the ammunition in use at this period, since it can be taken as representing the acme of the smoothbore period and it will serve as a useful base of comparison for evaluating some of the ideas which came later. Solid shot, of course, was just that; a solid sphere of cast iron with few pretensions to refinement or science. Its only improvement across the years was the provision of a somewhat better degree of finish on the outer surface which was a by-product of slightly more careful casting in order to obtain a more precise windage figure.

The propelling charge was still gunpowder. By the middle of the eighteenth century the proportions had become fixed at 75 parts potassium nitrate, 15 parts charcoal and 10 parts sulphur, and grained powder was the standard.

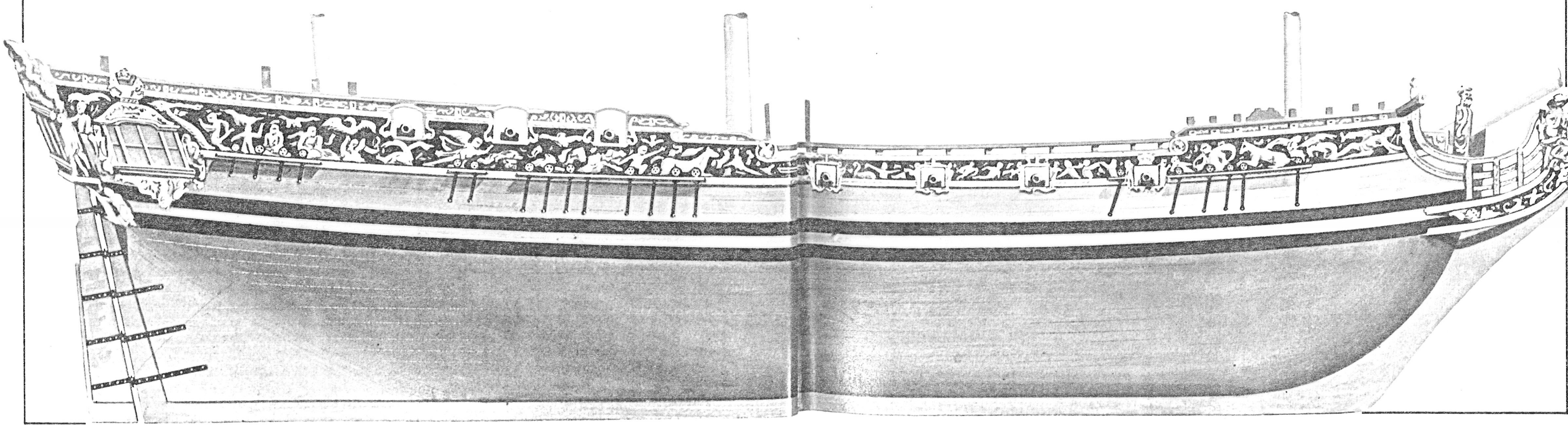
The precise weight of the charge for any gun was, strangely enough, not laid down in any hard and fast manner until the middle of the nineteenth century and tended to vary as of the inclination of the gunner. A rule of thumb gave 'about one-quarter the weight of the projectile' as being the standard charge for use with shot, though this could be increased at the gunner's discretion; shell guns had a charge of from one-sixth to one-twelfth of the weight of shell; carronades one-twelfth of the weight of whatever projectile was fired; and mortars varied their charge according to the range, since they were always fired at 45 deg. elevation.

The system of firing the charge had taken some steps during the life of the smoothbore gun. Originally, as we have seen, it was simply by thrusting a red-hot iron into the vent; this was soon superseded by the use of 'slow match', a length of loosely-spun twine soaked in a solution of saltpetre and allowed to dry. When ignited, this burned steadily and the glowing end could be presented to the vent to fire the gun. But this system had its hazards, and in the middle 1700s came the adoption, in land service ordnance, of the 'quickmatch tube'. Quick match was a saltpetre-permeated cord which had been rolled in fine gunpowder before drying, so that it burned much more rapidly, and this was cut into short lengths and inserted into a thin tinplate tube of a length to pass down the gun vent to the chamber. The top was belled out and 'primed' with a paste of gunpowder and spirits of wine, allowed to dry hard. It still required lighting with slow match, but it did away with the haphazard scattering of loose powder about the gundecks which was almost inseparable from the old system of priming the vent.

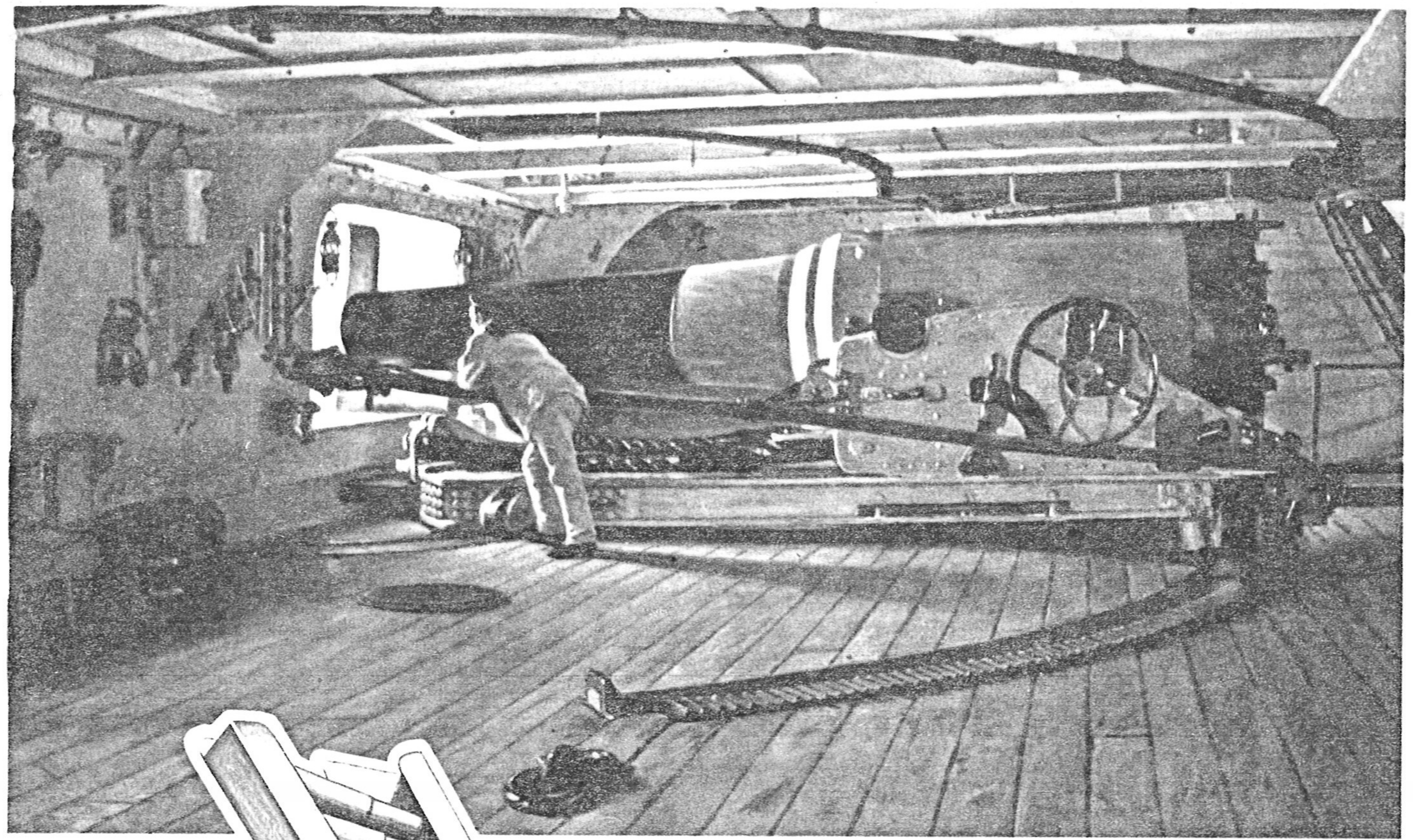
Although the flintlock had been used in muskets and pistols since the beginning of the sixteenth century, there does not seem to have been any attempt to fit such a mechanism to a gun vent until 1778, when Sir Charles Douglas urged the use of flintlocks on the Admiralty. The Admiralty, however, refused to adopt the system; their objection was that the service tubes used with land ordnance at the time were all of metal, and would be blown from the vent when the gun fired due to the back-pressure. Having been blown out they would land on the deck, and since the sailors of the day were given to running about bare-footed, the expended tubes, lying on the deck, would cut their feet.



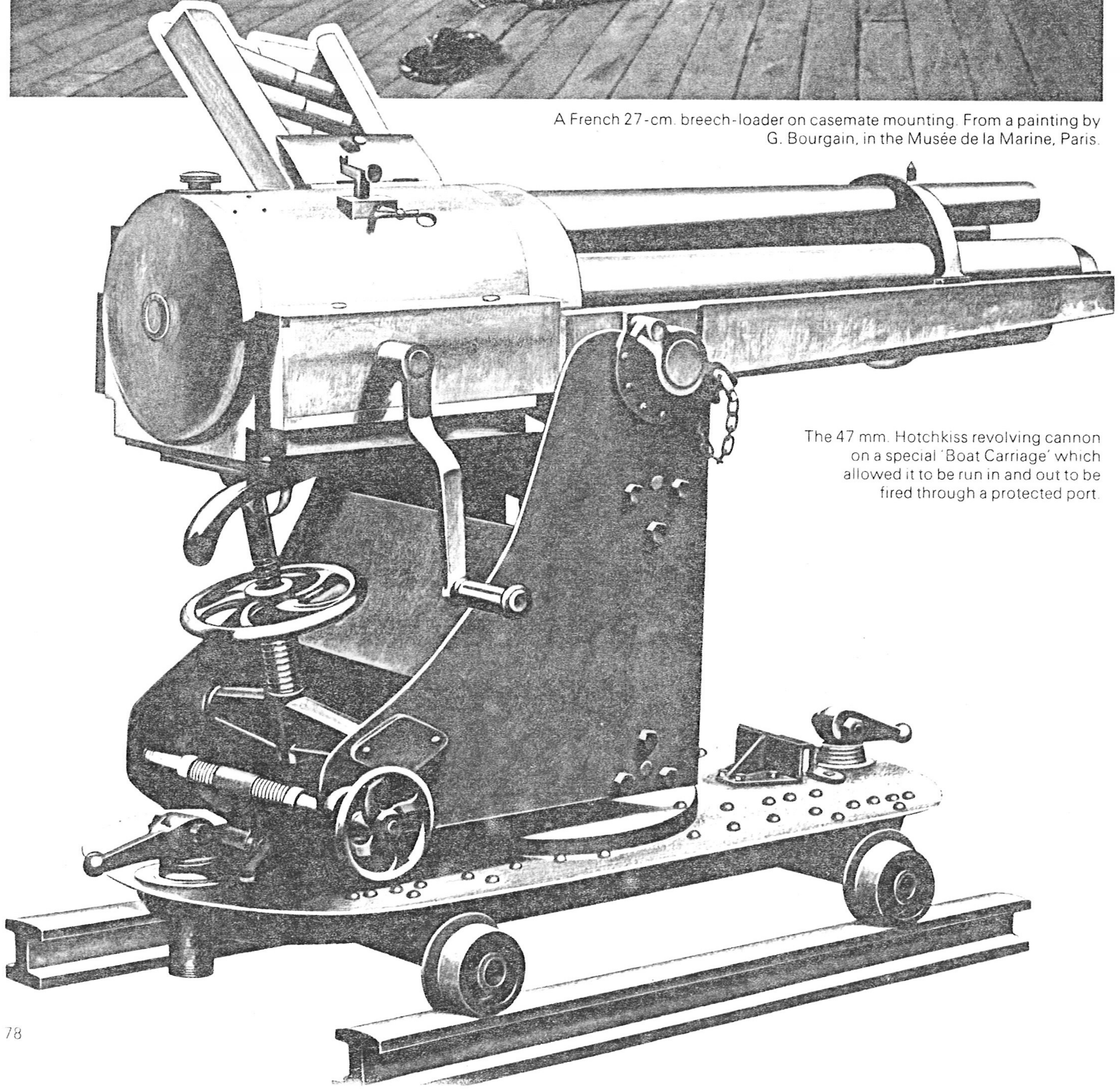
A British carronade on sliding carriage, showing how the top section could recoil across the lower.



The Armed Yacht *Caroline*, an interesting eighteenth century relic which survived into the breech-loading era.



A French 27-cm. breech-loader on casemate mounting. From a painting by G. Bourgain, in the Musée de la Marine, Paris.



The 47 mm. Hotchkiss revolving cannon on a special 'Boat Carriage' which allowed it to be run in and out to be fired through a protected port.

Ironclad to Dreadnought

Having arrived at the breech-loading era, it is now necessary to go back a little in order to examine how the improvements in ordnance were being assimilated into ships. As the Ironclad age began, the standard arrangement was for the guns to be arranged in broadsides down each side of the ship, deck above deck, with the addition of one or two 'pivot guns', guns mounted on centre-pivot carriages on the open fore and after decks. All that iron armour did to this was to conceal the broadside tiers behind iron plate, but a very little experience with iron ships soon showed that taking the old pattern and encasing it in iron was by no means the entire solution.

The first difficulty arose with the disposition of the armour; simply placing a belt of iron from stem to stern would protect the guns, but it would impair the sailing ability of the ship and would also place enormous strains on the hull due to the weight, particularly in a seaway. *Warrior* avoided this by leaving the ends unarmoured, though subdivided into water-tight compartments. Unfortunately this meant that of the forty-eight guns, twelve were outside the armour's protection. But *Warrior* proved to be unhandy, largely due to her length. In 1861 the 'Minotaur' class was laid down, and this was given armour for the full length of the ship in order to give protection to the steering arrangements and also to all the armament. *Minotaur* was even longer than *Warrior* and proportionately more unhandy; as was the current system, a combination of sail and steam power was provided, neither of which was sufficient on its own, and, as a result of this class, the size of warships was generally reduced until the steam engine system of propulsion had been perfected.

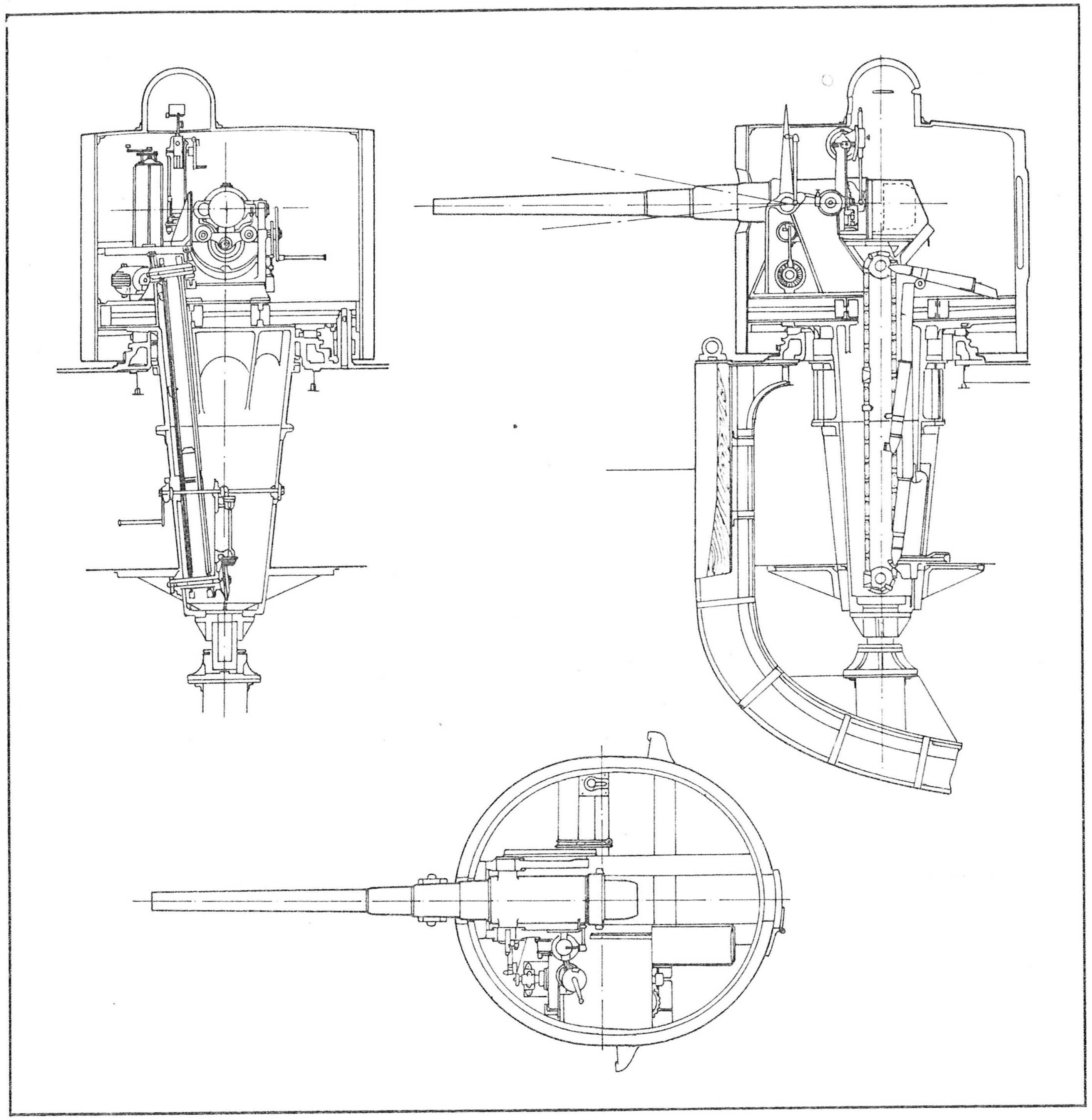
Another factor was the increasing demand for guns capable of firing ahead, rather than being confined to broadside fire. The *Warrior* guns could fire at about thirty degrees before and aft of the beam, but it was often pointed out that since the ship sailed forward into battle, it would be advantageous if some of the armament could be fired in that direction. The pivot gun was a step in the right direction, but it represented only a small proportion of the gun strength.

The central battery was the first solution; this brought the armament into an iron-plated citadel in the middle of the ship, reducing the need for armour plating and thus saving weight while concentrating the fire. This was coincident with the demise of the truck carriage, which was just as well since the close confinement of the guns would have made the citadel an absolute Bedlam with truck-carriage guns recoiling across the deck. The carriage-and-slide became the standard mounting, and this allowed the guns to be packed relatively close together.

In order to provide for ahead firing the forward bulkhead of the central battery was cut with ports and guns installed; an alternative to this was to mount the forward guns on turntables so that they could rapidly be shifted from broadside firing to ahead firing, being provided with two ports, one of which could be stopped with an armoured plug when not in use. A slightly more involved way of achieving the same result was to mount the two guns on slides supported on flanged wheels, and sink a species of railway track into the deck, complete with switches. The carriage was locked to the ships' side for broadside firing, functioning in the normal way. For ahead firing, the carriage was detached from the side, run back along the track, and then switched to a second track which curved round to bring the gun up to a forward-firing port, where the carriage was again pinned to the side. It was a desperate system and it had some dangers of its own when attempting to shift the carriage in any sort of seaway.

A method tried with some success was to re-orient the central battery by turning it through forty-five degrees so that it became a lozenge on top of the hull; this meant that the faces now split the angle between ahead and broadside and thus the guns, so long as they managed forty-five deg. angle of training, could command both directions equally well. It was a good solution on paper, but the enormous angle of train meant that the mechanical arrangements for moving the guns tended to become involved and overlapping. In the days of muzzle-loading guns and truck carriages, it was quite feasible to shift the carriages sideways by means of handspikes, iron-shod wooden levers six or eight feet long manipulated by two or three men. But as the guns and their mountings gained in power and weight, this system was no longer physically possible and mechanical assistance had to be brought into play. The slide was carried on truck wheels set transversely to the axis of the gun and riding upon iron 'racers', smooth iron paths set into the decks. From each side of the carriage rope tackle was hooked to the ship's side, so that by hauling on one set and loosing-off the other, the whole carriage and slide could be rapidly swung round the front pivot. The 7-inch, $6\frac{1}{2}$-ton RML gun, with its carriage and slide, weighed $10\frac{1}{4}$ tons and took fifteen men on the tackle to move it. It will thus be appreciated that packing guns too closely led to a spider's wed of traversing tackle which could doubtless have hung an unwary sailor in the heat of action.

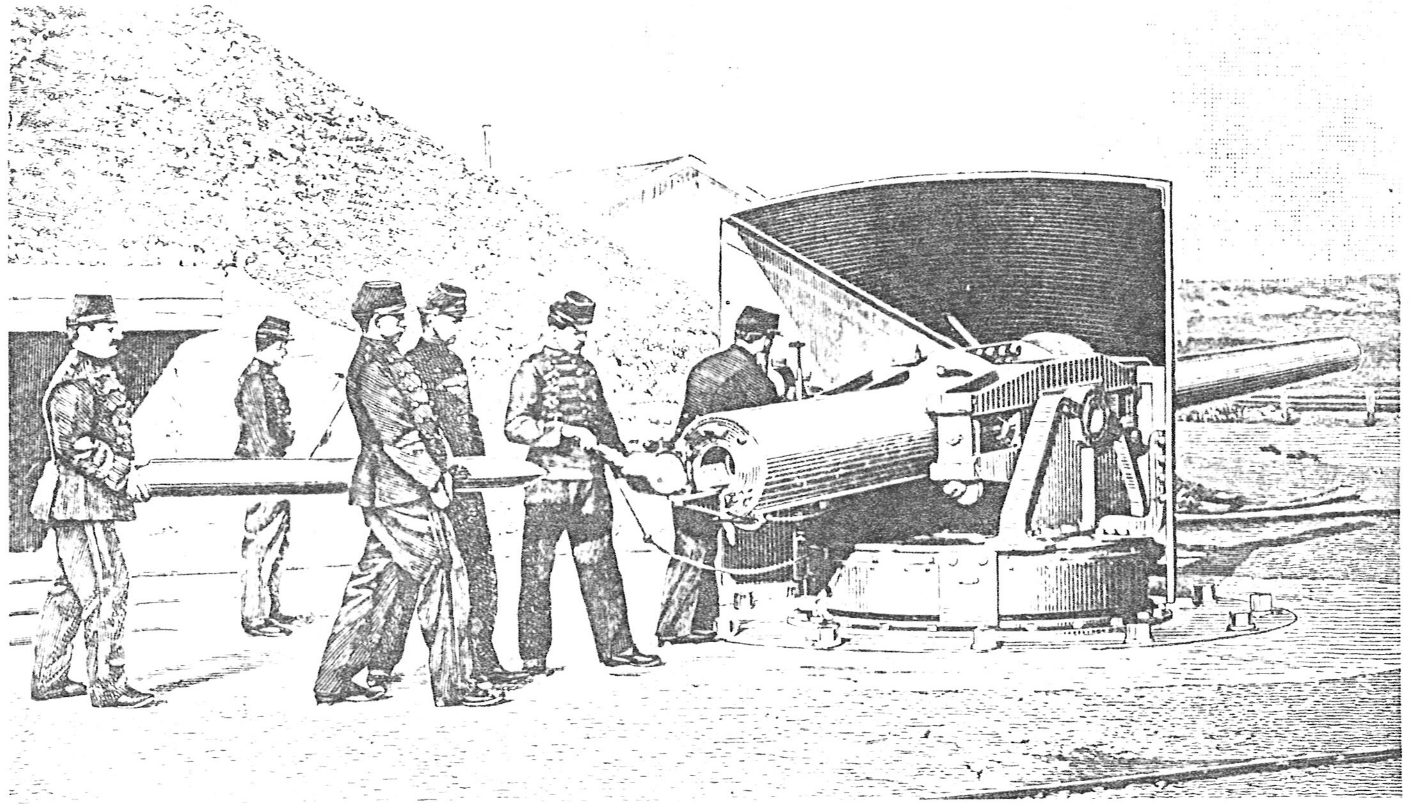
The tackle system was gradually replaced by a method involving gearing hand cranks to the wheels of the slide; first attempts at this ran into trouble due to slipping and remedied it by making a toothed traversing rack in front



of the rear racer and placing a suitable cog-wheel on the slide, so that by turning the crank, the cog-wheel moved along the rack and traversed the slide. This reduced the web of tackle, but the interlocking of the slide racers and traversing racks turned the once-smooth decks into something resembling a railway yard.

The need for ahead fire was being emphasised by a tactical theory which had been gaining support during the 1850s and 1860s, that of ramming the enemy rather than engaging him with gunfire. The ramming tactic was as old as naval warfare itself, having been extensively employed by the galleys of old, but once oar propulsion gave way to sail, the day of the ram was over since the motive power could not be depended upon to propel the ship in the correct direction to ram an enemy. Once steam power appeared, however, thought turned once again to the ram, which was in itself an admission of the relative failure of gunnery at that time. The events of the American Civil War appeared to bear out the theorists when the *Virginia* rammed and sank the wooden ship *Cumberland* on the day before it fought the sterile duel with *Monitor*. But the zenith of the ramming school came at the Battle of Lissa, in 1866; the Italian fleet was ineptly commanded, by the Count of Persano who neglected to give his captains any tactical instructions, while the Austrian fleet was most ably led by Vice-Admiral Tegethoff. Though outnumbered by two ships and over a hundred guns, Tegethoff signalled 'Armoured ships will charge the enemy and sink him', an order which left little room for argument.

The battle developed into a disorganised mêlée, ships attacking with guns or ram as the opportunity offered; the Austrian *Kaiser* rammed the Italian *Rei de Portogallo*,



A French Schneider 15 cm. naval gun on test, demonstrating the inconvenience of an over-large fixed round of ammunition which needed three men to carry and load it.

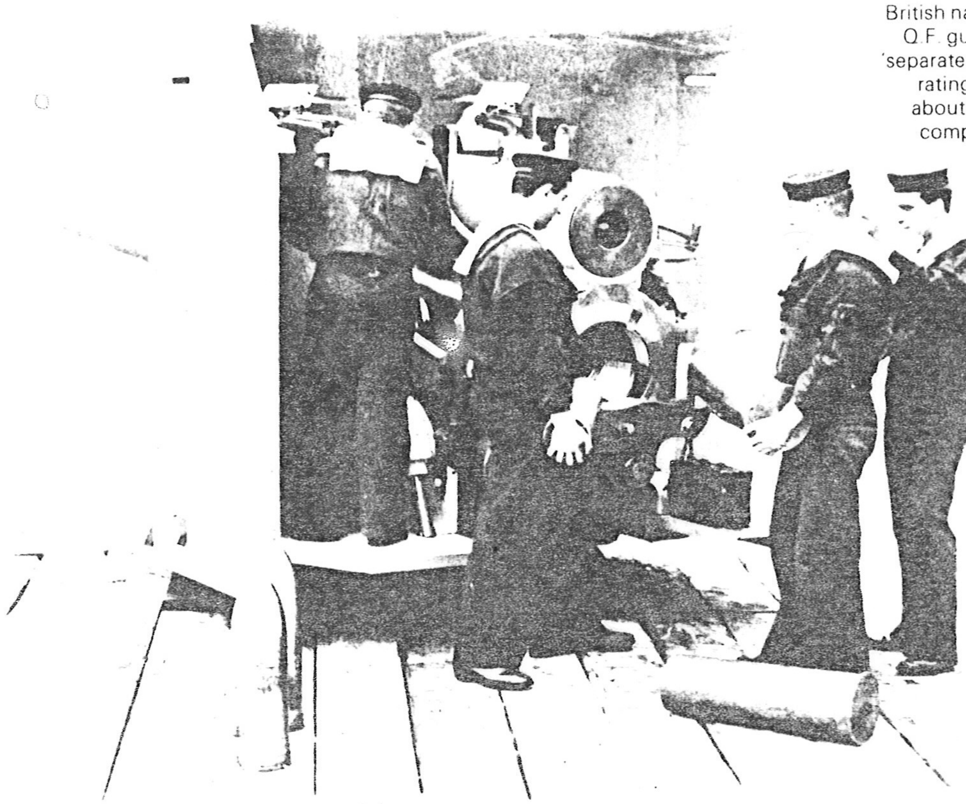
A French 12 cm. turret gun of the 1870s; three views, showing the pivoting arrangements, ammunition handling system and traversing system.

while the Italian poured fire into the Austrian at a rapidly shortening range. After some forty minutes of confusion, the *Rei d'Italia* suffered damage to her steering gear and went out of control; seeing this, Tegethoff's flagship *Ferdinand Max* turned and rammed her amidships, making a breach of some 300 square feet and sending the Italian ship to the bottom almost immediately. An interesting point about this action is that the fatal blow was struck at a speed of only five knots, a far cry from the bold and spirited collisions forecast by the theorists.

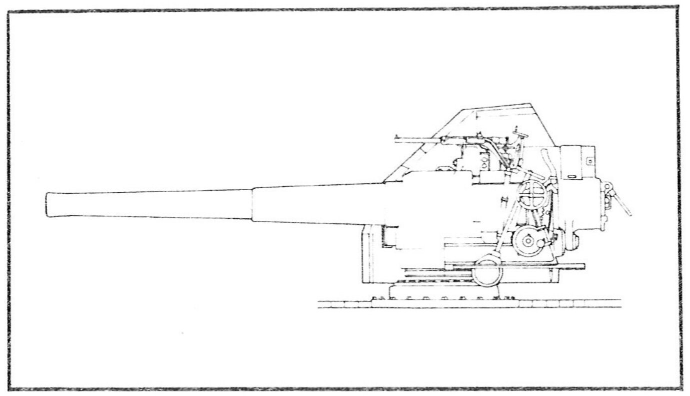
Nevertheless, the fact that the flagship had been sunk by ram led to the ramming tactic becoming the dominant weapon of naval combat, the gun being relegated to second place. (Indeed, for a short time in the 1880s, after the invention of the self-propelled torpedo, the gun fell to third place.) This, of course, meant that the ship would now be head-on to her opponent as often as could be managed, and therefore the demand for ahead-firing armament grew.

In 1868 the British *Bellerophon* appeared, with a central armoured battery mounting twin 9-inch RML guns for broadside fire and a second, smaller, armoured battery structure in the bows, mounting two 7-inch RML guns. After it came the *Enterprise* which dispensed with the forward battery and reverted to the idea of using forward-facing ports in the central battery, and this was followed by designs in which the sides of the ship were indented, forward of the main battery, so as to permit a clearer field of fire. The *Sultan* mounted a double-decked armoured central battery, the lower deck of which provided broadside fire and the upper fore-and-aft fire. The French developed the 'sponson', a semi-circular platform projecting from the side of the ship upon which a gun was placed so that it could fire through an arc of 180 deg., from aft through broadside to forward. But, in general, it was impossible to achieve a balance of firepower with this form of construction; either there was a preponderance of broadside fire and lack of frontal, or vice-versa. An interesting attempt to solve the problem was the *Temeraire*, completed in 1877 at Chatham; this used a central battery structure, but in addition, mounted two pivot guns, one at each end of the ship. The pivot gun had fallen into disrepute due to the difficulty of protecting it, but in the *Temeraire* this was solved by adopting a device which had been originally developed for coast defence; the disappearing carriage.

In the 1860s, with the rise of the Ironclad and the general improvement in shipboard armament, the coast defences of the world had been extensively overhauled in an attempt to keep pace with naval ordnance and capabilities. At the beginning of this period, the standard method of deploying coast guns was in open batteries, but the advent of armour and powerful guns on ships led to the adoption of armoured forts in which the guns were protected by casemates with enormous thicknesses of iron and granite to protect them. This was an expensive method of construction; a single armoured casemate for one gun, together with its necessary magazine arrangements, cost over £3800 without the cost of the gun being counted, and the slowness of fire of the heavy RML gun demanded large forts with numerous guns to swamp an enemy with fire. Picklecombe Fort in Plymouth Sound, for example, was prepared with forty-two armoured casemates, an expense of £160,000 before the guns were installed.



British naval ratings loading a 6-in. Q.F. gun. Note that this gun used 'separate loading' ammunition. The rating to the left of the breech is about to load the shell, while his companion holds the cartridge.



An Elswick Ordnance Company design for a 6-in. Upper Deck mounting using a quick-firing gun. Numbers were adopted by the Royal Navy and it was widely sold abroad.

The heaviest British gun of the nineteenth century was this 16·25-in. destined for H.M.S. *Victoria* and seen here on its proof mounting at Woolwich Arsenal. The barrel weighed 111 tons, and fired an 1800-lb shell to give a muzzle energy of over 53,000 tons.

The Elswick design for a between-decks mounting for their 6 in. QF gun.

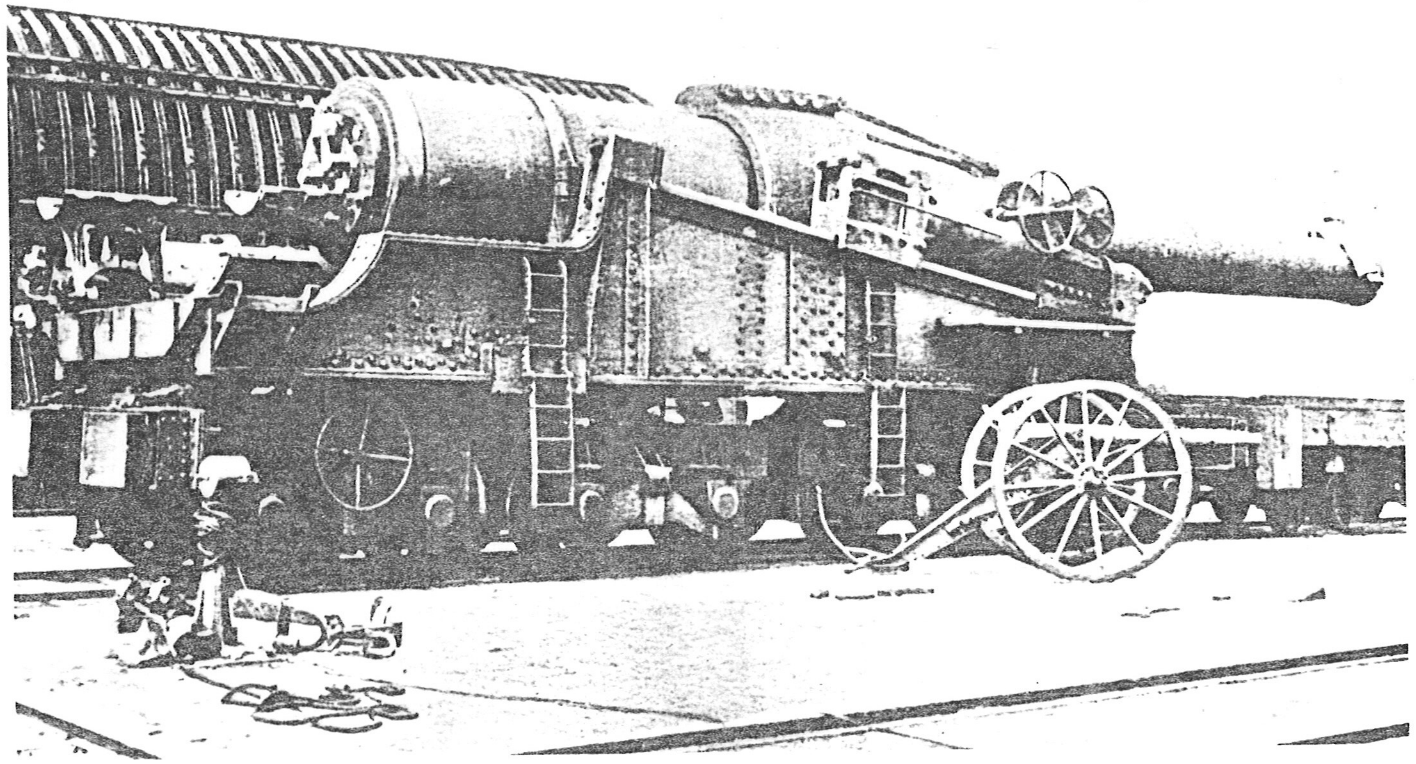
A round of fixed ammunition; the common pointed shell, filled with gunpowder, for the Hotchkiss 6-pdr gun.

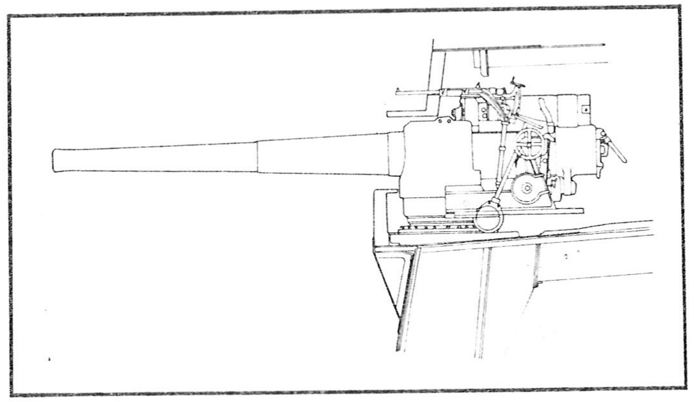
liam Armstrong. The British reply to this was the *Inflexible*, which had a similar arrangement of turrets mounting 16-inch 80-ton RML guns.

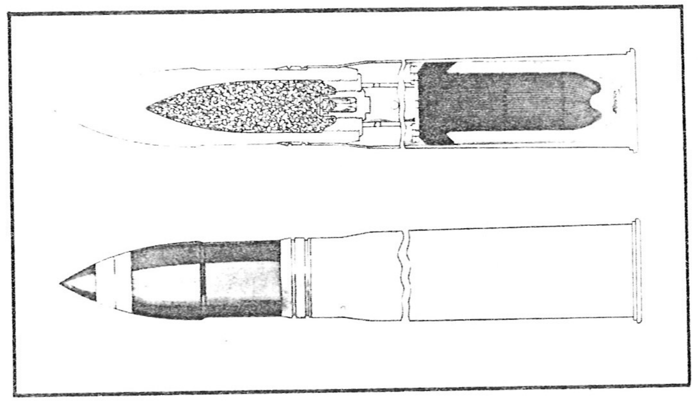
It is obvious from this recitation of calibres that guns were becoming larger every day, and the simple reason for this was that the armour was getting thicker by the hour. *Inflexible* carried 24 inches of plate surrounding the central battery area, and both the armour and the guns had been born in 1873 when the Admiralty asked the Royal Gun Factory for a weapon which would defeat 20 inches of iron armour at 1000 yards range; as they did this with one hand, as it were, they began the design of *Inflexible*, with its 24-inch plate, with the other.

At that time, the heaviest service gun was the 12-inch of 35 tons, the *Woolwich Infant*, which fired a 698-lb piercing shell at 1364 feet a second, had a muzzle energy of 9208 foot-tons, and could penetrate about 15 inches of iron at 1000 yards range. Boosting the penetration by another five inches meant a considerable increase in power; from experience it was known that very slight changes in calibre could have considerable effects upon performance, and it was decided that a prototype gun would be built, bored to 14-inch calibre, and tested: if it survived this, it would then be bored out to 15-inch calibre and tested again; if this proved successful it would again be bored out, this time to 16 inches, for a final test, after which the figures would be analysed and conclusions drawn. The estimated cost of this was £8000 and in 1874 construction was authorised.

In 1876 it was completed and trials fired; these began at 14·5-inch calibre, at which twenty-one shots were fired; then thirty-two rounds in 15-inch. At this point it was decided to bore out the chamber to 16-inch diameter, leaving the barrel at 15 inches, in order to pursue a theory which had arisen regarding the better combustion of powder with an enlarged chamber. Another twenty-one shots were fired, with results which seemed to bear out the advantages claimed for 'chambering', and the gun was then bored out to 16 inches throughout. Another ninety-two shots were fired, and the gun was about to be sent to Plumstead Marshes for trials against iron plates, when it was discovered that the 166th shot had cracked the steel barrel liner. Notwithstanding this, it was sent to Plumstead and fired against a target composed of four 8-inch plates with 5-inch intervals between, the gaps being filled with teak, and a robust teak backing. The 1700-lb shot penetrated







48 inches into this. The gun was then 'chambered', the chamber being bored out to 18 inches, and with this the performance improved to the extent of piercing 56 inches into the target. The cracked tube was hardly affected by this enormous power; the powder charge weighed 425 lbs, the shot 1700 lbs, the muzzle velocity was 1700 feet a second, and the striking energy of the shot was computed as being 29,607 foot-tons. The performance was sufficiently in excess of the Admiralty's specification as to be able to pierce 23 inches of solid iron plate at the specified range of 1000 yards.

Although not directly connected with the naval requirement, it is worth noting that the Army acquired two of these 16-inch guns in 1879 and mounted them in an armoured turret at the end of Admiralty Pier, Dover. They were first fired there in July 1883, amid great apprehension that the cliffs would collapse under the shock. Although declared obsolete in 1902, they were not removed for scrap and are still there to this day, remarkably well preserved.

It is obvious that armour had come some way from the four inches of *La Gloire* and *Warrior*. The thickness of plates gradually increased to nine or ten inches, but at this point difficulties began to arise in manufacturing such thicknesses and in manipulating them during construction. In about 1864 the 'sandwich' method of construction appeared, in which multiple plates were used, separated by layers of elastic material. A series of trials in Britain in 1867 showed that three five-inch plates withstood attack better than a single 15-inch plate, and the sandwich system was adopted both for coast defence forts and for warships. The 'elastic material' varied; sometimes it was solid teak, sometimes 'iron concrete', a mixture of pitch and iron swarf. Generally the former was preferred for ships since it weighed less than the latter.

Faced with this sort of target, it was obvious to the gunners that something better than plain iron shot was needed. The first attempt to provide specialist projectiles largely concerned with shape; some argued that a flat-headed shot would punch clean holes in the target, others argued for jagged and saw-toothed points which, given the spin of the projectile, would perform somewhat in the manner of drills and carve their way through. These ideas always seemed to work when the inventor tried them at home, but they always failed when tried against service targets.