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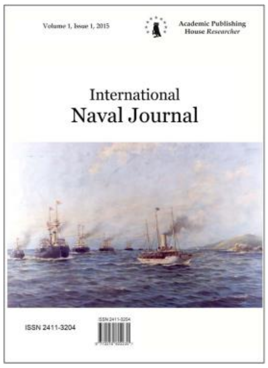

Articles and Statements

Swansong: Blakely, Brooke and Vavasseur. Part 2*

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Abstract

The decades of the 1860s and 1870s were characterized by one of the most thorough-going Technical Revolutions the world had ever seen, which has been characterized as the 'Second Industrial Revolution.' And this Revolution affected the world's Navies no less than every other human endeavor. In the field of ordnance, iron smooth-bore cannon firing solid round shot were replaced by rifled cannon, initially to lob elongated exploding shell with greater accuracy, but soon firing elongated solid shot needed to pierce armor plate. History recalls the many designers and/or manufacturers of the Great Guns. Yet the work of lesser known figures has been overlooked.

This is a continuation of the story of Captain A.T. Blakely, R.A. by examining the work of John Mercer Brooke, a licensee, and his successor, Josiah Vavasseur. Context is provided by an examination of the gradual abandonment of the Armstrong System reliance on wrought iron and the eventual adoption of steel by the British Government.

Keywords: Naval, artillery, Blakeley, gun.

John Mercer Brooke's career as an ordnance designer and chief of the Confederate Navy's Bureau of Ordnance ended in the chaos and confusion of the collapse of the Confederacy in April 1865. But during that brief four years, he made what should be considered an indelible mark in the history of ordnance technology, especially considering the constraints imposed by the Confederacy's limited technical and industrial base.

Brooke labored under the limitation of only having cast iron, though of high quality, to work with, and only wrought iron available for the reinforce/hoops/bands. What little steel that was available in the Confederacy was of the 'puddle' variety and in insufficient quantity for use in heavy ordnance. And as the war continued, brass/bronze became in short supply. In addition, the capacity to produce wrought iron bands of greater than two inches thick and six inches wide was virtually non-existent, though in compensation, the use of scientifically and mathematically 'adjusted' hoops produced sufficient initial tension and hence greater strength compared to the contemporary Parrott guns.

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In addition to a few 'Blakely Conversions' – invariably called 'Brooke Conversions,' which included the first seven 7in Single Banded guns converted from Dahlgren 9in blocks – he designed a 'family' of Great Guns that were the best of the type in either side of the conflict. These ranged from 6.4in Single Banded to 11in Triple Banded. He also designed numerous projectiles and gas checks, and was responsible for approving projectile and gas check designs for use in rifled naval guns of all sizes.

He is also credited, quite erroneously, with virtually every rifled and banded smooth-bore in Confederate military service. And given the Confederacy's great need for rifled artillery, there were many such guns, ranging from field guns to 10in Rodman 'Columbiads.'

To be accurately classified as a 'Brooke' – more appropriately a 'Blakely' – Conversion, three criteria must be applied:

First, the gun must be either newly cast or a block (cast but not bored out). This is necessary to avoid any cracks or dents that invariably and inevitably result from use over time, and why merely rifling an existing smooth-bore is considered 'weaker' than a new gun, and not able to get the full advantage of the initial tension from the reinforce.

Second, Brooke was Navy, not Army, meaning the guns were for use by the Navy. The sole exception was a small lot of newly cast 42pdr 7in guns cast by the Tredegar and Bellona foundries in 1861, probably not more than 14 pieces in all. Perhaps ten of these guns were used to arm an ironclad of the naval squadron defending Charleston.

Third, and unique to the Confederacy, Brooke specified the hook-slant rifling favored by Blakely. This limits the number of rifling facilities to two; Tredegar and the Naval Ordnance Works, both in Richmond, Virginia. That number would be expanded to three when the new Selma Ordnance Works began operation in 1863. James Eason and Brothers Foundry of Charleston rifled and banded a considerable number of guns during the war, including a number of 42pdrs, but used Parrott rifling.

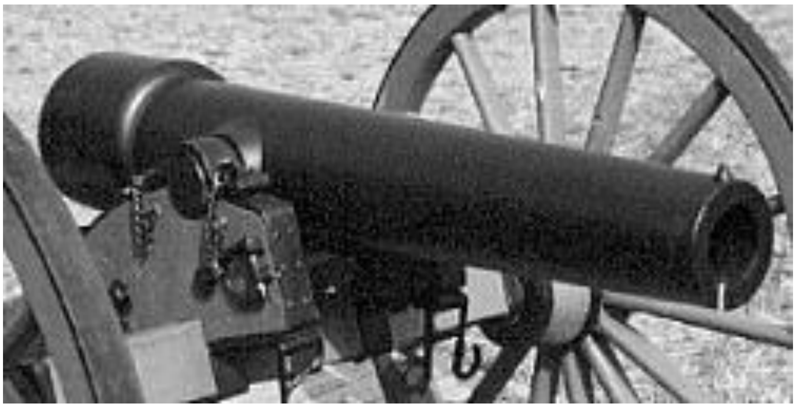

Fig 1. Confederate Banded 12pdr Napoleon

Excluding the various 'Conversions' – seven IX inch Dahlgrens into 7in Single Banded rifles, perhaps fourteen 42pdr 7in 3.79 T smooth-bores into 7in 4.24 T rifles, and an unknown but substantial number of 32 pdr 57 cwt smooth-bores into 6.4 in 61 cwt rifles – very few actual Brooke pattern guns were produced during the war. Only 306 guns were cast, compared to 585 Parrott 100pdr 6.4in guns alone produced during the war, 352 of which for the Navy.

Tredegar cast eleven 6.4 in Single Banded guns through October 1862, when Secretary of the Navy Stephan Mallory mandated the change to Double Banded. An additional three under construction were then altered to be Double Banded.

Tredegar produced a total of 27 Double Banded, including the three mentioned above, from November 1862 to 1864 when production of the type ceased.

Fig 2. Confederate banded and rifled 12pdr naval gun

The new Selma Ordnance Works cast 27 of the Double Banded pattern, but delivered only 15. The remaining 12 exhibited flaws in the casting; likely cracks or fissures caused by uneven cooling, and were deemed unsuitable for withstanding the pressures and strains of firing heavy rifled projectiles. Five of these were bored up to 8in caliber for use as smooth-bores, having been deemed to be strong enough for such use. This implies that the flaws were relatively shallow and could be eliminated by the 1.6in increase in the bore. The fate of the other seven is unknown.

Tredegar produced 19 of the 7in Single Banded pattern in 1862 prior to the change to the Double Banded pattern.

Tredegar produced 36 of the 7in Double Banded pattern from November 1862 to early 1865.

Selma cast 54 to that pattern, but due to casting flaws only delivered 39. Attempts to bore these up to 9in failed, implying that the flaws were too deep and/or the barrel would be too weak after losing two inches of metal.

Only three of the superb 7in Triple Banded pattern were produced by Tredegar.

Tredegar produced four of the 8in Double Banded pattern, in April and May of 1864. Two were known to have been mounted in ironclad warships. Sources differ on the fate of the other two. Some say they were seconded to the Army for coast defense, a not uncommon ultimate use of heavy naval ordnance, or they were bored up to 10in and deployed as smooth-bores.

Selma produced seven of the 10in pattern and Tredegar four, all in 1864. And all were deployed as smooth-bores, at least one to an ironclad warship, but most for coast defense.

Selma cast twelve 11in Double Banded guns in 1864, all as smooth-bores, but due to the casting problems that plagued their production of heavy guns, only eight were delivered, and all used in coast defense.

Tredegar produced two 11in Triple Banded guns as smooth-bores in 1863-64, but their disposition and fate are unknown, and neither has survived.

There is something of a legend that Brooke **designed** the large bore guns as smooth-bores. With the exception of the 6.4in Double Banded Selma guns, the essential difference between a smooth-bore and a rifled gun is the **rifling**. Armstrong's 100pdr 9.22in smooth-bore became a 200pdr rifled gun, his 150pdr 10.5in smooth-bore became a 300pdr rifled gun, and his 300pdr 13.3in smooth-bore became the infamous 600pdr rifled gun. And rifled guns could and did fire spherical projectiles. Indeed, for close range engagements, solid round shot and cylindrical bolts could and were fired by smooth-bores and rifles. Rifling may be the intent, but it is also an option.

From the closing months of 1863 on, the war was going increasingly badly for the Confederacy, and the demand for heavy ordnance greatly exceeded their industry's ability to produce. It was therefore **expedient** to forego the weeks or even months required to rifle the Great Guns in the few back-logged rifling facilities.

An interesting theory regarding the disposition of some or all of the Selma casting failures, seven 6.4 in and fifteen 7 in guns, is that they were converted into siege howitzers through the expedient of cutting the barrel down to produce an overall length of around 80 inches, boring the shortened barrel to 8in caliber, removing the second band and a hoop from the first, and providing suitable carriages for fortress or field deployment. Such guns were actually purpose built by Tredegar and Bellona for a total of 35 such weapons, from late 1863, with the final gun 'finished' in March 1865. From the contemporary photo, they have a very 'Brooke' appearance, which is very suggestive, although the gun is not listed as a Brooke design. Details are lacking, though Tredegar reports the weight at 5862 lbs (2659 kg), and certainly lighter than any conversions of the Selma guns.

Fig 3. Confederate 8in Siege Howitzer

Josiah Vavasseur established himself as the successor to his friend Blakely by fulfilling several orders left hanging by the bankruptcy of the Blakely Ordnance Co., Ltd. Under the auspices of J. Vavasseur and Co, during 1867-8 he assembled a number of guns from the components left on hand in 1866, which included guns for Chile, Peru and Russia.

He also devoted that time to preparing new designs so that when The London Ordnance Co. opened for business on November 27, 1868 he had a full line of product to offer. Anyone who doubts that his new designs were firmly based on the last Blakely designs – which Vavasseur undoubtedly had a hand in creating – need merely compare the diagrams of his 7 inch and 12 inch guns with the diagram of the Blakely 11inch gun, all included below. So it seems entirely fair to say that the Vavasseur designs represented an evolution and refinement of the successful established pattern.

In general, the Vavasseur design implemented three alterations. First, the reinforcement was extended more forward toward the muzzle, covering more of the chase. Second, the truncated bottom of the bore and hemispherical bottom favored by Blakely were replaced with a simple cylinder with a diameter somewhat smaller than the bore, but serving the same purpose; providing an air space behind the charge to reduce the initial strain on the breech from the ignition and gas expansion of the propellant charge, thereby 'smoothing' the initial pressure wave.

The third alteration was more fundamental, to wit, the rifling. As mentioned above, he and the Captain had explored the idea of the 'rib' system, and even had gone so far as to design a projectile for rib rifling. Vavasseur implemented the idea for all of his muzzle-loading guns, with uniformity regardless of caliber; three ribs of appropriate width and a standard twist. Blakely had originally used a uniform 1:48 caliber twist which was considered ideal for the Britten shells, but in 1863 had chosen 1:36 as appropriate for the copper cup brass check. Vavasseur used a uniform 1:30, the proverbial ideal.

It is likely that Vavasseur and Blakely had considered the advantages of the rib system at length, but no record of their discussions and trials has survived. However, The Engineer Magazine, in the April 19, 1872 edition, made extensive mention of each.

Less windage. Neither Woolwich nor Vavasseur used Blakely's copper cup gas check, but the tolerances Vavasseur allowed were materially less than in the shunt rifled Woolwich system. Each rib rose above the surface of the bore a mere 0.2 inch. Windage around the projectile was 0.08 inches, but between the rib and the projectile was only 0.05 inches. Less windage translated into more of the gas pressure acting on the projectile.

Sure centering. The ribs structurally center the projectile in the bore. Centering had been a matter of some concern in the Russian Trials of 1863, and the rib system answered that concern. Proper centering also produces more accuracy for both range and drift/deflection.

"The tube was not weakened by having grooves cut into it; on the contrary, the ribs projecting from the bore materially strengthen it."

In a contest of scale, the metal cut of the body of a 12in shunt projectile by the nine countersinks for fixing the studs is 3.75 square inches. The area left vacant for a 3-rib 12in projectile is only 1.35 square inches. Thus the Vavasseur projectile is materially stronger.

"The bearing surface for turning or driving the projectile is immensely in favor of the rib system." Again, this harkens back to the 1863 Russian Trials, and the criticism of relying on studs of minor metals for both centering and driving in the grooves, especially in cases of increasing twist in the rifling, lessons lost on the Select Committee and Sir William Armstrong, on which more below.

"There is also considerably less scoring with a gun rifled on the rib system than one rifled with grooves, being the highest part of the bore, act as channels along which the gas rushes, while with the rib rifling the highest part of the bore – and the part most affected by the rush of the gas – is the part between two ribs, nearly one-third of the whole circumference of the bore in width; the scoring is therefore much less local [ized], and takes place in a part of the bore not weakened by grooves cut into it, as is the case with a grooved gun."

The ribs projecting from the surface of the bore are also much more effectively cleaned by the act of sponging than are grooves..."

Vavasseur also designed the projectiles for his guns, which were much more aerodynamic than the norm for the time. The effect of this becomes evident when comparing official trial reports from Shoeburyness. The Mechanics' Magazine of February 10, 1872 compared the results of the late 1871 trial of the Vavaseur gun with the performance of the Woolwich 7in gun contained in the Ordnance Select Committee report of June 6, 1867. Table 3 is a summary of the results.

Table 3. Shooting of the 7-inch Gun

Initial velocity, ft/sec	Charge, lbs/type	Eleva-tion	Mean range, yards	Mean variation of range, yards	Mean reduced deflection, yards
Shooting of the Woolwich 7-inch Gun					
1430	22 RLG	2°	1427	26,4	0,6
"	"	4°	2267	20,8	1,0
"	"	6°	2791	40,1	2,0
Shooting of the Vavasseur 7-inch Gun					
1411	22 A4 RLG	2°	1414	22,2	0,6
"	"	4°	2317	15	1,1
"	"	6°	3094	20,4	2,2

It should be noted that while both guns used charges of 22 lbs of RLG powder, as noted above, not all RLG was the same. The A4 type was discontinued in 1865, and replaced by a more uniform and denser powder; hence the shoots for range in early 1867 for the Woolwich guns. That the powder provided for the 1871 trials of the Vavasseur gun was specifically noted as A4 indicates why the initial velocity was lower than would be expected. Yet in spite of the inferior powder, the superior aerodynamic shape of the projectile lost less velocity as the elevation increased, and thus produced greater ranges. Against a target at the same range, say 4000 yards, the striking velocity of the Vavasseur projectile would be markedly greater, and the trajectory flatter.

Another point worth mentioning is that Vavasseur produced a gun longer, stronger and lighter than the corresponding Woolwich gun, due to the all-steel construction. The Woolwich 7in had a bore length of 111 inches, and weighed 14560 lbs (6 ½ Tons). Vavasseur's 7in gun had a bore length of 126 inches but weighed only 11312 lbs (5.05 Tons). The 3248 lb difference can be explained in great part by the mass of wrought iron coils intended to reinforce the steel 'A' tube, a carry-over from the unsound and otherwise rejected Armstrong system.

The same remains true of corresponding calibers. The Woolwich 9in gun weighed 12 Tons (26880 lbs) and had a bore length of 125 inches. The Vavasseur 9in weighed 10 Tons (22400 lbs) with a bore of 144 inches. Woolwich's newest 12in gun weighed 35 Tons (78400 lbs) with a 162.5 inch bore. The older 12in gun weighed 25 Tons (56000 lbs) with a bore of only 145 inches. Vavasseur's 12in gun had a bore length of 187 inches and weighed only 27 Tons (60480 lbs), some 8 Tons lighter than its contemporary from Woolwich.

The only apparent exception was the purpose-built 64pdr 6.4in 64cwt (7168 lbs) gun, with a 97.5 inch bore. Vavasseur's contemporary was a 6.3in 100pdr of 80cwt (4 Tons) with a 111 inch bore. But the difference was not just weight, but strength. The 64pdr was limited to a 10 lb charge of RLG powder, and a 64 lb shell. The 100pdr used a 20 lb charge of pellet powder to fire 100 lb AP Shot.

There is considerable evidence that along side of his RMLs, Vavasseur also offered breech-loader versions. This should not come as a surprise as he and the Captain had patented copper bands for breech loaded projectiles, and it appears likely that they were designing or had designed a gun to fire the new type projectiles. Indeed, The Engineer Magazine, in the June 15th, 1866 edition, mentions that smaller caliber BLRs were in production, though no examples have survived as confirmation, though Chinese lists do mention a 4.5in breech-loader. Likely these first production breech-loaders would be mostly 3.5in 12pdr, 4.2in 20pdr, 4.5in 36pdr and possibly 4.62in 40pdrs. Vavasseur (jointly with Blakely?) received a Patent in 1865 or early 66 for 'improvements' to the breech-closing mechanism having to do with ignition of the charge, which certainly implies there was a breech mechanism to improve.

But the feature that draws the most surprised comment was the enlarged powder chamber. No doubt those comments were based on the sad experience with Armstrong's wrought iron breech-loading guns, where the slightly enlarged chamber proved to be a point of weakness. If one discounts the experimental and very advanced all-steel *Marie Jeanne*, none of the French breech-loaders were cast with an enlarged chamber, nor did the contemporary Krupp guns prior to 1868. However, given the emphasis both Vavasseur and Blakely placed on sufficient air space to lessen the initial pressures of propellant ignition, an enlarged chamber for a breech-loader is the logical conclusion. (The relative failure of Blakely's 1860 design was due to too much air space for such a small charge.) And, from an internal ballistics perspective, enlarging the chamber allows for a large charge without impinging on the rifled bore, preserving the 'distance traveled' from the seat to the muzzle.

Writing in 1880, Edward W. Very, USN, noted that "Vavasseur ordnance is used considerably in China, and has found some use in other quarters of the world." In light of this general statement, and in the complete absence of production records, sales records, correspondence or any other documentation save pieces of information can provide a dim vision of the impact Vavasseur had.

In January of 1864, the shipbuilder A. Hall launched a small ironclad sloop or cruiser. It was a speculative venture in hopes of selling the ship to the Confederacy, but this proved a false hope. The virtually complete but unarmed warship lay idle until 1869 when she was sold to Prince Kumamoto. Completed and armed, she arrived at Nagasaki in January of 1870, and by the end of the year she had been presented to the Emperor as the *Ryujo*. Her armament consisted of two 6.5in 100pdr guns (bored-up 6.3in?) on pivot mountings fore and aft, with ten 5.5in 60pdrs on the broadsides, all breech-loaders from The London Ordnance Co.

From the available evidence, it seems that Vavasseur guns were significant in the early years of the Imperial Japanese Navy.

Unyo was ordered from A. Hall, of Aberdeen, by the Choshu Domain, in 1868. She was delivered in February of 1870, and taken into the IJN of July 25, 1871. Her armament was one 6.3in and one 5.5in guns on pivot mounts.

Dai IchiTeibo and *Dai Ni Teibo* were also ordered by the Choshu Domain in 1868 as armed transports. But upon arrival, they were armed and converted into gunboats. Taken into the IJN in 1870, they were armed differently, the first with one 6in and one 5.5in, and the second with two 6 ½ inch (bored-up 6.3in?).

Hosho was also built in Aberdeen (A. Hall?) for the Choshu Domain. She was delivered in 1869, and taken into the IJN in May of 1871. Her armament was one 7in and one 5.5in, both MLRs.

Nisshin was built in the Netherlands for the Saga Domain. She was commissioned on March 3, 1870, and taken into the IJN in June. She was armed with one 7in on a pivot mount, four 6.3in on the broadsides, two 2.5in boat guns and a smoothbore mortar on a pivot mount.

The saga of the *Fujiyama* presents a number of questions. The ship, a 1000 Ton small frigate, was ordered from the United States by the Shogun in 1862 as part of an arms deal for two such frigates and a gunboat. Delays caused by the Shimonoseki incident and complications due to the Civil War delayed construction, and only *Fujiyama* was laid down in 1863. The rest of the order was cancelled by the Shogun, but he took delivery of *Fujiyama* in December of 1866. The designed armament was for 28 guns, likely traditional smooth-bores, but as completed the hull was pierced for only ten. Her armament under the Shogun is unknown. The victorious Meiji government took the ship into the fledgling IJN in July of 1869. Her subsequent armament was listed as one 6.3in MLR, two 15cm MLRs and ten smaller guns. 6.3in was the Vavasseur caliber, and as noted in Appendix C, Vavasseur had the contacts through his brother and the Henry Leighton Co. to obtain access to the Japanese market. So it is likely that the '15cm' guns were really Vavasseur 6in 80pdrs, and the unidentified 'smaller' guns 3.75in 20pdrs.

Except for the mortar, all of the guns were likely built by The London Ordnance Co.

In the mid-1870s, Mexico took delivery of twoarmed troop transports/cruisers, named *Democrata* and the *Mexico*. Both were armed with two Vavasseur6.3 inch guns on pivot mounts, and two 3.75in 20pdr boat/landing guns. These were companions of two gunboats, *Independencia* and *Libertad*, which were armed with one 6.3in on a pivot mount and four 20pdrs. All were muzzle-loaders.

Argentina acquired two gunboats, *Parana* and *Uruguay*, armed with four 7in Vavasseur guns, two on pivot mounts fore and aft, and one on each broadside.

The London Ordnance Co. seems to have provided guns for Portugal from 1869 through the 1870s. As mentioned above, Blakely Ordnance Co, Ltd, provided four 5 ¼ inch 56pdr and an unknown number of 4.62 inch 40pdr and 3.5 inch 12pdrs in 1865.

The 56pdrs were pivot mounts on the corvettes *Duque de Palmela* and her *sister Dom Joao*, and *Duque de Terceira* and her sister *Sa da Bandeira*. The rest of the armament comprised twelve (fourteen for *Teceira*) bronze 32pdr Paixhans 'shell' guns. In the early to mid-1870s, all four ships were re-armed with eight 165mm guns, almost certainly a 6.3in (16cm)100pdr from The London Ordnance Co.

The 28 gun frigate *Bartholomeu Dias* (1858) was re-armed in the mid-1870s. Her new armament was listed as a 6in breech loading rifle, ten 40pdrs and six smaller guns; these last presumably muzzle loaders. Armstrong invariably get the credit for BLRs that appear on lists for the 1870s, in much the same sloppy fashion as all MLRs by definition must be Armstrong's. The simple truth is that Armstrong did not introduce BLRs of bores larger than field artillery size until the early 1880s. The 6in L/23 and 8in L/26 of 1879 were experimental guns. Hence, if a BLR during the 1869 to 1882 period was not of Krupp or French construction, then it was most likely a Vavasseur, though an early, short version of the Armstrong 12cm L/20 appeared in 1876. And the 40pdrs and, likely 20pdrs, whether muzzle- or breech-loaders, were also from The London Ordnance Co.

Most Portuguese naval construction in the late 1860s through the 1870s consisted of gunboats and small cruisers suitable for colonial service, of which there were four 'classes.'

Tejo (1869), *Douro* (1873) and *Quanza* (1877) form the first group. Their original armament consisted of one 16cm and two 40pdr MLRs. All three were re-armed with Armstrong BLRs in the 1880s.

Rio Sada, *Rio Tamega* and *Rio Lima* (all 1875) were originally armed with a 7in and four 40pdr MLRs. In the 1880s, the 7in was replaced by a 6in Armstrong BLR and the 40pdrs with Armstrong 4.7in (12cm) BLRs. The fourth sister, *Rio Vouga* (1882) was completed with a 6in L/27 Armstrong (which dates to 1882-3) and four 100mm French Schneider guns.

Rainha de Portugal and *Mindello* (both 1876) mounted two 7in and four 20pdrs, all MLRs.

Mondovi, *Bengo* (both 1879) and *Rio Ave* (1880) were originally armed with one 16cm and two 40pdr MLRs. All three were re-armed in the 1880s, but not uniformly. *Mondavi* received one Armstrong 6in BLR and two 8.7cm Krupp guns. *Bengo* seems to have received the same 6in L/26 guns available around 1885, but two 4.7in (12cm) guns. And *Rio Ave* received a 4in and two 3in BLRs.

In 1870-71, some twenty eight 3in 12pdr field guns were hurriedly built on order of the French government. (They also acquired two batteries of Blakely 3.5in 12pdr guns from Fawcett, Preston.) The French were not impressed. Vavasseur redesigned the gun, making it longer and stronger but maintaining the same weight. And with carefully and properly fabricated shells, rather the hurriedly cast under emergency time constraints, the gun was tried in 1873-4. The French military authorities proclaimed it superior to any other guns they had tried. Their only reservation was that the quality of the shells for the rib rifling might be a problem in time of war.

The Carlist revolutionaries bought a number of 3in 12pdr and 3.75in 20pdr guns during their war with the Spanish government in 1872-75. Post-revolution, the Spanish authorities had nothing good to say about those guns.

The opening Chinese market as a whole presented lucrative commercial opportunities to western merchants. But for ordnance manufacturers, China was not a single market, but rather five separate markets! The reasons for this complexity were fairly straight forward, but the ramifications were not. Essentially, the Imperial Government in Peking (Beijing) reigned increasingly lightly over the country, while real power, both civil and military, was vested in the Regional Governors – often referred to as Governor-generals.' Consequently, these powerful men were free to exercise their own judgments and methods within their Regions in addressing Imperial policies. There was no viable central authority.

In practical terms, this included trade, military and naval policy. Each Regional Governor was responsible for training and equipping his military forces, protecting his own coasts, acquiring his own naval ships from the Imperial government, and especially acquiring the guns and munitions necessary. For example, artillery of all sizes were considered as 'capital assets' of the Region, and were not transferrable without compensation. Thus, the Regional Governors bought whatever they preferred, limited only by what they could afford. No standardization was required.

Evolving naval policy called for four 'fleets,' the Peiyang (Beiyang) 'Northern Seas' Fleet based around the Gulf of Pe-chili, the Nanyang or 'Southern Waters' Fleet based at Shanghai, the Fukien (Fujian) Fleet based at Foochow, and the Kwangtung (Guangdong) Fleet based at Canton. In addition, the Governor of Canton operated a small flotilla of gunboats for piracy suppression, separate from the Fleet, as did the Governors of Shanghai and Foochow, though to a much lesser extent.

Blakely 'broke into' the 'Chinese' market in 1864 through the use of third parties in the trading community. So it follows that the customers were the Governor-generals of the Regions containing the most important Treaty Ports of Shanghai, Foochow and Canton. Vavasseur inherited this network, and may have begun using it under the auspices of J Vavasseur Co in 1867, but certainly with the London Ordnance Co.

Krupp, who had begun wooing the Chinese officials in 1866, appointed Friedrich Peil to solely represent Krupp in China in 1870. This strategy proved successful, as the following year it appears that a combination of orders from Nanyang and Fukien amounted to 318 guns of all sizes. And a follow-on order was placed in 1874.

It also appears Whitworth (Manchester Ordnance & Rifle Co) established at least a presence in the late 1860s in the Shanghai area.

From all indications, Armstrong/EOC did not enter the Chinese market until 1876, through the sales of Rendel gunboats, also known as the 'flat iron' gunboats, and then primarily with the Peiyang fleet.

The permutations were complex. As mentioned above, the guns were capital assets. Consequently, a ship transferred from the Fukien fleet to the Peiyang fleet would first land her guns, projectiles and ammunition. Upon arrival at the new duty station, Peiyang owned guns and suitable projectiles and ammunition would be installed and loaded. This consideration played against transferring ships.

Another consideration was that projectiles were not inter-changeable, even if calibers were the same. A Blakely gun would not be able to fire Vavasseur, Whitworth or Armstrong projectiles, and *vice versa*. And of course Krupp guns did not match calibers. To a considerable degree, this tied ships to their home fleet. It also played against manufacturers entering the market.

There are a considerable number of data points that illustrate the situation:

An 1876 British report on Foochow noted that the artillery park contained a number of Blakely, Whitworth and Krupp guns along with a number of old smooth-bores.

Of the 56 major pieces of ordnance on the 11 Chinese ships at Foochow in 1884, 3 were 8-inchers [sic. Krupp 21cm] and 30 were Vavasseur of less than 6-in caliber [sic. 16cm or 6.3in].

Two forts destroyed by the French squadron as they retired from the Battle of Foochow, Ft. Kimpai mounted two 7in Vavasseur guns, and Ft. 'Blanc' mounted four 7in Vavasseur and one 21cm Krupp guns.

In 1867-68, Governor-General of the two 'Kwangs' Jui-lin purchased eight steamers from British and French sources for the Kwangtung fleet, and appears to have served as agent for another ship for the Nanyang fleet. Other than ship names, virtually no information has survived. One of these was the *An Lan*. The name appears again in 1871 in Foochow as an armed transport/gunboat of 1005 Tons, armed with one 7in, four 5.5in and two 4.5in breech loading guns. 5.5in is a Vavasseur caliber, 4.5in is a Blakely caliber, and 7in is common to both. Was the *An Lan* of 1871 the same ship as the *An Lan* of 1867, at Foochow to enhance her original armament of Blakely guns (7in and 4.5in)? Or was the ship of new construction whose armament reflected the mixture of guns available? Or perhaps the *An Lan* had been transferred from the Kwangtung to the Fukien fleet? *An Lan* sank in a storm off Taiwan in 1874.

Table 4 summarizes what can reasonably be inferred from the available data. But it is not completely accurate due to two major factors. First, assuming the *An Lan* was a single ship, there are at least nine and likely fourteen ships of the Kwangyang fleet, all dating in the 1861 to 1868 time period, whose armament is unknown. The same applies to two ships of the Fukien fleet, four of the Nanyang fleet, and at least one for the Peiyang fleet. So it is quite likely that Blakely guns are under-represented. And second, a considerable number of the ships in the Nanyang and Fukien fleets were were of the armed transport/gunboat variety, carrying a minimal armament of three or five guns, but with a fairly large cargo capacity. Fitting them out as dedicated warships required docking to mount the additional guns and arrange magazines, projectile stowage and crew quarters One such ship, the *Yang Wu*, was completed with a full armament of one 6.4/7in 150pdr, eight 5/5.5in 70pdr and two or four 4.2/4.5in 24pdr Whitworth guns. Another, the *Fu Po*, was 'converted' following the undeclared Sino-French war of 1884-85. In addition to her peace time armament of five Vavasseur guns she received an 8in muzzle loader and six short 4.7in breech loaders from EOC. In other words, the armament of that type as warships was understated.

Table 4. Imported Naval Guns That Can Be Accounted For, 1861–1883

	Blakely	Vavasseur	Krupp	Whitworth	EOC	Other	Total
Nanyang		58	11	52	13	15	149
Kwangtung	3	4			5		12
Fukien		32	5	11	4		52
Peiyang		26			45		71
Total	3	120	16	63	67	15	284
	1,06%	42,25%	5,63%	22,18%	23,59%	5,28%	284

And of course, light and field artillery and coast defense guns are an unknown quantity. The coast defense guns present an especially vexing problem as they were inter-twined with the needs of the various fleets. In other words, the central artillery park of each region had to supply both. Armament for a new or transferred ship needed to be supplied from 'regional' resources. Richard N.J. Wright documented this unusual practice to the greatest extent possible.

Edward Very, writing in 1880, gives what may be an extreme example. The two 'Alpha' and the two 'Gamma' class Rendel gunboats, originally intended for the Nanyang fleet but usurped by the Peiyang fleet, were transferred to the Nanyang fleet when the four 'Epsilon' class arrived at Tientsin in 1879. One of the 'Iota' class followed in 1880. According to Very, three were armed with 12in Vavasseur guns. Other sources state the guns were taken form coast defense fortifications. If Very is correct, and no other standard source confirms his information, the process would be in keeping with standard practice, and the preferences demonstrated by the Governor-General. Presumably, the other two gunboats, likely the smaller 'Alpha' boats, were also provided new armament, either Vavasseur – there was a 10in 16 Ton gun, but no detailed information has survived (a hypothetical reconstruction is included below) – or Krupp guns. And by implication, the coastal fortifications in the Peiyang region would have received five Armstrong guns, while the Nanyang region would have been temporarily reduced by five guns.

There are numerous other examples of the inter-play between the regional fleet and the administration and allocation of guns.

The Nanyang wooden frigates *Hai An* and *Yu Yuan*, completed in 1872-3, were originally armed with two '9' inch on pivot mounts and twenty four 70pdrs, all Whitworth guns. By the end of the decade, Whitworth had fallen out of favor, and in the early 1880s both were re-armed with two 21cm on pivot mounts, four 15cm and twenty 12cm Krupp guns. The Whitworth guns would be allocated as needed.

The gunboat/transport *T'aiAn* was completed at Foochow in 1877, and apparently fitted out for the standard armament of one 16cm and four 40pdrs, presumably Vavasseur guns. But the ship was allocated to the Peiyang fleet, and on arrival was armed with ten guns, presumably from EOC; likely two 70pdr 6.4in on pivot mounts fore and aft and eight 40pdrs on the broadsides. The Tientsin Arsenal was constructed from 1866 to sometime in the early 1870s, with British assistance, so by 1877 there would be a sufficient supply of ordnance to arm ships with whatever types Li Hung-Chang preferred.

Much the same situation applied to the composite gunboat *Wei Yuan*, also completed at Foochow in 1877. She was armed with seven guns upon arrival at Tientsin, likely a 70pdr but possibly a 7in, and six 40pdrs on the broadsides.

The available evidence indicates that to 1875, the Nanyang, Fukien and Kwangtung Regions bought 12in 27Ton, 7in 5Ton 1cwt, 6.3in 100pdr, 4.75in 40pdr, and 3in 9pdr muzzle-loading rifles, and 5.5in 60pdr and 3in 12pdr breech-loading rifles from Vavasseur. Post-1875 purchases are unknown but likely substantial, and of course ended in 1883, while Krupp's market share grew and became dominate in the decade of the 1880s.

"At the close of 1882 the authorities [the War Office acting on the recommendation of the Ordnance Committee] arrived at the important decision that all guns manufactured in future are to consist wholly of steel...When once steel had clearly shown that it was superior to wrought iron, even in the very qualities to which wrought iron owed its popularity, the results of the competition between steel and wrought iron was a foregone conclusion." So wrote The Engineer on January 12, 1883, which can only be seen as a very belated complete vindication of Blakely's work from 1863, Vavasseur's work, and to a lesser extent, Whitworth's work, and their advocacy of built-up all-steel guns. The long overdue repudiation of wrought iron as a material for ordnance construction also cast off the last remnant of the 'Armstrong system, which had never been viable.

Three years previously, as recorded in The Engineer (November 28, 1879), "A decisive step has just been taken by the War-office in reference to the breech-loading question. Orders have been given for the manufacture of two large breech-loading guns at the Royal Arsenal [Woolwich], one to weigh 25 Tons and the other 40 Tons... The precise method to be adopted as concerns the breech-closing arrangement is not yet disclosed; but it is certain that the guns themselves will be constructed on the Fraser system."

This effectively brought an end to the muzzle-loading rifled gun which had, according to Captain H. Garbett writing in 1897, "...undoubtedly set us back, as compared with France and Germany, some fifteen years in the art of gun construction..." The two-pronged question is, why the inexplicable delay in adopting all-steel construction and breech loading ordnance, and what accumulated events finally forced the two great changes?

Lt. C.E. Dutton of the U.S. Ordnance Corps revealed part of the answer in an article published in 1872. "...The English constructors [at Woolwich] have a pious hatred of both steel and cast iron, on account of what they term their 'treacherous' character, and maintain that they use steel in the bore, not for its strength, but for its hardness and freedom from welds, which are necessary in [wrought iron] coils. They depend upon the coils for the restraint against bursting, and consider the steel tube a mere lining, charging upon the tube all failures. On the other hand, the opponents of the Woolwich [and by extension, Armstrong/EOC] construction say that it is weak, because the soft wrought iron, with an inferior elasticity, relaxes its grip [loses much of the initial tension] on the central tube after a few fires, giving it very little support, and compelling it to sustain, almost unaided, the stress of firing...It can be shown, I think, that the Woolwich people very much underrate the efficiency of the steel tube, and somewhat overrate the efficiency of the coils, while their adversaries as obviously are guilty of the reverse error. If either party could prove its position, it would prove what is not a fact, viz., that the Woolwich gun is a very bad gun..."

Lt. Dutton may have the right of it! The aversion to steel represents Armstrong's philosophical legacy; an attitude based on the false belief that the reinforcing coils of wrought iron would signal a problem in advance of a catastrophic failure and prevent the gun from bursting explosively. This may well have been the experience of the Armstrong RBLs and even with his experimental large muzzle-loaders, all of which featured an inner coil ['A' tube] which would generally fail early but also more slowly, with bugles and/or deformations. But the situation changed completely with the introduction of oil-tempered steel 'A' tubes which were the main strength of the gun; pressures great enough to burst the steel would hardly be contained by soft wrought iron coils. Yet this blind faith in masses of wrought iron coils – though great mass does have a certain value – seems to have forestalled an objective investigation of alternatives from 1864 on.

The attitude of the authorities of the War Office, who alone controlled all matters relating to the ordnance for Her Majesty's Armed Services, "...can ask what guns, if we are not to return to our old stock of smooth bores, have been **proved** to be better than the Armstrong..." system? The answer, simply put, is that competition had not been allowed; EOC and Woolwich jointly had exclusively dominated the provision of guns since 1859.

1864

1864 marks the first of Captain H. Garbett's fifteen-year period of relative 'stagnation' in the field of ordnance. It also presented a 'golden opportunity' to 'catch up' with rapidly advancing technology and experimentation. A quick review of the resources available to replace the failed Armstrong 'system' reveals several courses that could have been utilized to find a better way forward:

Mersey Steel and Iron Company, under the direction of Col. Cole, were marketing field caliber guns of ingenious design, though built of wrought iron. Rendered in steel, Britain could have availed herself of first-rate breech-loading artillery.

Henry Bessemer, of steel fame, had been experimenting with mild steel field caliber artillery since 1858. In 1861 he designed and built a breech-loader for 'larger' calibers, either solid cast or built up with reinforcing rings.

Joseph Whitworth, the talented metallurgist, was at the cutting edge in developing steel suitable for Great Guns. The problems with his guns were faulty construction, the hexagonal rifling and the 'quick' twist of that rifling. "Improvements in the manufacture of homogeneous metal [steel] now enable me to use hammered moulded hoops of that metal, which have double the strength of welded coiled hoops of wrought iron, and which I have therefore, always preferred and used for the inner tube of my rifled guns." [Letter to the *Times*, October 1862]

The Blakely Ordnance Company was enjoying considerable success under the leadership of the Captain and Josiah Vavasseur. They offered a complete line of all-steel muzzle-loading rifles from field calibers up to 11in Great Guns, and were investigating a breech-loading system.

Vickers had developed an Annealing process for ordnance in 1863:

1. Around a solid – or hollow cast – central core are fitted concentric rings so as to create one mass;
2. The core is bored out to a bit less than the desired final caliber;
3. The mass is then placed in an annealing furnace and heated;
4. The cooling process is from the inside out, using a stream of water or other liquid, or a jet of air.

Thus, each succeeding ring cools at an even rate and shrinks onto the next inner ring, combining the Rodman process with initial tension for a very strong gun.

From this partial list of available assets, the Select Committee on Ordnance was in the unique position of being able to discard the errors of the previous six years and chart a course forward. However, they opted for more of the same.

Professional opinion, as reflected by The Engineer Magazine, Mechanics' Magazine and Engineering Magazine, had not been shy about their reasoned preferences.

"With a [steel] casting equally strong throughout, and nowhere weaker than 100,000 lb. to the square inch, it would be perfectly practicable to make a gun…We cannot think, after what has been already demonstrated…that the day is not far distant when English steel cannon will outnumber the vast batteries already mounted on the Continent…" [August 2, 1861]

"Captain Blakely is supplying foreign Governments with guns capable of smashing the Warrior's sides like and egg shell, but the authorities deny him all opportunities for firing at Shoeburyness or Woolwich." [October 17, 1862]

"The English Government would do well to note the progress the Russians are making in gunnery. Cast steel guns are decidedly before any yet produced in England of any other material." [October 23, 1863)

"…Solid bars of Sheffield steel, 14 ft. long and 24in. or more in diameter, are being bored out…to calibers of 9in, in others of 11in…Heavy cast steel jackets are shrunk accurately over these, and over these again a serried of steel hoops formed from bars 4in. square…Now, why are not such guns adopted in our Navy? Why should the makers of such guns have no other customers than foreigners?" [November 6, 1863]

"…Steel is, of course, a stronger and more durable material than wrought iron, and every ordnance engineer but Sir William Armstrong perceived this, as a matter of course." [November 13, 1863]

"…The whole question of good guns is embraced in the question, 'How to make a strong gun?' To make the strongest gun we must employ the strongest metal. That metal is steel…The 'coil system' merely permits of securing the whole strength of wrought iron in the direction of the diameter of the gun; but it cannot in any way increase that strength…Tough steel, when cast, is equally strong in all directions, and at least one-half [50 %] stronger than wrought iron in any direction. This fact is founded in nature, and it must hold true…" [December 11, 1863]

"Wrought iron… is quite inferior to cast iron in respect of resistance to crushing, and here the real weakness of wrought iron when employed in the chase of a gun. The grain of the metal is crushed into itself, with the destruction of the fiber of the metal, which, therefore, gives way in the form of internal cracks. For a long time all the Armstrong guns were formed of wrought iron throughout, and it was not until after repeated failures that the reform of the chases, which are now made of steel, was affected… The common sense conclusion of the whole question is, let Government apply itself to the discovery of the strongest gun, leaving the schemers the refinements which have so long been inflated to the dignity of so-called 'systems of ordnance.'" (February 5, 1864].

"That the Government will have the courage to confess, what every disinterested person clearly sees, to wit, that the whole system of Armstrong heavy guns is a failure, is not likely until the actual test of war shall have proved this…Can it be that we need to go again over the reasons why wrought iron heavy guns can never bear heavy firing beyond, at the most, a few hundred rounds?…We think official eyes have been shut to a great deal of what is passing elsewhere, and that at Woolwich there has been no opportunity for the admission of proof…steel, however, promises the best results as a material for guns…" [March 4, 1864]

In Parliament, Mr. Berkeley addressed the situation, stating in part, "…Because in this age, when our Ministers propound the doctrine of throwing everything open to competition, they yet allowed a profound monopoly to exist in guns, shutting out all our most competent engineers. Everything must be done by Sir William Armstrong, who, when he made an expensive failure, was not discharged, but was left to try again; whereas everybody who opposed him received the cold shoulder…and Captain Blakely also was making guns for the Russians – offering, Englishman-like to back his weapon for a thousand guineas. Our Government…gave the cold shoulder to native talent, and that talent was now seeking a market elsewhere." [March 18, 1864],

"Whatever may be the real improvements made in the construction of guns it is immediately taken advantage of to increase their size, and thus their destructive effect…Sir William Armstrong has succeeded in making a 13 1/3-in. gun which has successfully withstood a 90 lb. charge… It has been feared that, with such large guns, there would be no adequate means of working them; but the rapid improvements being made, and the resources of science, render it more likely that 20-Ton guns may yet be worked, even on shipboard, and certainly within casemated forts. The Blakely Ordnance Company are first sending to Russia a 11-in. gun, weighing 23 Tons, and intended to bear a very heavy powder charge…are the heaviest [caliber actually in service], the most effective, and the most easily managed guns ever made in England…Reports still reach us from Russia that Krupp's large steel guns sent to St. Petersburg are found to burst [more preciously, one 9in. and two 8in. blocks from Krupp bored out in Russia as muzzle-loading rifles. Of breech-loaders, four 9in, burst between 4/1864 and 7/1869. All were solid cast and not reinforced.] …The results…of the trial of a 9.22in. and a 7in. gun at Portsmouth, and with considerable charges of powder and steel shot, do not bear out what was anticipated of the destructive effect of the projectiles against iron plate…Our only course is to continue our efforts to increase the strength, and thus the destructive effect of the gun…" [May 6, 1864]

"…In the meantime, some extraordinary results have been obtained from 12-pounder guns made from Naylor, Vickers and Co's steel, and this, too, is chiefly employed by the Blakely Ordnance Company. That guns stronger than any yet known can be made from the best steel, we need not now predict, but it may prove in various ways that steel guns are stronger than those formed upon any combination whatsoever of iron, and it is evident that, other Powers having taken to steel, we are likely to be placed at a disadvantage…It is with steel guns that we must expect to fire heavy steel punch-headed shot, and it is only with those shot that we can expect to pierce heavy armour plates. We advocated steel guns while the Armstrong delusion of heavy wrought iron naval guns was at its height, and it is some satisfaction to know that the principle portion [the 'A' tube] of every gun manufactured at Woolwich is now made of steel. It will not be long, we believe, before what is now admitted to be the best for the most important part will be found to be preferred for the whole of the gun." [July 1, 1864]

Referring to Armstrong's 600pdr gun, "The resistance due to a sharper twist is more than the whole gun could stand, the result is that long [heavy] shot cannot be used; they turn over like a boy's arrow without a feather [due to stripping of the studs]. [August 19, 1864]. See Appendix G.

"The future of the Armstrong gun looks dark and grim for those who take an interest in its success. After the expenditure of millions on his ideas and schemes, Sir William has absolutely failed to provide us with a gun worth the first cost of the material used in its manufacture. Mechanically wrong in principle, his ordnance can never be right in fact, and we trust that the day is not far distant when his gun, and the gigantic job which led to its construction, will have alike become matter of history." [August 19, 1864].

"The shunt system…in some respects is the very worst system of rifling ever proposed to be applied to naval purposes. From the peculiar nipping action which takes place near the muzzle of the gun [torque due to the increasing twist of the rifling]…it is anything but expedient to attempt the use of shells of any kind, as they are almost certain to be broken up or exploded by the true concussion which occurs at the moment the projectile enters the tightening portion of the length of the grooves. The acute angle…is very unfavourable to strength…Many shunts have failed after the first few rounds – one was destroyed by the fourth [round]… Apart even from these considerations…the shunt is not easily loaded, because it rapidly becomes foul [with powder residue]…" [September 9, 1864].

To all appearances, the end of 1864 promised long overdue and much needed reform for the provision of guns for Her Majesty's armed services. The resources, expertise and experience necessary to completely discard the Armstrong system (wrought iron coiled inner tube, wrought iron coils to reinforce that tube, and latterly shunt rifling with an increasing twist) were in place, merely awaiting action by the Select Committee on Ordnance. Indeed, the weak coiled inner tube had already been discarded in favor of oil tempered steel, and in October the Committee began a well-conceived and comprehensive program of trials to determine the best form of rifling. Surely the Select Committee would take advantage of the opportunity fortune had provided.

Table 5. Strength of Metals used for Artillery

Material	Tons per Square Inch		Elongation per Inch at Breaking
	Yielding	Breaking	
Bronze	6,8	14,9	0,29
Cast Iron	c. 4	9 to 14	
Wrought Iron	11	22	0,3
Steel -- Soft	18	31	0,21
Steel -- Oil Tempered	31	47	0,11

<u>1866</u>

"It is not too much to say…that these four systems of rifling are the best yet produced for naval purposes; and if causes are to be followed by their proper effects, it is much more than probably that the [rifling] regarded as the best by the committee, will be accepted by the Government as the representative of the future armaments of our iron-clad frigates. It is true that only certain functions…are being tested, but it must be remembered that the character of any system of rifling adopted, modifies and governs everything else – except, perhaps, mere weight – connected with the use or manufacture o ordnance. On this element ultimately depends not only the powers of endurance of the piece, but its practical adaptation to the ends sought…So powerful, indeed, is the influence exerted, that the general characteristics of a gun can be determined with approximate accuracy from the mere consideration of the…projectile employed, and the nature of the grooving intended to give it…rotation…The balance of advantages [and results to date] appears to lie with the invention of Commander Scott." See **Appendix H**. [March 3, 1865].

"…We do doubt, however, and seriously doubt, whether the solid cast steel guns [not built-up or reinforced] now being so largely adopted in Russia, are one whit stronger than cast iron guns of the same caliber made in America [think Double and Triple Banded Brooke guns, not Parrotts]…The 'Parrotts' are simply Blakely guns of [very] early construction, and Captain Blakely would not himself now think of employing cast and wrought iron, but trusts almost entirely to cast steel…We do not for one moment deny that steel has a far greater tensile strength than cast iron, yet it does not follow that cast steel [unreinforced] will make the strongest gun…Whether Captain Blakely can rely upon a tougher quality than can be produced in [a single] ten-ton castings, is not certain. His guns are gaining a high reputation for strength, and it may prove that his are the strongest made. It is clearly the duty of our Government, now well out of the Armstrong nightmare, to inform itself fully upon this point, and to let its information be known." [March 10, 1865]

On May 15th, at the RUSI, Major Owens, Professor of Land Artillery, delivered a paper entitled "On the Present State of the Artillery Question." He revealed in the paper and subsequent discussion a number of startling actions by the Select Committee.

That the remainder of the trials program had been suspended,

That there had been no trials with live shells, but a small "private" practice involving two guns (Scott rifling and the modified 'French' rifling) firing five rounds each with shells filled with sand,

That the Committee had already reported to the Government [War Office] in favor of the modified 'French' rifling for the 'Woolwich gun,' the final details of which had not been determined [**see Appendix F**]. (Officially accepted on June 7, 1865),

That the rifling grooves were to have an increasing twist, even though the Americans and the French had abandoned that form as having caused premature shell bursts in the chase, Begrudgingly, that General Lafroy, President of the Committee was of the opinion that the grooves were too deep and too wide [1/4 in. deep by 2.09 in. wide versus Scott's 1/8 in. deep and 0.8 in. wide] and increased the windage,

That the battering charge for the 7in gun being developed at Woolwich was reduced from 25 lb. to 22 lb,

That there had been no rapid-fire trials. [May 19, 1865]

"It is far from easy to regard the proceedings of the Ordnance Select Committee without feelings very nearly akin to surprise and alarm. We feel surprised that its members should have overstepped the line marked out by duty, and… assumed the position of original inventors. We feel alarm because an investigation from which really great things were expected… bids fair to prove utterly useless.

"Having arrived at a point where it was impossible longer to remain in doubt, the members of the Ordnance Select Committee, instead of continuing the trial in order to carry out the provisions contained in their own programme, and to still further test a [rifling system] which had already distanced its competitors, stop short, and, without resigning their position as judges, assume that of inventors…" [June 2, 1865].

"…Guns should never be tested directly against each other, but a definite duty should be laid for each piece as a standard of comparison, the standard to be settled before a shot was fired. Any number of different guns might, of course, be tested against this standard. The advantages due to such a system are obvious. Competitors would know beforehand exactly what they were expected to perform. It would be easy to determine what were the lowest qualifications which would suffice to fit a gun for service… Such a test would possess an important advantage in fact, that a very few trials and very moderate outlay, would suffice to show whether it was or was not worthwhile to proceed further. What we really require is, not a gun which shall comply with all sorts of conditions, but one which shall be capable of doing a certain specified duty efficiently and certainly. The search for such a gun must prove futile unless we know in the first, what that duty is, and…" whether the gun tested does or does not comply with the specifications [June 9, 1865].

The "…Committee have selected the simpler uniform [rifling for the 7in gun] so ably advocated by Captains Fishbourne and Selwyn, of our own navy, as well as General Gilmore [of the U.S. Army Ordnance Department], and other distinguished foreign artillerists, and adopted by Commander Scott, R.N." But the 8in and 9in guns under development at Woolwich remain undetermined [September 22, 1865].

The Committee partly based their decision in favor of the modified 'French' rifling on ease of loading – i.e. three groves are easier than five [September 29, 1865].

The trials revealed injuries to the powder chambers due to the large charges. The center of the conical bottoms developed 'defects' in the form of cracks or fissures 0.35in deep in the Lancaster gun, 1.5in in the new 'French' gun and 2.8in in the Scott gun. These were officially attributed to weakness in the cast steel.

The smaller 'centering' studs of the modified 'French' projectiles were placed to as to use the lands to keep the projectile centered in the bore, and not intended to engage the grooves. But examination of recovered projectiles revealed those studs were worn and had taken the rifling, likely from the increasing twist in the chase [October 6, 1865].

The 'French' rifling was added at the specific request of the Select Committee. The increasing twist was a feature of the M.1858-60 guns, which they abandoned with their M.1864-66 guns. Twist increased from 0:0 [straight] to 1:37. The variance evident in the performance of the Scott rifling originates with the Committee experimenting with a zinc layer on the 'rib' of one batch of shot. This had a detrimental effect on the smooth progression of the projectile, and reduced performance [October 1865 edition].

The new 'French' 7 ½ Ton gun was …"found to be deeply fissured along the grooves reaching…quite through the steel lining tube." Likely in the chase where the stresses of the increasing twist was greatest. "The 7-inch Armstrong shunt gun met with the same disaster, after very little practice…The Frederick 7-inch 135cwt [6.75 Ton] gun, a six-groove shunt rifle had only fired a few experimental rounds before it was also split at the angles…" [December 29, 1865].

"Major Palliser has at last succeeded in producing a rifled gun from an old iron 68-pdr smooth-bore, which has displayed very fair powers of endurance. The gun has been tested to destruction, going to pieces at Shoeburyness after 904 rounds had been fired." Unfortunately the charge and projectile weights were not released.

Palliser guns at this time involve boring out the cast iron barrel – intended to eliminate and indentations, cracks or fissures caused by normal use over time – and then inserting a wrought iron coil tube, *a' la* the Armstrong system, and an additional inverted 'cup' for additional strength at the bottom of the bore protecting the breech. The 68pdr was a particularly strong gun, able to withstand proof charges of 22 lb. of LGP and battering charges of 18 lb. The question becomes how much of that strength is lost when bored out, especially in the chase forward of the trunnions, even though replaced by slightly thicker but softer wrought iron coils? Experience has demonstrated that the performance of such coils using heavy charges is not encouraging, and hence Palliser's theory must be flawed [April 13, 1866].

"The defeat of the Spanish Fleet at Callao is undoubtedly a triumph for the Blakely and Armstrong guns (the first most especially), used by the victorious Peruvians…

The Blakely guns "…are entirely of steel, except at the trunnions, which are of wrought iron, and they weigh 15 (sic. 14) Tons; their caliber is 11in…with charges of 60 lb, 50 lb. and 40 lb. of [RLG] powder. The construction of these guns was that first advocated by Captain Blakely.

Fig 4. Large Blakely gun and battery at Callao

"Guns of a smaller size, some of which are breech-loaders, have been sent by Captain Blakely to all parts of the world…The Blakely Ordnance Company's guns at Callao are, in fact, the heaviest rifled ordnance that has ever been in action…".

Accounts of this action vary considerably, and details are scarce. The battle, fought on May 2nd, lasted about five and a half hours; from the time the Spanish fired the first shots at 11:50 in the morning, to when the Peruvians fired the last shots at the withdrawing Spanish ships, after 5:00 in the afternoon.

The Spanish fleet mounted some 240 guns, almost all 20cm and 16.1cm smooth bores. A small number of C.H.S.R. 16-cm guns were present, providing some irony. That type gun, constructed at theTrubia Arsenal between 1860 and 1862, were 'first generation' Blakely patent guns, cast iron hooped with wrought iron or steel.

The Peruvian defenses mounted some forty five guns, plus an additional twelve carried by their warships. But twelve of those coastal defense guns were modern heavy ordnance, composed of three 9in Blakely, four 10in Armstrong and five 11in Blakely muzzle-loading rifles. The remaining thirty-three guns were 32pdr smooth bores. One of the Blakely guns recoiled so violently that it ran off the end of its wooden mounting, and though undamaged, was out of action. The four Armstrong 300pdrs were mounted in pairs on top of two iron turrets. This was less than ideal as it made loading difficult. One shell fell to the ground and exploded, killing a number of the defenders.

One shot or bolt hit the Spanish iron-clad frigate *Numancia* forward, piercing the 5 ½ inch armor and exiting below the armor on the unengaged side of the ship. The Spanish claim the projectile came from a 10in Armstrong gun, but the Peruvians just as adamantly claim it was fired by an 11in Blakely. The plate has been preserved at a Spanish museum, but does not prove the claims of either side.

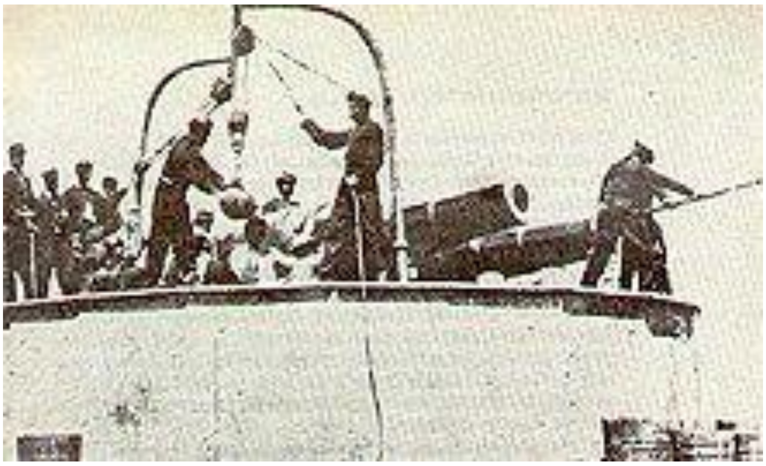

Fig 5. Armstrong 300pdr mounted on turret

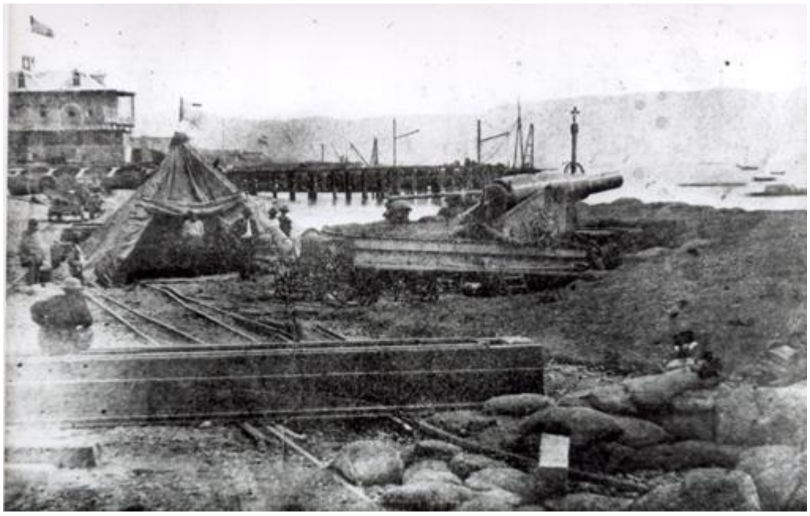

Fig 6. Blakely 11in at Callao

The Blakely guns withstood the large, even excessive, charges of RLG well, even though the steel had not been tempered, and none showed any injuries. Beyond the American Civil War, where Blakely guns of older patterns built around reinforced cast iron which did perform well, the Battle of Callao offers the only 'trial by combat' of the newer all-steel built-up patterns. Yet even this apparent success, which followed years of ignoring Blakely ordnance, did not cause the authorities at the War Office to reconsider.

"Further particulars, such as the number and weight of the charges fired from the heavy Blakely rifles, and their present state after such service, will no doubt be looked for with avidity in this country. It will be Captain Blakely's own fault if he does not make political, or, rather, commercial capital out of this affair. It is more than probable that the performance of his guns will contrast favourably with those of the 'Big Wills' of Elswick of a not much heavier caliber...we find that the Armstrong 13.0 in. [sic. 13.3in] caliber shunt gun with ten grooves, weighing 22 Tons 15cwt, was found unserviceable after only fifty-one rounds...'The steel tube is split in at least eight of the grooves; the external [reinforcing wrought iron] coil is split at the breech at one of the intermediate coils…full extent of injury is not ascertained.' [Another] Armstrong 13.3in. gun (ten-grooved shunt) weighing 22 Tons 18cwt, was fired 202 rounds…The gun is, however, still reported to be serviceable. 'There are various superficial defects and incipient fissures in the bore, and a bad weld [in the reinforcing wrought iron coil] 10in. from the muzzle, but nothing to cause the condemnation of the gun.' It is more than probable that the steel Blakely's at Callao may give better results than this" [June 15, 1866].

Fig 7. Image Blakely 11in 14 T gun

The authorship of the following item is unknown, and it is a paean to the Fraser system of gun construction at Woolwich, which suggests its origin may be in the War Office, which had previously made its official position clear, and which the author is in full agreement.

"The outbreak of hostilities on the Continent has once more attracted the attention not only of engineers but of the general public to questions connected with the construction of guns and armor-plated ships, and the columns of the daily press teem with articles on such subjects. It is to be regretted that the writers, as a rule, display much ignorance regarding the real nature of the great problems to be solved, while it is evident that they are completely in the dark as to the steps which have recently been made toward a satisfactory solution…We ask in vain for instances of better results obtained by other makers or in other countries. The Government manufacture of guns in Great Britain is represented by that which is done at Woolwich; and we may safely challenge private makers to prove that they have produced better guns than those turned out recently at the Royal Arsenal. We know that Sir William Armstrong, with all the resources of Elswick, has not been able to excel them. As to the steel guns of Krupp we know nothing definitely, except that they have given very indifferent results indeed on the Continent. As regards Captain Blakely's guns we are nearly in the dark. We know that they have given good service at Callao, but we are at a loss as to their powers of endurance which they have manifested…In point of fact, the gentlemen who so eagerly attack the Government…are absolutely unable to point out the direction in which we should seek for the 'gun of the future,' or the firm to which we should apply for its manufacture…" [See Appendix F].

The author then produces three statistical examples intended to prove the endurance of the new Fraser guns:

9 in. Fraser Gun, with Wrought Iron Tube

370 rounds fired, only two with charges greater than the 50 lb. battering charge, average charge weight – 42.69 lb, average projectile weight – 243.1 lb.

9 in. Fraser Gun, with Steel Tube

400 rounds fired, without details, average charge weight -- 42.84 lb, average projectile weight – 253.25 lb.

9.22 in. 200pdr Armstrong Gun (with Steel Tube), Burst at Shoeburyness

402 rounds fired, average charge weight – 39.81 lb, average projectile weight – 217.33 lb.

No mention of the condition of the Fraser guns following the trial.

"…Surely on the face of such facts as these it is unjust to blame Woolwich Arsenal, or to assert that the Government cannot produce a good gun. Many persons will no doubt dispute the accuracy of Mr. Fraser's theory: 'Few parts and ductile material;' but it cannot be disputed that he has achieved a great success…" [June 22, 1866]

Remarks of M. Dupuy de Lome on the present state of French Ordnance, the M.1864-66 guns:

"As to artillery, it was impossible that progress should not be made. But there was evidently no reason why we should exhibit inconsiderate haste. War was not imminent. It was necessary to examine all the systems known. At the present moment – I have no reason for keeping the secret – we have succeeded in making pieces, the efficacy of which is greater than that of any of the pieces possessed by foreign nations! Amongst our new pieces there are three different models intended for the navy; the first is 16 centimeters [6.48in.]…; the second 19 centimeters [7.64in.]; the third 24 centimeters [9.45in]…The piece of 16 centimeters…weighs five tons [11023 lb, 4.92 Tons, 98.4cwt]; it throws oblong solid shot weighing 45 [and 30] kilograms, explosive shells of [31.3 kg, 69 lb.] and, although rifled, round shot of 15 kilograms [33 lbs]. The second piece, that of 19 centimeters, weighs eight tons [17636.8 lb, 7.87 Tons, 157.5cwt]; its projectiles are an elongated solid steel shot of 75 kilograms [c. 165.4 lb.], an explosive shell of 52 kilograms [c. 115.2 lb.], and a round shot of 25 kilograms [c. 55.1 lb.]. The piece of 24 centimeters weighs fourteen tons [30864.4 lb, 13.78 Tons, 275.6cwt] – it is the heaviest that can be employed on board ship; it throws elongated solid steel shot of 144kilograms [c. 317.5 lb.], explosive shells of 100 kilograms [c. 220.5 lb.], and solid round shot of 48 kilograms [c. 105.8 lb.]. All these pieces have a range of about six kilometers [c. 6560 yards].

"What pieces can be opposed to these? I do not hesitate to say that it is in England we must seek for the means of comparison. She possesses pieces of [7in.] and [9in.]…which are not so large as the corresponding pieces I have mentioned. The English powder, it is true, is quicker in its action; the projectiles have, therefore, a greater initial velocity, but in consequence of the superior weight of our projectiles we arrive at the same range. The active power, that which results from the multiplication of the weight of the projectile by the square of the velocity, is one greater in the case of our pieces.

"These works have not been improvised, a series of most careful experiments, extending over several years, has been made under the direction of the most competent men…that by proceeding slowly and wisely a great economy has been achieved; we have constructed our pieces of cast iron without having had recourse to cast steel, of which our ironworks do not yet supply a sufficient quantity [for gun construction]. [Note that the guns of the M.1858-60 and the new M.1864-66 were of Blakely patent construction; cast iron liberally hooped with steel.] The soundness of these pieces is beyond all question. The 19 centimeter guns have been placed on board the fleet after the most trying experiments. They were fired 700 or 800 times, with proof charges [generally understood to be heavier than the service battering charge] without undergoing any alteration [injury?]…We are studying the fabrication of pieces in cast steel, which would be an advantage in point of weight…" [June 29, 1866].

The firm of Deakin and Johnson have improved on their previous patents, and developed a method for producing steel or iron tubes with great precision, suitable for guns both large and small. The process involves working the metal while hot and under hydraulic pressure, with a mandrill forming the interior of the tube to the diameter desired. The 'A' tube may be closed for muzzle-loaders or open suitable for breech-loaders. Guns may be built-up of successive tubes as required [August 24, 1866].

In trial, both Palliser and Gruson chilled shot and shell were effective against 8in armor plate with 18in of wood backing. The range was only 200 yards, so the impact was near 'normal,' i.e. near 90-deg. As obliquity increased, effectiveness decreased.

As the depth of the 'chill' increased, so too did brittleness, which effectively limited the angle of attack to near normal, and hence close range.

Chilled cast steel would have been more effective than cast iron, but also more expensive.

Black powder filler for shot was about 1.5 % of total weight, but was not always filled. For 'shell,' the burster was around 2.5 %, which would explode in the plate or immediately after penetration, in the backing. [Palliser 'shell' does not rely of a fuze, as does 'common explosive' shell. Detonation of the filler relies on a combination of impact and friction heat to ignite the burster] [September 28 and October 26, 1866].

On December 13, 1866, the Royal Navy, supported by the Metropolitan Police, seized a new 1000 Ton iron three-masted screw steamer in the Thames under the suspicion that it was a 'Fenian privateer…' On board were discovered several Blakely guns, 32 barrels of gunpowder, rifles, pistols and bayonets. After several days it was admitted that the vessel, the *Bolivar*, belonged to the United States of Colombia, and was one of three guard-ship/transports to protect their coast from smugglers and pirates, as was confirmed by the British Foreign Office.

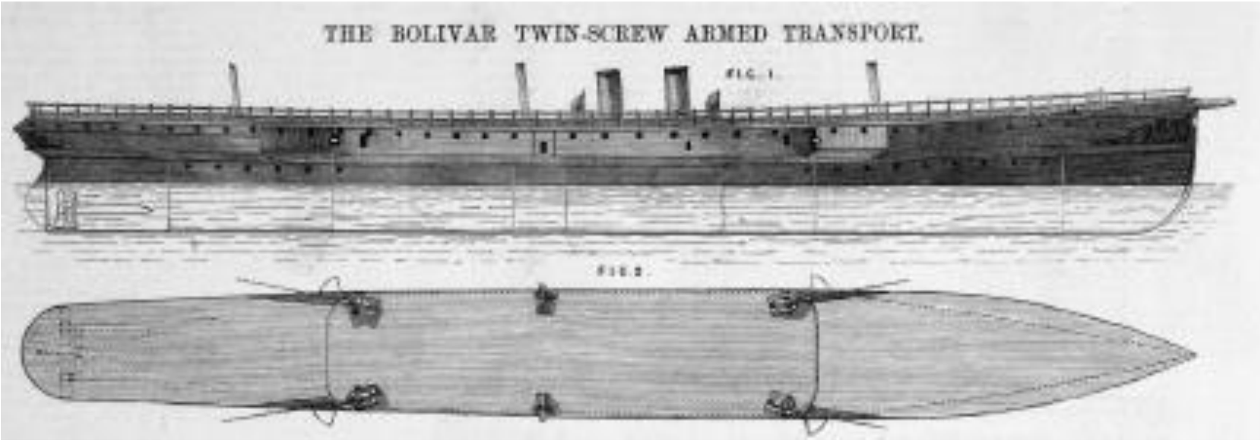

Fig 8. Blakely Bolivar

"The *Bolivar* is a type of vessel possessing several novel and valuable features, the most prominent being…the indented side, by which the landing of troops can be effectually covered by her 70-pounder guns…During her voyage the Bolivar encountered very bad weather, but excellent practice was made with her guns, the ports…apparently proving that heavy guns may be carried by sharp high-speed vessels…without detriment to any of their sea-going qualities…" [December 21, 1866].

The precise armament of the *Bolivar* is difficult to determine. The late Steven Roberts mentions two 40pdrs of 4.62in bore, and two 20pdrs of 3.5in bore. The Engineer mentions 70pdr 5.8in guns, which the four on the gun deck of the image above surely are. However, the image does not show any chase or pivot mounts, which would be normal practice. The 70pdrs can cover within 10-deg. of the line of the keel fore and aft, and with races can use the broadside ports. So it appears that the most reasonable armament would be the 70pdrs and 20pdrs shown on the gun deck, and two 40pdr pivot guns mounted on the center line of the weather deck.

These guns were among the last produced by the Blakely Ordnance Company Ltd.

The year 1866 ended with the War Office having decided on the 'gun of the future,' which, to borrow a phrase, amounted to "re-arranging the deck chairs on the *Titanic*." The Fraser system of gun construction retained the soft wrought iron coils in a different form; mantels rather than multiple hoops. The Woolwich rifling combined the worst features of the French *la Hitte* system with the worst features of Armstrong's shunt system, both in great mass. The issues of strength and endurance would continue, though the use of tempered steel 'A' tubes would give the illusion that all was well.

The various 'assets' available to provide alternatives to Woolwich suffered a net reduction from the end of 1864; the Blakely Ordnance Company Ltd. entered bankruptcy in July, and Deakin and Johnson were not up to filling the void. But the two great questions remained – What material and method of construction are best for guns, and should the 'gun of the future' be a muzzle-loader or breech loader – remained unanswered.

1872

"It may be taken as established fact that the 7in. and 9in. guns of 6 ½ and 12 ½ tons respectively, now being manufactured at Woolwich Arsenal at the rate of about thirty guns per week, we have, in one sense, better weapons than those by any other power in the world.

"...when we come to closely investigate the characteristics of our guns we quickly perceive that they are very far indeed from that perfection which it is to be hoped may be ultimately obtained. That the guns of today are superior to those of a few years back only in two respects, they are able to stand heavier charges with certainty – in other words, they have more power of endurance – and they cost less money... For the only advances which have been made in the construction of heavy ordnance the nation is indebted not to the Ordnance Select Committee, but to the superintendents and managers of the gun factories, to Woolwich Arsenal, in fact, representing engineering talent... To the Ordnance Select Committee our new guns owe nothing but the rifling.

"The result of [the Competitive Trials] was that the committee recommended the adoption of the French system of rifling, slightly modified...Nothing in the results obtained by the Ordnance Select Committee during their experiments justified its employment; and we believe it may be shown that it is about one of the worst systems, for naval purposes, which could have been adopted.

"Perhaps...when Parliament meets...we shall then...learn...what are the concealed virtues of the French [rifling] which have determined its adoption, yet do not appear in the reports of the Ordnance Select Committee, and how it is possible for serious arithmetical blunders, all tending one way, to creep into reports which profess to be, what they should be – as exact as the resources of science can make them." [January 11, 1867].

"...in the first place is it true that Major Palliser can produce a very good gun? We think not. The Palliser gun is and must be a bad gun...Major Palliser's limit of present approximate success may be regarded as the 64-pounder [6.4in.], and this gun, it is known, cannot be trusted with battering charges after conversion.

Even when using a steel liner, if the steel gives way, the cast iron body [or soft wrought iron 'reinforcing' coils or jackets of Armstrong and Woolwich construction] cannot long endure the pressures released [December 6, 1867].

"Not many months since a heavy Palliser gun, built at Elswick, flew to pieces at the first or second round...Not discouraged, he had a second 9in. 12-Ton gun made by casting an iron envelope round wrought iron coiled tubes. This gun was tried at Woolwich last week, and as might have been anticipated, went to pieces at the second round, fired with a 250 lb. shot and 55 lb. of [A4 RLG] powder. The destruction of the gun was complete, and the character of the failure excessively dangerous. The weapon was blown into four pieces, the breech being projected some thirty yards to the rear, while the remainder, from the cascabel to the trunnions, was blown off to each side." [June 5, 1868].

In August of 1868, a 9in Armstrong gun and a competing 23.54cm all-steel built-up reinforced Krupp breech-loading gun were subjected to an endurance trial. "The Armstrong gun developed a fissure [in the steel inner tube] after round 138, and was a [unserviceable] ruin after the 300th round. But the Krupp gun was still in working order after 676 rounds, even though one of the chilled AP shells had burst in and injured the bore after the 640th shot!".

On September 25th, 1868, a 9in. Fraser gun burst explosively with the first proof round at the Royal Arsenal, Woolwich. The charge was 53 ¾ lb. of A4 RLG powder, some 10 ¾ lb. greater than the battering charge allowed, and the shot was the standard 250 lb.

"Fragments of the gun were scattered right and left, but the cascabel was only projected a yard or two to the rear. The destruction of the gun is complete.

"This is the first gun on the Fraser system which has thus given way, and it is exceedingly difficult to account satisfactorily for the casualty. The metal of the steel inner tube has been carefully tested, and broke with the following results. A piece taken from the solid breech end gave way under a tensile strength of 34 tons per square inch, a piece taken from the tube about 6 in. from the end broke with 34 tons, and a third specimen cut from the tube 18 in. from the breech sustained a strain of 38 tons. Many specimens from the iron coils were tested, and gave an average breaking strain of 20 tons per square inch. All the strains passed through the specimens in a direction at right angles to the bore of the gun. There was no want of elongation, and the metal must so far be pronounced perfectly satisfactory…

"A close examination goes to show that a serious flaw existed in the inner steel tube; but the existence of this flaw was not detected before the explosion…".

For some reason, the engineers at Woolwich cannot understand why the soft wrought iron gave way… [October 2, 1868].

"Some time ago four guns were made to try four different systems of construction: – 1sr, an old Armstrong pattern; 2nd, Fraser's modified Armstrong with a steel tune 3in. thick, and over it one mass of wrought iron, coiled and welded; 3rd, Fraser's also, but with a steel tube only 2in. thick, the wrought iron exterior in two parts over the inner; 4th, Palliser's heavy gun with coiled iron inner tube and cast iron over the exterior. About 600 rounds were fired from each, and they remained sound, except for the Palliser, which was cracked in the tube near the muzzle. There the experiments ceased for a time, but they are now in progress again. The guns are all 9in caliber. The Frazer gun, with the thin steel tube has lately fired another 500 rounds with bettering charges, and remains perfectly serviceable. The test which it had hither endured is as follows;--First, 400 rounds with 30 lb. charges, the vent being at the rear of the charge, then 200 rounds with battering charges of 43 lb. At this time, the gun was wanted for experiments at Shoeburyness, and was re-vented for the purpose. There it was fired fourteen times with43 lb. charges. Before continuing the test it was decided to do so with the vent in the service position. The gun was accordingly turned round and vented in the previous lower side. It has just continued its third series – five hundred rounds, this time all with 43 lb. battering charges. From the commencement the projectiles have always weighed 250 lb, the service weight. The gun has, therefore, fired up to this time 400 rounds with 30 lb. charges and 250 lb. projectiles, and714 rounds with full battering charges of 43 lb. with [A4 RLG] powder…The steel tube is worn at the seat of the shot but remains in excellent condition for firing. We know of no gun, either English or foreign, of equal size, which has endured so severe a test." [March 18, 1869].

Item from the Times: "…a suspension of the manufacture of Palliser chilled shot has been ordered in consequence of a report from Shoeburyness of the breaking of several of them in the bore of the gun when fired. It appears that the stud or bouche at the sides near the bottom of the shot are forced in by the explosive power of the powder, which breaks and destroys the missile, and until this defect can be remedied no more will be made.".

"The fault does not lie with the material of the chilled shot, but with the system of rifling. Perhaps the authorities will perceive now that there was some method in our madness when years ago we advocated Captain Scott's rifled shot as infinitely superior to studded projectiles." [March 19, 1869].

In response to an article in the Times condemning the Woolwich guns for breaking Palliser shot and shell, The Engineer goes right to the heart of the matter:

"It has been known, indeed, for some time that, under certain conditions, such breaking up is pretty much certain to happen. We are not at all surprised; therefore, to hear that a few projectiles have broken up in the guns of the *Hercules*…A Fraser gun, rifled on Captain Scott's system – in which the projectile carries ribs cast on, instead of studs riveted into countersunk holes – would probably fire chilled shot and shell forever without breaking one." [January 21, 1870].

"Reports received within the last few days confirm…four 10in. shells exploded in the guns [of *Hercules*] from causes not yet determined – possibly from the shock due to the burning of very large charges behind the shells. If this proves to be the true explanation, nothing is easier than to prevent anything of the kind happening in future. It is only necessary to put the [filler] in flannel cartridges to neutralize the effects of the concussion." [February 4, 1870].

A Whitworth 9in 14 ½ Ton gun participated in a trial bombardment of a fortress protection system – see March 18, 1869 entry above – with telling results.

First round – tubular charge of 50 lb. RLG powder, flat-headed steel shell weighing 403 lb. filled with a mixture of sand and saw-dust, 31 ½ inches long; easy mechanical fit, diameter of flat head 6.2 in. Elevation set at 24 minutes, initial velocity 1169 ft/sec. Hit below the middle of the plate, 2 ft. 1 in. from the bottom, well away from the aiming point, smashed out a portion of the 5 in. front plate but glanced off the middle plate and broke into 14 pieces.

Second round – same charge, 1.5 crh ogival nosed shell weighing 392 ¼ lb and 33.7 in. long. Elevation set at 19 minutes, initial velocity 1185 ft/sec. Hit well to the left of the aiming point, 1 ft

9 in from the edge of the plate and 1 ft. 9 in. from the top. "Projectile buried whole to within 8 in. of the rear; penetration 25.7 in."

Third round – same charge, flat-headed shell as for the first round but weight 2 lb. less, easy mechanical fit. Elevation set at 18 minutes. Projectile broke up in gun.

"No more rounds were fired from the Whitworth gun. It will be seen from the foregoing – first, that the shooting of this gun at 200 yards range was as wild as it well could be;and thirdly, that out of three rounds fired one was rendered useless by the breaking up of the shell in the gun..."

Observations not made in the publication bear mentioning. 50 lb. of RLG is an excessive charge, even considering the 'super-heavy' projectiles. And while the hexagonal rifling twist was uniform, it was also very sharp, which resisted the advancement of the projectile. So, the combination of gas pressure from behind, resistance from ahead, and the centrifugal force of the 'quick' rotation greatly stressed the projectile and the gun. [March 4, 1870]

"Our heavy ordnance is not what it ought to be. If it were we should not hear so many stories of the breaking up of shot and the premature bursting of shell...We complain now, as we have done before...because the chief feature of the rifling at present use is a gaining twist, and the chief feature of the projectile a number of holes in its sides. We do not hesitate to say that these are two radical defects, either of which would suffice to vitiate the symptoms; the combination of the two leaves no room for surprise..." [June 10, 1870]

"The French naval and fort heavy guns consist of...a solid cylindro-conic body of cast iron...which gives in longitudinal section the largest smooth-bores or rifled gun they understood to possess. Upon the cylindrical part of this body is shrunk on one ply of steel rings, and upon these a second ply, f which the great trunnion ring forms a portion. These are all breech-loaders...

"That there are positive advantages, both theoretical and practical, in [the French] system of breech-loading...does not admit of doubt on the part of any competent and unbiased artillerist. It is equally certain that, both in theory and actual results, it is far before any one of the methods, or so-called systems, that have been tried by ourselves..." [For part discussion, October 21 & 28, November 4 & 11, 1870]

"A mystery surrounds the cracking of the steel lining of the 35-Ton gun, which puzzles many people. The pressure proper to the 120 lb. charge of Pebble powder employed is only 30 to 40 tons on the square inch, while that actually realized was 66 tons on the square inch. As the steel lining was estimated for 50 tons only it naturally gave way at the weakest point, viz. the rifling. This latter consists of nine grooves, each 1 ½ in. wide, .2 in. deep, and 135 in. long, whilst effort of rotation is concentrated upon one point in each groove by use of a driving ring of metal studs in the projectile. It is supposed that this concentration of rotary effort on such small points...thus led to the extraordinary pressure in the powder chamber. Similar cracks have unaccountably taken place in other guns firing studded projectiles...and the material of the guns has been blamed for that which is due to the rifling..." [December 15, 1871]

Without mentioning Vavasseur by name, the writer states a preference for the rib form of rifling.

"The large sums which have been expended in experimenting with, manufacturing, storing, destroying, and recasting studded projectiles, and the hopelessness which still awaits the task of making a half-inch bearing do all the work of rotation...

"In 1868 – though the increasing spiral groove and its pair of studs had been adopted three before – we read of the 12 in. 25-Ton gun that 'The practice with common shells was stopped on account of the shells appearing to turn over in flight.' Again, a month later, we read of the same gun that out of ten 600 lb. shells, fired with a 55 lb. charge, 'two surged in flight, eight very unsteady,' seventh round 'shell jammed 3 in. off end of bore, and could not be forced home.' Ten were fired with 60 lb. charges, 'all very unsteady.

[To reduce the length, the shell weight was reduced to 495 lg.]...we find that, in October, 1868, ten of the reduced shell having been recovered after firing from the 12 in. 25-Ton gun, 'In several the rear-studs have been slightly moved forward by the explosion of the charge, and all are scored on the base (for about one-fifth of the circumference) by the grooving of the gun. The length of the scoring averages about 3 in.' But if the shell went truly out of the gun, neither the base nor any part of the body of the projectile should have touched the bore at all...

"Three months later we find that of eight shrapnel shell fired from the same gun, 'two burst on graze, and one in the gun.' These had been shortened to suit the capabilities of the half-inch bearing stud…

"[For the 11 in. 25-Ton gun] …five common shell, 530 lb…were fired with a 54 lb. pellet powder, 'all very unsteady,' and 'the practice was discontinued on account of their extreme unsteadiness in flight'…Two rounds were fired with 65 lb. charge, to ascertain what effect increased charge had on shooting. The inaccuracy of the shells was, however, greater than before. The 11 in. Palliser chilled shell proved too weak to withstand the battering charge. Out of eight fired, 'two shells broke up in the gun, and three on graze.' Of thirteen cast iron shot fired, 'the last jammed about 4 ft. from the bottom of the bore and was eventually forced home within 2 in. by a railway bar.' The fourth Palliser cored shot 'broke completely up in the gun.' The practice was stopped on account of the shells breaking up. The broken shells have been recovered, and out of the eight fired only two were undamaged. The condition of the rest are as follows:--

"8th shell fired, which broke up in the gun – 'head broken into three pieces, and off **at the front row of studs**; the body was broken up through the base into four large pieces.'

"7th shell fired, which broke up in the gun – 'head broken off entire **at the front row of studs**; the body was broken up through the base into large pieces.'

"The other four with 'head broken off entire **at the front row of studs**; two of these broke at first graze and two at last graze.'" [December 29, 1871]

"These fine steel guns are manufactured by Messrs. J. Vavasseur and Co, London Ordnance Works…The guns, from 7 inches and upwards, are manufactured entirely from mild steel, except the trunnions, which are of wrought iron. The inner tube, A, of the gun is first rough bored and turned to within 2to3-tenths of an inch of the finished dimensions; it is then oil-tempered… The effect of this oil-tempering is to double the elastic limit of the steel…and also to render it much more uniform.

"The tube after being oil-tempered is turned on the exterior, and fitted or adjusted [for the jackets], the proper difference being allowed for the shrinking. To adjust this shrinkage as accurately as possible, the [jackets], after being bored to the required dimensions, is gauged every 2 to 12 inches of its own length, according to its size…the desired amount of difference for shrinkage being allowed between the internal diameter of the jacket and the external diameter of the tube. [The jackets are then heated and installed in the proper place, one at a time.]

"The outer tier or tiers of hoops or rings are preferred in short lengths of 6 to 8 inches, for the following reasons:-- Those rings are comparatively small pieces of steel, so that they can be well worked under the hammer, and in the rolling mill, being thus far more reliable than if made in one length, sufficient to reach from the trunnion to the breech. Defects in the metal can be more readily detected. They can be more readily and exactly adjusted to the outside of the gun, and they are considerably cheaper than if made in one piece.

"The rifling, on the rib system, is a modification of the plan introduced by Lynall Thomas some ten years ago…One angle has been adopted for guns of all calibers; this angle is about equal to one turn in 30 calibers [1:30]. Excellent results have been obtained in a 12-pounder field gun of 3-inch bore, in a 7-inch gun of 5 Tons, and the principle is to be still further tested in a 12-inch gun of 28 Tons, now in the course of construction.

"The advantages of steel as a material for the construction of heavy guns are so severe, that it is difficult to understand why it is not more extensively employed. Heavy guns have to resist such great and sudden strains that homogeneity of structure must be of the highest importance; the pressure of gas produced by the combustion of large charges of powder is so great, that it seems folly not to select for the construction of guns from all the metals at our command the one which has by far the greatest strength and elasticity.

"To combine in the structure of a gun so highly elastic a material as oil-tempered steel with so ductile a material as wrought iron seems to be wrong in principle, especially when we consider that in a gun the ductile material is outside the elastic and the explosive force applied from within.

"Surrounding the steel tube of a large gun with wrought iron may be a god plan to prevent the gun from bursting explosively (experience shows that this is not always the case), but it certainly appears to have the disadvantage of limiting the number of rounds the gun will sustain, the wrought iron being too ductile to properly support the steel tube. This is proved most conclusively by the failure of the 9-inch Armstrong guns in Prussia and Austria in 1868 and 1870.

The first gun failed through the steel tube cracking at the 282nd round, and the second gun from the same cause at the 111th round, (notwithstanding that in Austria the prismatic powder was used); and still further by the cracking (at the muzzle) of the steel tube of a 10-inch 18-Ton Fraser gun on board H.M. Ship *Hercules*, through the premature explosion of a shell near the muzzle of the gun.

"The charge so often and so strongly urged against steel guns that they burst explosively is hardly borne out by practice. Steel guns that have been burst have almost invariably been solid steel guns, a plan of construction that has been, at all events as far as large guns are concerned, the exclusive practice of Krupp. Since the necessity of building up guns has been forced on this eminent maker, no large guns have burst, the recent accident in Russia being to the unhooped muzzle portion of an 11-inch gun. It is therefore an open question as to whether they will burst explosively or not; what experience there is on this question goes to show that they will fail, theory says they should, from the outside, -- and this opinion is strengthened by the following facts…[See list of injured Blakely Guns above].

"The Parsons 8-inch gun, made at [Blakely's] works, is also a further instance that steel guns do not burst explosively – this gun failed from the outside, as all properly constructed guns should do. These guns, it must be remembered, were all fired with the strong RLG powder now abandoned as too brutal and destructive for Armstrong guns. In this last instance the cast iron outer case cracked, the steel tube remaining uninjured.

"Built-up steel guns can be made very much lighter and not less strong than the guns now in the use in the English service; this saving in the material will make the guns not more costly than guns of corresponding sizes, constructed on the Armstrong system, while there remains the advantage of a handier gun.

"The 11-inch built-up Blakely guns now at Callao weigh only 14 Tons, yet these guns were proved at Woolwich with charges of 60 lbs. of powder, and projectiles of 480 lbs. weight. These guns were used against the Spanish fleet in 1866, and wee fired a considerable number of rounds, some of them over 50 per gun.

"The 9-inch Blakely guns, also at Callao, though of only 8 Tons weight, were proved with charges of 45 lbs, and projectiles of 240 lbs. weight. None of these guns…sustained the slightest injury; although the tubes were not oil-tempered, and the strongest [A4] RLG powder was used." [February 10, 1872]

"The [Vavasseur 7-inch Steel] gun is built entirely of Firth's steel, except the trunnion band 'F,' which is of wrought iron. The tube 'A,' jackets 'B,' 'C,' 'D,' and the cascabel 'G,' are of cast steel, the tube 'A' being oil tempered. The exterior rings 'E' are forged and rolled in a similar manner to railway ties, so that the fiber runs circumferentially around the gun…

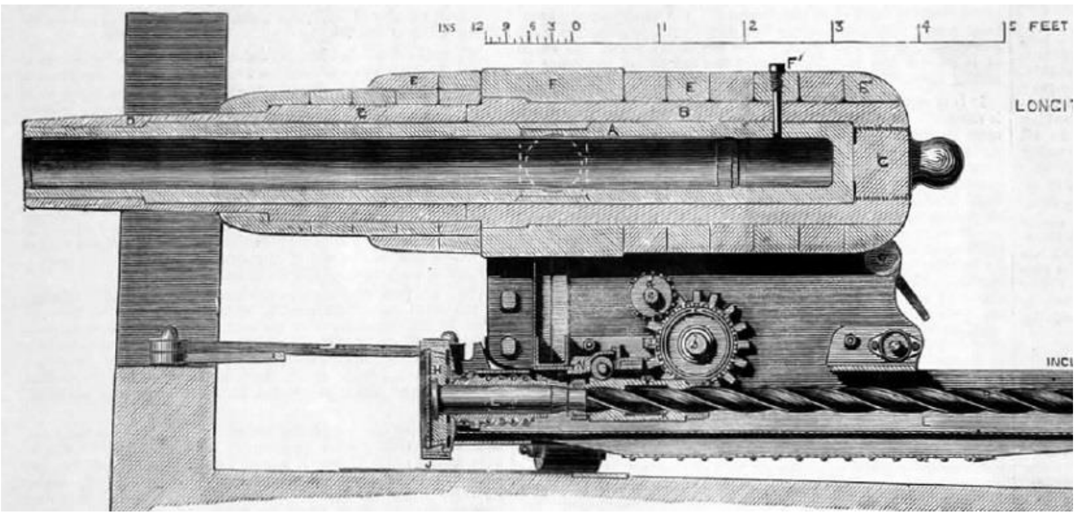

Fig 9. Vavasseur 7-in Steel Gun

"…The gun is rifled with three raised ribs, 1.0 in. wide and 0.2 in. high, the projectile being grooved to correspond, the windage being 0.08 in. over body and 0.05 in. in the grooves… It must be borne in mind that the 7.0 in. gun here referred to – though firing the same charges and weight of projectile as the 7 in. Woolwich gun – is nearly 25 percent lighter…

"Initial velocity with 22 lb. charge, 1412 ft. per second; initial velocity with 14 lb. charge, 1218 ft. per second. The powder used when these velocities were taken was the RLG – with the new Pebble powder the velocity would probably be increased to 1540 ft. per second, without any additional strain being put on the gun.

"This gun has now been fired 225 rounds…The gun was carefully gauged after 168 rounds, but no enlargement could be detected…During recent experiments in France with a 7 in. gun, fifty rounds were fired without the slightest difficulty at any one round." [April 10, 1872].

"Our stand-point has always been [sic.], and is now, that steel, especially Bessemer steel, is so uncertain in quality that the utmost caution should be exercised in its use…We find…that Krupp's steel guns are not trustworthy, and we at once come to the logical argument that if Krupp's guns fail, then steel must be a bad material for guns…Now this is just the point on which we venture to join issue for the first time [sic.], and we have given much prominence to the Vavasseur steel gun…because the system of construction adopted is totally different from Herr Krupp's [sic. prior to 1869]; because the system of construction appears to us to be based on sound principles, and because the results obtained from the gun in question have been up to the present extremely satisfactory.

No of rounds fired.	Weight of projectile.	Charge of powder R.L.G. (A⁴).	Elevation.	Time of flight.	Ranges. Minimum	Ranges. Maximum	Ranges. Mean.	Mean difference of range.	Mean observed deflection.	Mean reduced deflection.
	lb.	lb.	deg.	sec.	yds.	yds.	yds.			
3	115	22	1·19	not taken	879	944	905	26·3	0·8	0·5
5	,,	,,	2·11	4·11	1456	1546	1502	22·2	4·5	1·2
5	,,	,,	4·7	6·56	2334	2383	2362	15·2	11·1	1·1
5	,,	,,	6·5	8·46	3092	3173	3125	20·4	20·7	2·2
3	,,	,,	7·5	not taken	3475	3497	3487	8·3	18·4	2·3
5	,,	,,	8·4	10·9	3762	3895	3839	37·2	37·4	1·8
1	,,	,,	19·32	24·3	—	—	7450	—	6·4	—

Fig 10. Vavasseur 7-in Trial at Shoeburyness

"No one believes that wrought iron is absolutely the best material for guns. We only hold that it has hitherto proved to be better than steel because steel has lacked certain characteristics. If it could be proved that steel not only possessed these but its own excellent qualities as well, then the days of iron guns would be numbered. The whole question really narrows itself to a simple point – can, or cannot, a perfectly reliable tough steel be obtained in sufficient quantity with sufficient ease? Mr. Vavasseur holds that it can…Mr. Vavasseur states that Messrs. Firth are now able to supply…in any reasonable quantity of perfectly sound and uniform quality…No one can for a moment dispute that being in possession of such a material, Mr. Vavasseur has used it to the best possible advantages.

"It will be seen that, although the gun in question is much lighter than our own 7 in. gun, it has withstood 225 rounds, mostly with 22 lb. [RLG battering] charges, and projectiles weighing 115 lb. This is a satisfactory performance, because the gun manifests no evidence as yet of the smallest injury." [April 19, 1872].

Commander W. Dawson, R.N, read a paper entitled “On the Increasing Spiral in Heavy Rifled Ordnance” before the Institution of Naval Architects, which was subsequently published by The Engineer Magazine. The salient points were:

“Rotation is usually imparted to elongated projectiles by means of ribs, studs, or other projections, which, in their exit from the gun, traverse suitable parallel grooves or slots cut to receive them in the bore, at an angle with the axis of the piece proportioned to the desired rapidity of spin. When the angle which the slots make with axis of the gun is the same throughout uniform spirals are the result; but when the angle becomes greater towards the muzzle the grooves form curves known as increasing spirals…parabolas. Each point in those parabolas makes a different angle with the axis of the gun, and would impart, if possible, a different amount of rotation to every part of the projectile. As, however, a rigid iron cylindrical body cannot have every point in its length rotated at different speeds…” which is what happens with studded projectiles with the rear ‘driving’ studs at one angle and the fore ‘guiding’ studs at another.

Increasing twist diminishes muzzle velocity. “In the heavy gun competition of 1863-5, where all the conditions, except the rifling projections and grooves, were identical, Scott’s uniform spiral 7 in. gun projected its iron bearing flanged=centering 110 lb. shot from its muzzle 59 ft[/sec] faster… than the… French, or, as it is now mis-called, Woolwich gun, with increasing spiral and studs, the report stating that ‘the French system has decidedly the lowest velocities.’ Again, in 1865, two 7 in. guns were rifled with the same final angle of twist, on the French or Woolwich system; one with uniform and the other with increasing spiral, and the latter gave 21.2 ft.[/sec] less initial velocity… The Professor of Artillery at Woolwich, Col. F.H. Owens, mentions in his book, Modern Artillery, the case of …” two 8 in. 6 ½ Ton experimental guns, one rifled with uniform twist and the other with increasing twist. The former produced an initial velocity of 1338 ft/sec, the latter 1303 ft/sec, a 35 ft/sec difference in favor of the uniform twist.

“So far as the advantages claimed for the increasing spiral are concerned, they are pure guesses opposed to facts… The Committee on Explosives have recently discovered that the maximum powder pressure is relieved as the shot has moved [past] ¼ in. in its seat when using RLG powder, and [past] 6in. using Pebble powder.” However, the maximum pressure from compressed pellet-type powders is much less than that produced by RLG, by intention. Nor is there a measurable difference time involved in moving ¼ inch with RLG; nor in moving 6 inches using Pebble/pellet-type powder, unless the uniform twist is so sharp that resistance becomes a material factor.

Commander Dawson quite accurately termed guns damaged by their own projectiles as “suicides” and “self-inflicted injuries.” He also mentions two guns ‘officially’ still ‘serviceable,’ that should be included in the list below;

“First…the father of the system, the [new] competitive Woolwich 7in. gun [noted previously]…which, after 567 rounds had so battered its bore and spied its upper grove by the slows of its front upper stud, that it was ordered to ‘be fired under precaution’ against bursting…

“The ‘Woolwich Infant’ of 35 Tons [the original and much tried experimental gun] , though not yet committed t the ‘cemetery of suicides,’ was spiked in the lower groove by its lower rear stud, from 8in. to 20in. outside the point to which the maximum powder pressure extends…” [May 3, 1872].

Date.	Place.	Gun.		Self-inflicted injuries.	Cessation of fire.
1865	Shoeburyness	7in.	7 ton	Upper groove cracked by stud, dented and enlarged tube	Permanent.
1865	"	9in.	12½ ton	Much worn by gas after 315 rounds	No.
1865	"	9in.	12½ ton	Cracked grooves and burst, 400 rounds	Burst.
1865	"	"	"	Cracked tube, disabled, 1049 rounds	Permanent.
1868	Tegel, Berlin	"	"	Cracked tube, disabled, 311 rounds	Permanent.
1869	Woolwich	"	"	Explosive burst, by projectile jamming, one round	Burst explosively.
1869	Bellerophon	"	"	Grooves over-ridden by studs	Permanent.
1869	Redwing	7in.	6½ ton	Muzzle split	Permanent.
1870	Favorita	"	"	Grooves over-ridden by studs	No.
1869	Shoeburyness	10in.	18 ton	Grooves burred, bore dented, tube split, 534 rounds	Permanent.
1869	Hercules	"	"	Muzzle split, 43 rounds	Permanent.
1869	"	"	"	Vent damaged, 46 rounds	— hours.
1870	Staunch	9in.	12½ ton	Bore dented, grooves bored, gun disabled	Permanent.
1870	Royal Sovereign	"	"	Bore deeply cut into	— hours.
1869	Warrior	7in.	6½ ton	Bore dented, and had to be filed down	— hours.
1871	Bellerophon	9in.	12½ ton	Bore dented	No.
1871	"	"	"	Bore considerably scored by gas, 165 rounds	No.
1871	"	"	"	Muzzle coil split	Permanent.
1870	Shoeburyness	7in. / 68-pr.	95 cwt.	Burst violently into 76 pieces, shot jammed, one round	Burst explosively.
1870	Aldershot	9-pounder, bronze		Grooves worn away, &c., disabled, 543 rounds	Permanent.
1870	"	"	"	Ditto ditto ditto ditto	Permanent.
1870	"	"	"	Grooves worn by studs, ditto	No.
1870	Shoeburyness	"	"	Grooves over-ridden by studs, bore expanded	Permanent.
1870	"	"	"	Ditto ditto ditto	Permanent.
1870	Monarch	12in.	25 ton	Grooves slightly burred in four guns, average 85 rounds each	No.
1871	Shoeburyness	7in. / 68-pr.	95 cwt.	Grooves enlarged near origin	No.
1871	Woolwich	12in.	35 ton	Lower groove cracked by stud from 17in. to 25in. of origin, 68 rounds	No.
1872	Bellerophon	9in.	12½ ton	? Bore dented, had to be filed down	— hours.
1872	"	"	"	Ditto ditto ditto	— hours.
1872	Royal Oak	8in.	9 ton	Bore dented by projectiles	No.

Fig 11. Woolwich Guns Self-Injury

"The recent arrival of the Bellerophon from Gibraltar has enabled us to inquire into her alleged disarmament by the action of projectiles fired at targets from her 9 in. 12 ½-Ton guns. One 12 ½-Ton gun has opened slightly in the outer coil on the chase about 12 in. from the muzzle, just where the increasing spiral offers the maximum of resistance to the escape of the shot. But the interior steel tube is uninjured. Another…has given way in like manner about 2 ft. 6 in. from the muzzle, the interior steel tube being also uninjured. In two other guns the steel tube stands out rather beyond the iron jackets, whether from the increasing spiral drawing the tube out, or from the outer coils being set back, is not very clear… Still, the fissures have an ugly look, and, taken in connection with a 12 ½-Ton gun in this ship being so damaged in its rifling in 1869 as to require removal…and two others in 1870 being severely injured, one by the projectile and the other by corrosion, we can well understand the faith of officers and men being somewhat rudely shaken." [May 17, 1872].

"The offensive force of the *Glatton* being limited to two 25-Ton guns, and that of the *Hotspur* to one similar gun, the endurance of these weapons is a matter of vital consequence to ships so armed. It appears, however, that these 25-Ton guns have never been subjected to such a trial of endurance as would naturally occur in any well-contested contest or bombardment." [May 17, 1872].

"The Navy has recently taken alarm at the frequency of petty mishaps to the rifled portion of the bores of his heavy guns…for the purpose of training their crews, Her Majesty's ships are in the habit of firing eight rounds from each heavy gun every quarter, making thirty-two discharges annually…these discharges are usually effected with great deliberation, giving abundant time for the metal to cool… Thus it happens that, in peace time, naval guns are carefully preserved, and are subjected to very slight stress. When, then, guns show signs of wear under such favorable conditions o slow firing, with three-monthly intervals between every eight rounds, the question naturally arises as to the endurance to be anticipated in battle… In the absence of experimental test, we are driven to reason upon the comparatively slight mishaps which have occurred on shipboard, with a view to analyzing the grounds which have led seamen to regard their weapons with suspicion. During the last three years about eighteen mishaps are known to have occurred to naval guns, but so much secrecy has been preserved as to the reports of the Inspectors of Ordnance that it is very probable many more guns have been equally damaged. For our present inquiries, however, these eighteen injured guns will suffice. It is remarkable that not one of these guns shows marks of having suffered from excessive powder pressures. The sufferings written iin their interior steel tubes proceed in every case from the action of their projectiles. Referring solely to those of which we have exact official data, we find...

"*Monarch*'s four 12 in. 25-Ton guns, having been examined after firing an average of 35 charges each, in April 1870 to have 'a very slight burring up of the driving sides of the grooves for a short distance from their origin.' However slight, this damage after 35 discharges spread over three years, lends naval artillerists to doubt the effect of even the same number of rounds in continuous firing. That the authorities have declined to subject a gun of this caliber to the test of 100 rounds fired in the same day tends to confirm suspicion, especially as the 'official' life of the gun has been reduced to 160 rounds with battering charges.

"In 1868 it was recorded that a 10 in. 18-Ton gun that 'No. 1 groove up is slightly burred on driving edge from muzzle to 54 in, and slightly scored to 78 ½ in, also deep cut into from 32 ½ in. to 41in.' Four other guns were 'slightly burred and scored, and 'the bore and grooves were' slightly grazed all around...' The grooves Nos. 5 and 6 are 'slightly dented by studs of shot at 116 in.' After a total of 400 rounds, damage recorded on 9 April 1869, [included] damage to the lands and grooves. 'the scoring of the bore caused the escape of gas' and 'it now requires re-venting, and he [the Inspector] thinks it should be turned over and re-vented on present under side.' This being done, the gun became unserviceable at the 534th round, 'through the [steel] tube being split in the powder chamber, evidently caused by the erosion of the bore, consequent upon the rush of gas over the projectile.' The history of this is that of all, and shows that erosion of the bore above the shot, and consequent hammering down upon the seat, naturally tends either to spike the gun on its studs or so to flatten the stud on which the shell is balanced as to admit of the body of the shell touching the bore, in which case the body has to be dragged across the lands rough with fouling matter by the already overworked stud. That this 'wobbling' in the bore takes place in other calibers also appears from ten recovered 12-inch shells of the pattern which has been reduced to five-sixths of the original weight, so as to diminish the 'wobbling.'

"*Hercules* had two [sic. three] of her 10 in. 18-Ton guns disabled during a target shoot in the Atlantic, one having fired some years 43 rounds, the other 46. These had fired only 2 and 4 rounds on the day they were disabled. In both cases, shells had broken up through their stud holes opposite the grooving, just where the increasing spiral offers its maximum resistance... Lord Gilford reported –'The A tube in one gun was found to have split right through to the B tube [wrought iron coil] at the muzzle; the crack extends from the muzzle to the loading edge of the groove, ten inches up the bore, where it disappears suddenly. The B tube has been apparently much strained, immediately above the crack in the A tube... This gun, as well as **another** lost the lower part of the vent the same day while firing at a target... Three guns remain serviceable.' On this the Director-General of Naval Ordnance remarks that, 'the crack in the A tube and the strained condition of the B tube over the crack **are exactly what I should have expected**.'

"The system of rifling employed is an outrage on all mechanical principles." [June 7 & 14, 1872].

"Waterloo-Day was marked at Shoeburyness by the bursting of a 400 lb. 'Common' shell, in the usual part of an 18-Ton [10 in.] gun, near the muzzle. A mine of this sort, containing 26 ¼ lb. bursting charge, exploding within a gun, must necessarily test its endurance very severely. It is satisfactory to find that the damage sustained...was confined to the steel lining, which had only three splits in it, each about three inches long, at the muzzle. The worst crack was, as might be expected, at the 'driving' edge of the upper groove, for, this groove being one at the inner end, has the largest share of the work of rotation. This crack was right through the steel to the wrought iron coils. Another crack was in the 'loading side of the lower groove; and the third crack was in a side land, through the steel tube as far as to the hole for the shot-bearer pin. The firing was stopped at once; the gun dismounted, and, after examination by the Royal Gun Factory officials, was...removed to the Royal Arsenal for repairs." [July 26, 1872].

The 'Woolwich Infant' "fired sixty-eight discharges of ordinary [700 lb cast iron] projectiles with mild Pebble powder charges, only in one instance exceeding in amount that for which the gun was built, produced 'an incipient crack' in the lower groove of the steel tube, the center of which was 14 in. in advance of the seat of the rear stud on which the projectile rests, and 8 in. in advance of that point in the bore to which the maximum powder pressure usually reaches. After five more discharges the 'right top' and 'right bottom' grooves, looking from the muzzle, were found split some inches in advance of the seat of the studs. Slight fissures were found in the centers of one or two other grooves, and in the lands, and the metal in the powder chamber appeared to be crushed from the violent strains endured.

"So long as our present un-mechanical system of rifling is persisted in, guns must be occasionally disabled…but, as the rear stud…the hard gun-metal protuberances are apt to wedge themselves over the grooves and between the lands and the projectiles. Thus wedged, accumulation of powder gasses occur in the chamber of greater pressure than the breaking strength of the tempered steel barrel…".

Supposedly, the tensile strength of the tempered steel was 30 tons per square inch, with the wrought iron coils from 15 to 20 tons per square inch, producing the total strength of the material at 45 to 50 tons per square inch. These figures do not compare well with those given for the 9in Fraser gun which burst explosively on the first proof round . Tests determined the steel inner tube broke at 34 to 38 tons per square inch, with the wrought iron coiled mantel averaging 20 tons. The claimed pressure build-up in the 'Infant' was 66 tons per square inch. If true, then between 21 and 16 tons per square inch in excess of what the material could possibly contain would most likely have created an explosive burst. Obviously, the pressures were a great deal less than 66 tons, but sufficient to ruin the inner steel tube **and** the 'B' coiled mantel, and render the gun unserviceable.

Far from providing proof of "an important advantage in the Armstrong – Fraser coil system," this 'suicidal' incident exposed the very real weakness of the coil system as compared to an all-steel built-up construction [September 13, 1872].

"The super-abundant proofs which exist that the stud or 'Woolwich' system of rifling heavy guns is a disastrous failure render it to the last degree unlikely that the system can much longer be retained in the service. Indeed, there is good ground to believe that early in the ensuing year, the whole subject of rifling heavy guns will be brought before Parliament in a way that will compel the adoption of some less destructive arrangement for imparting rotation to heavy shot…" [September 27, 1872].

"It may be of interest to compare the Krupp construction with that of Mr. J. Vavasseur, of London Ordnance Works. The Vavasseur gun consists of a steel tube, with hoops of the same metal. The tube, however, is much thinner than Krupp's, and is jacketed from the breech to a space beyond the trunnions [which are attached to a separate hoop], with a second tube shrunk upon it – the hoops encircling the jacket. The unjacketed part of the tube is also hooped clear to the muzzle. In this gun the strength is cast more upon the hoops, and less on the tube, than in Krupp's, and the initial tension is more effectually carried out. Mr. Vavasseur's gun is certainly worthy of more attention than has been bestowed upon it." (Dutton, 1872).

At the close of 1866, two facets of Armstrong's 'system' remained; wrought iron coils as 'reinforcement' for the rifled inner steel tube, and 'shunt' rifling, morphed into the 'French' or 'Woolwich' system, with an increasing twist and studded projectiles. But in spite of professional opinion, Naval Service opinion, scientific, technical and industrial advances, and clear proof that both those facets were flawed and faulty failures, they remained firmly in place at the end of 1872, even though the necessary assets to support change and reform were, if anything, even stronger than they had been in 1864.

Josiah Vavasseur's London Ordnance Company had been building all-steel built-up muzzle loaders and breech-loaders since 1868 by capitalizing and evolving Blakely's principles. The steel industry, led by Firth's, could produce both quantity and consistent quality product suitable for gun construction. Following a pro-longed but ultimately trial in a head-to-head contest with Armstrong, Krupp adopted built-up construction with reinforcement under initial tension. French guns had been of Blakely patent construction since the M.1858-60, and with their new M.1870 they were further strengthened by a steel tube flush with the bore in the powder chamber, the seat of the projectile, and the approaches to the breech opening. Russia had moved progressively into all-steel guns from 1863, and their initial domestic production of the M.1867 was all-steel built-up guns using initial tension with the reinforces; Blakely patent construction.

The end of 1872 also contained another harbinger requiring change. Simply put, progress in the manufacture of gunpowder as a propellant, a field pioneered by Rodman and DuPont in the early 1860s, had led to a selection of compressed, slower-burning grains that reduced gas pressures and rewarded barrel length with better performance, and hence better endurance. As early as 1864, A4 RLG-type powders were being replaced for small bore guns by 5mm (0.197in.) compressed spheres. By 1868, improved spheres from 6 to 10mm (0.236 to 0.394n.) were in wide use. By 1872, various grain forms of compressed powder of good density (c. 1.75) were available from such firms as DuPont and Curtis & Harvey, and included Prismatic, Spherical of various sizes, Mammoth Powder cubic of various sizes, cylindrical of various sizes with or without perforation, Hexagonal...

Table 6. Comparison of Bore Lengths in calibers

Woolwich		Vavasseur		French M.1870		Krupp C/72		Russian M.1867	
12in 35-Ton	13,5	12in 27-Ton	15,6	12.6in	19,5			12in	20
12in 25-Ton	12,1								
11in 25-Ton	13,2			10.8in	18			11in	20
10in 18-Ton	14,55	10in 16-Ton	16,8						
9in 12-Ton	13,9	9in 10-Ton	16	9,45	18,1	9.27in	22	9in	20
8in 9-Ton	14,1					8.2in	22	8in	21,9
7in 6 1/2-Ton	15,35	7in 5-Ton	18	7.64in	19,8	6.8in	25		
6.3in 3.2-Ton	15	6.3in 4-Ton	17,6	6.48in	21,2	5.87in	26	6in	23,3

To obtain maximal benefit from the slower-burning pellet-type powders, length of bore is a primary factor. The reverse is also true; a short bore length cannot use the slowest burning form of powder efficiently. Both Germany/Krupp and Russia used Prismatic, which offered great flexibility for 'tuning' the grain to the gun. France introduced a slower-burning pellet type with considerable flexibility in grain size to match the gun. And Vavasseur most assuredly designed his guns for a pellet-type powder, as evidenced by both the greater bore length and the larger charge weights in the medium caliber range. But the short Woolwich guns simply could not use the most efficient forms of slower-burning powder because the bore-length required simply was not available, so their only recourse was to increase the charge weights well past the point of diminishing returns.

1879

"Length is a restriction that most completely cripples the powers of the 35-Ton gun. At present for sea service this is unavoidable, the size of the turret being an insurmountable obstacle to any increase beyond 16ft. 3 in. now allowed for the total length of the Woolwich Infant, the actual length of the bore being 13 ft. 6 1/2 in. This, with a diameter of 12 in, does not admit of the complete burning 110 lb. of Pebble powder...so that it can hardly be questioned that the first necessity to obtain in a piece of ordnance with greater power than the present 35-Ton gun...is a bore of increased dimensions. A land service gun not being restricted in length...it is proposed – taking the 35-Ton gun as a starting point – to add about 3 ft. to its present length." [August 1, 1873]

In January "...we had occasion to notice the results of a trial at Bourges between the French *canon de 4*, the Woolwich 9-ppounder field gun, and two guns constructed by...The London Ordnance Works, the successor of Captain Blakely, R.A...the Vavasseur gun being now on official trial, both here...and on the Continent, it is desirable to bestow more attention on it... We have used the term Vavasseur gun; it must be understood...that there are several guns to which the name may be applied. At Bourges...there was a grooved and a ribbed Vavasseur 12-pounder gun, while at Vienna there is under trial a breech-loading gun with an enlarged chamber... The most striking feature in the Vavasseur breech-loading system is, perhaps, the device to diminish windage and prevent scoring by the application of a copper washer-like ring to the base of the projectile [the patented gas-check noted above]. It is worth mentioning that this gun has fired a projectile with considerably more than 1900 ft.[/second] muzzle velocity.

"The piece we not wish to consider...is the ribbed one...trial was made in 1873 between the Vavasseur ribbed and the Woolwich steel guns, both firing Woolwich 9-pounder projectiles and with similar charges, grooves being cut in the Woolwich shells...to adapt them to the Vavasseur ribs.

"The conclusions of the French Committee were briefly as follows:-- The Vavasseur ribbed gun with 9-pound projectile and 2-pound charge, was reported superior in initial velocity, range, and accuracy...

	MV, ft/sec	Rangeat 14-deg, yards	Deviation for Range, yards	Drift, feet
Woolwich gun	1443.6	4396.2	11.48	0.984
Vavasseur gun	c.1460	4538.7	5.25	0.973

"...The figures above speak for themselves... It is high time then to consider the features and claims of the 'ribbed system' more fully than hitherto, a system which we have long held to have certain mechanical recommendations." [March 6, 1874].

Sir William Armstrong and his Elswick Ordnance Company made a break with the established orthodoxy as represented by the 'Woolwich system' and his own previous practice. He abandoned the 'pressure curve' form of applying the wrought iron coils to 'reinforce, the inner steel tube, as the slower-burning compressed pellet-type powders moved the point of maximum gas pressure forward, and in appearance his guns resembled the Fraser form, though made of single layer jackets rather than double layer mantels. He also abandoned the shunt/'French'/Woolwich rifling with studded projectiles.

EOC constructed an experimental gun of 8.8 in. bore for "combining most of the advantages of the breech-loading system with all the simplicity of an ordinary muzzle-loading gun... The rifling is poly-grooved, with an increasing spiral terminating in a reasonably sharp curve.

"Both gun and projectiles are so contrived as to prevent, so far as is possible, the occurrence of scoring, and to secure as closely as can be attained, perfect centering of the one within the bore of the other..." The means of attaining these two goals were twofold. First, the windage between the lands of the bore and the body of the projectile were reduced to the least possible difference consistent with loading a muzzle-loader. Absent the necessity of aligning studs with grooves, little leeway was necessary with poly-groove rifling. The second was a copper ring gas-check around the beveled or coned base of the projectile; a concept 'borrowed' from the American Civil War period, as used by Brooke, Blakely, Parrott, Absterdam, Tennessee and many others. The ring was flush with the diameter of the projectile to ease loading, but would expand under the gas pressure of the burning powder to grip the rifling. "We need hardly say that soft metal rings have been used to impart rotation to projectiles before, but the precise modification proposed by the Elswick firm in the present instance is, we fancy, entirely novel, and possesses many original points of advantage."

Whether there was anything "entirely novel" or "original" is questionable at least, and highly doubtful. However, one vitally important lesson EOC did not take to heart, which was emphasized by General Quincy Adams Gilmore in his book about the siege of Charleston; copper ring or 'cup' gas-checks fail with increasing twist rifling and excessively large charges. The sharp twist tends to rip and tear the soft metal, allowing gas to rush past the projectile, reducing the pressure that is pushing the projectile leading to reduced muzzle velocity and allowing violent 'wobbling' or 'knocking about' in the bore, which was associated with premature shell bursts inside Parrott guns, and a reduction in both range and accuracy. A uniform twist, such as adopted by both Blakely and Vavasseur, 1:36 and 1:30 respectively, would avoid a tendency for such "self-inflicted injuries." But for all that, reducing windage, abandoning large grooves, and stud-less projectiles with a gas-check were small steps in the right direction. [April 10, 1874].

"The subject which Mr. Charles Lancaster brought last week before the Institution of Civil Engineers, viz, the rapid destruction of the interior of our heavy rifled artillery by the action of the inflamed powder, is one of great...importance." Since the introduction of rifled guns, "...the artillerist was faced by a new difficulty, for iron and steel, with all their magnificent powers of mechanical resistance, presented greatly changed chemical relations to the erosive action of the intensely heated gases of the ignited powder... The rifled shot in our system lies upon the lower side of the chase in advance of the powder cartridge, so that the greater proportion of the windage is accumulated about the upper half of the bore, between the shot and the chase. When the charge is fired, the intensely heated gases act at once chemically and mechanically upon all parts of the seat of the charge, but with greatest and most destructive effect upon the upper segment of the chase, and for a length of about twice that of the projectile, where before the latter has acquired its full velocity these inflamed gases are swept with enormous velocity through the area of windage.

"Where such erosion had taken place largely it was observed that fine longitudinal lines could be seen traversing the chases. They were supposed to be merely superficial, to be mere 'fire marks' or other such indefinite things. But upon splitting up some of those eroded 'A' tubes longitudinally, and opening the tube out flat by a slow and steady pull upon the opposite edges, it was found that these lines were in fact the lips of longitudinal fractures of various depths, some as much as half an inch…" The conclusion was, the larger the bore, the heavier the projectile, the larger the powder charge, the greater the damage to the metal of the 'A' tube.

"Various attempts have been made in Russia, Germany, and England to meet this evil by means of different forms of gas ring applied to the rear of the shot: but we doubt that any form of gas ring can do more than mitigate the evil… What Mr. Lancaster proposes is the application not merely of a gas ring in the rear of the shot, but also certain arrangements…not only is all windage…stopped…but at the same instant the true centering of the projectile is secured… This proposal seems to deserve a full and patient trial…".

In the Woolwich studded projectile system, the rear of the projectile was more or less 'centered' by the ring of 'driving' studs, but not so the points forward, almost bringing the shoulder of the projectile into contact with the bore, and allowing some 'knocking about' as the projectile moves forward, damaging the lands. This angular difference also had a negative effect on accuracy of shooting in both range and deflection/drift [February 26, 1875].

In a debate in the House of Commons, Captain Price asked the Secretary of State for War whether it was intended to order any more 81-Ton (16 in.) guns, whether a 35-Ton gun had been tested to destruction, whether the War Department were satisfied with the Woolwich system of rifling, and whether the Ordnance were or were not prepared with a (Palliser) shell able to sustain battering charges in 18-Ton (10 in.) and larger guns.

Captain Nolan availed himself of the opportunity to re-open the question of breech-loading versus muzzle loading guns, citing the advantages of breech-loaders, and sought an assurance from the Government that no more muzzle-loaders would be ordered until breech-loading had been thoroughly investigated.

Oddly, The Engineer attempted, rather weakly, to counter Captain Nolan's 'argument,' after having spent years noting the progress of Krupp and the French, and more recently that of Vavasseur, and even more time addressing the myriad flaws in the entire Woolwich system; save for an inexplicable and unfounded loyalty to wrought iron coils which only dates to 1866, as prior to the bankruptcy of the Blakely Ordnance Company they had been strongly in favor of all-steel built-up guns [April 9, 1875].

The Duke of Somerset moved in the House of Lords for a Return from the Government relative to naval guns and projectiles, which was a means of calling for the Government's attention to the question of the merits of breech-loading versus muzzle-loading ordnance. The motion passed.

The Engineer correctly noted that the question is more complicated than it would appear, and involves the manner of gun construction and the material used (all-steel versus the Armstrong/Woolwich wrought iron coils), and pointed out that the changes would be 'revolutionary.' "There is reason to believe that the present movement in favor of breech-loading ordnance has originated with inventors of particular systems of constructing ordnance…

"It must be proved, and that conclusively, that breech-loading guns will give notably superior results to the best muzzle-loaders before it would be justifiable to contemplate the abandonment of a system which, with all its faults, is yet sufficiently good to entitle Woolwich made guns to rank as the best in the world."

That conclusion is hyperbole, at best! At that time, there were only four systems to choose from: Krupp all-steel built-up breech-loaders, French built-up breech-loaders (all-steel as of the new M.1875), Vavasseur all-steel built-up breech- and muzzle-loaders, and Woolwich/EOC wrought iron with steel liner muzzle-loaders, last improved in 1865, and technically obsolete [May 7, 1875].

“Yet the question of muzzle- or breech-loading is one full of delicacy and difficulty… That breech-loading is practicable for all smaller natures of artillery may be viewed as proved. When we consider, however, the application of breech-loading to the heaviest natures of artillery now in use at sea and on land, the problem becomes far more doubtful and difficult of solution…breech-loading, as applied to heavy artillery, was flung aside without any attempt to exhaustive trial as soon as the signal failure of Sir W. Armstrong’s breech-loading arrangements as regard all natures of guns above his 40-pounder [4.75 in.] became apparent; and since then no serious attempt has been made experimentally amongst ourselves to discover conclusively whether it may be within the limits of mechanical practicability to produce any breech-loading arrangement which shall be applicable to the largest guns…” [June 25, 1875].

“A great deal has been said about Krupp guns, but on one has attempted to prove that Krupp guns do their work better than English guns…” [July 2, 1875].

“Some years since [Sir Joseph Whitworth] introduced compressed steel – that is to say, steel subjected while in a fluid state to heavy pressure… With this steel he has constructed guns; but not content with using a material unknown in Woolwich practice, he has made his guns breech-loaders… Waiving, for the moment the question of breech-loading, we have yet remaining for consideration the chances of success which attend the use of steel… Now all experience goes to show that, even if steel were as good a material for guns as wrought iron, it has certainly no advantage over it. A steel gun is a dearer gun than one of wrought iron; it is not more durable; it is not stronger; and it is very much less safe. What, then, is to be gained by the use of steel? Not a single point has ever been proved by extended experiment in its favor. It is quite true that certain successes have been achieved by steel guns, but they are not equivalent to the successes of Woolwich guns.

“The new Whitworth gun has…at last been tried at Gavre, and although minute details of the trial have not yet reached this country, enough information is available to prove that the principles adopted by Sir Joseph are utterly unsound… The gun tried at Gavre weighed 35 Tons, and was, we need hardly state, made as well as a gun could be made. It was tested first with Pebble powder, and it was found impossible to get sufficient initial velocity. The weapon failed to perform the work it ought to have done with ease. This being the case, Sir Joseph resorted to the somewhat desperate measure of using a charge of 120 lb. RLG – a very violent powder, the employment of which in such quantities could not be thought of in actual service. Sir Joseph, confident in the powers of compressed steel, adopted it…with the immediate result that he split the inner tube…and, according to the Standard, disabled the breech screw… [May 19, 1876].

“A little more information has reached us concerning the failure of a Whitworth gun at Gavre… The bore of the gun is 12 in, and Sir Joseph fired from it blind shell 48 in. long, and weighing as much as 1250 lb. With Pebble powder the results obtained were…unsatisfactory; and with a charge of RLG a velocity of only 1073 ft. per second was obtained. We are not in a position to say how many rounds were fired altogether; but at least one projectile broke up in the gun, the powder chamber was permanently enlarged by the strain, and the inner tube was split for nearly 3 ft. of its length near the muzzle… It is probable that Sir Joseph Whitworth would have obtained better results had he used a shorter projectile, a different mode of rifling, some other system of construction, and iron instead of steel…” [May 26, 1876].

The French view of the trials at Gavre, as reflected by comments from *Capitaine*Cavelier de Cuverville writing in 1881, present a rather different view;

“Whitworth, developing his system of artillery, perfecting his process for the production of homogenous steel by compressing it in the liquid state, together with his process of forging by means of powerful hydraulic presses (…capable of exercising a compression of 10000 tons), has reached the extent of a 35-Ton gun, caliber 12 inches, length 14.7 calibers, body of gun formed of five steel tubes superimposed under [mechanical pressure to provide initial tension]. One of these guns, designed for the Brazilian turreted ship *Independencia*, was tried in 1876 at Gavre; it used shell of compressed steel, long and short, with ogival heads and flat heads, varying from 816 pounds to 1168 pounds, the [armor] penetration of which, between 1090 and 2180 yards, was shown vastly superior to others of the same caliber; with a cast-iron projectile with truncated base weighing 747 pounds, with a charge of 122.5 pounds Pebble powder, the initial velocity being 1364 feet[/second], a range was obtained, with an elevation of 33°9’ of 9800 yards. This gun was a breech-loader, and considering the shortness of the bore the results obtained are remarkable.”.

The pieces of May 19 and May 26 are not so much an attack on Sir Joseph Whitworth as they are an attack on the use of steel for gun construction by making use of steel the equivalent of the known flaws in Whitworth's 'unsound' conceptions. This is a false equivalence and a logical fallacy. The injuries to the gun noted above were due causes other than the use of steel. Consider the following;

Whitworth's selection of hexagonal rifling had been a bad idea from the start, and had a long history of projectiles jamming in the bore.

Even though the twist of the rifling was uniform, the twist was overly sharp, and presented great resistance to the advancing projectile. If Woolwich guns suffered injuries near the muzzle due to increasing resistance from the increasing twist and centrifugal forces, so too did Whitworth guns.

To obtain performance in the face of the resistance of the rifling, over-sized charges were necessary. Yet the 'compressed steel' did not burst or give way.

The use of super-heavy projectiles in the face of the resistance from the rifling and with overly large charges would increase pressures in the powder chamber to dangerous levels. With an 1168 lb. projectile, 122.5 lb. of Pebble would produce an initial velocity of around 1090 ft./sec. If 120 lb. of RLG were used in the same circumstances, the pressures would indeed enlarge the chamber and disable the breech screw. Yet the 'compressed steel' did not burst at that point, though such pressures would likely burst a Woolwich gun.

With more reasonable shell weights, performance would indeed have been better, in spite of the resistance of the sharp-twist rifling. The 816 lb. shell would have had an initial velocity of about 1305 ft./sec, and the 600 lb. projectile such as was fired by the Woolwich 12 in. 25-Ton gun and the 12 in. Vavasseur gun would have had an initial velocity around 1520 ft. /sec.

The eight all-steel built-up Blakely heavy guns at Callao fired for about five and a half hours using large charges of RLG, some shooting in excess of fifty rounds without injury. No large Woolwich gun had been tried to that extreme; the 'Woolwich Infant' was a ruin after 73 rounds total, using Pebble powder, only one charge of which was heavy.

The only reasonable conclusion is that the 'compressed steel' was not the problem with the Whitworth guns, but rather Sir Joseph's other choices were, coupled with his refusal to learn from experience.

The Elswick Ordnance Company tried two experimental breech-loading guns, a light 4.75 in. 40pdr of 26cwt, and a 12in of 39-Tons. Both have a bore length of 22 calibers, and enlarged chambers. Rifling was poly-groove with an increasing twist; for the 40pdr this was from 0:0 to 1:40, and for the 12in. it was from 1:100 to 1:45.

Performance of the 40pdr was good, but not exceptional. With a charge of 7 ¾ lb. of pebble powder with a 33 lb. projectile, mean initial velocity was 1490 ft/sec, and pressure in the chamber 7 ½ tons per square inch. With an 8 lb. charge the initial velocity was around 1540 ft/sec, and 8 ¼ lb. produced about 1555 ft/sec. 7 ½ lb. of RLG gave 1600 ft/sec with 13 tons per square inch pressure in the chamber.

Three rounds were fired from the 12 in. gun, each with a 700 lb. projectile, but charges of pebble powder of a different weight.

- Round 1 – velocity not recorded, but pressure at the top of the chamber was 15.1 tons per square inch, with 15.0 at the bottom, with a 160 lb. charge.
- Round 2 – with a 170 lb. charge, initial velocity was 1563 ft/sec, with pressures of 17.1 and 18.3 tons per square inch respectively.
- Round 3 – with a 180 lb. charge, initial velocity was 1615 ft/sec, with pressures of 18.6 and 18.7 respectively.

Construction was of the Armstrong type, with a steel liner and wrought iron coil jackets. The breech mechanism was of the French type, and obturation by a thin steel cup. This method of closing off the breech was "highly thought of in the Royal Arsenal." [March 23, 1877].

In May, 1877, *Shah*'s action with the monitor *Huascar* provides an example of the Royal Navy's capabilities, and Andrew Smith's account deserves to be quoted at length:

"*Shah*'s port guns opened fire at 1,900 yards... De Horsey chose to use the *Shah*'s speed to fight at long range, namely 1,500 to 2,000 yards, although ranges (estimated by eye) varied from 300 to 3,000 yards. The *Amethyst*... kept at 1,500 to 2,500 yards; although Able Seaman Patrick Riley records a minimum range of 1,000 yards in his memoirs...Fire control was extremely primitive. Ranges were estimated by officer's eye, shouted at the gunners through the noise of battle, sights set accordingly, and guns mostly laid and fired individually. However, the *Shah* also fired several broadsides from her 7" guns, including three by electric firing, mostly aimed by the director sight at *Huascar*'s turret...The action had lasted about 2 hours 40 minutes. The *Shah* fired 32 rounds 9" (2 common shell, 11 Palliser shell, 19 Palliser shot), 149 rounds 7" (4 common shell, 145 Palliser shot), and 56 rounds 64-pounder shell, total 237 rounds. The *Amethyst* fired 190 rounds 64-pounder shell. Total... 427 rounds... We may safely conclude that the *Huascar* received at least 50 hits."

From the above account, several points of some importance bear emphasis. There was a 'director sight' that could and was used for aiming at a specific target, the guns could be fired electrically when under 'director control', but information/instructions were still passed verbally. But the overall gunnery performance of the two British ships was rather good, considering the constantly changing range and bearing at which they were firing, the sea state, and that the monitor did not present much of a target above water; freeboard being only 3 feet, a minimum of 11.7% hits, though some sources claim sixty to seventy hits for 14.05 to 16.39 %.

"The injuries inflicted on the ironclad are thus described by an eye-witness:-- 'As near as could be judged, from seventy to eighty projectiles must have struck the vessel, principally about the upper deck, funnel casing, bridge, masts, boats... The hull itself showed that several 64-pounder shells struck it, only leaving a mark... The turret had only been hit once by a 7 in. projectile, hitting direct and penetrating 3 in.' Considering that the *Shah* and her consort could bring about five guns to bear for one by the *Huascar*, the results are, to say the least, unsatisfactory.

"...at very moderate range only one 9 in. shell fairly penetrated the side of *Huascar*...the other shells either did not strike at all or did so at such an angle that they failed to go through... The endurance of *Huascar* will do much to reinstate thin ironclads in favor; and it goes far to show that the old *Warrior* and *Minotaur* may prove exceedingly useful vessels in naval warfare." [July 20, 1877].

"We consider in this country that we are generally in advance of Continental manufactures in war material, particularly in the construction of armor and projectiles... It is remarkable, therefore, that the chief question of interest with relation to this subject at present, namely, the trial of steel as a substitution for iron both in projectiles and in plate, in great measure...comes from experience learned abroad...

"The fact is...that we have been taught by the Spezia trials that steel may stop shot which would penetrate iron. At the same time, steel is much more liable to be destroyed by splitting, and much more liable to snap its bolts. The question may be put this way: – That shot may be stopped by expending its work [energy] in fracturing steel when it would penetrate iron, because steel, by transmitting the shock through its mass, absorbs it chiefly in making cracks in various directions, while soft iron does not transmit the blow, but receives the whole work on the immediate locality at the point of impact, and so must yield more easily...

"Our own authorities are feeling, we believe, in the direction of compound armor...and thus after rejecting steel for armor in an unqualified way for at all events thirteen years, we are brought to the serious contemplation of its introduction...

"...it is clear that under some circumstances the power of steel to hold together is an advantage in its favor, and the knowledge that steel shot have obtained latterly abroad has had the effect of causing fresh trials to be instituted at home." [August 24, 1877].

"A very important trial of armor-piercing shot submitted by the most successful makers has been recently commenced at Shoeburyness, in connection with the work of Gen. Younghusband's Committee on Heavy Guns. The investigation of this particular question is conducted by Col. Inglis, R.E, and certain members associated with him for this work..." [Note that the term 'shot' is used generically, and for these trials does not mean solid shot, but rather 'armor-piercing shell' of the 'Palliser shell' type, with the cavity filled with sawdust replacing the bursting charge. This type of projectile, the ancestor of all later AP projectiles, had no fuze, and relied on impact shock and/or friction heat to set off the burster].

To establish equity among the various projectiles, all were to be for a 9 in. 12-Ton rifled muzzle-loader. The weight was to be the standard 268 lb, including gas-check, with an ogival nose of 1 ½ calibers. All were to be studded by the Woolwich Arsenal to match the Woolwich system of rifling.

The target plates were 12 in. thick, provided by Messrs. Brown.

The standard charge was 65 lb. P2 [1 ½ in. cubic] powder. Range to target was 50 yards, to produce a striking velocity of 1500 ft/sec [though the 'near normal' angle of descent tended to favor the cast iron chilled shot, whose performance at oblique angles was lamentable]. Theoretical penetration under these conditions was 12.5 in, meaning the point of the shot would extend ½ in. beyond the plate. "Practically, it would be a very excellent shot that would do so."

Those presenting chilled iron shot were:

1. Gruson [Germany]
2. Krupp [Germany]
3. Finspang [Sweden]
4. Gregorini [Italy]
5. RN Service shot, Palliser
6. Experimental Palliser 'Improved'

Those presenting steel shot were:

7. Terre Noire [France]
8. Whitworth [compressed steel]
9. Hadfield
10. Landore
11. Vickers
12. Vickers with chilled iron nose
13. Cammell's compound shot with Wilson's steel with chilled iron nose

The format for this initial trial was to fire two rounds of shot from each presenter.

See Table 7 for the detailed results. [April 12, 1878].

In that first round of the trials, chilled iron shot, with the exception of the softer Finspang, broke up. But the Finspang shot did not penetrate as well. The steel projectiles held together better, and the performance of the Whitworth shot was extraordinary, but lack the necessary 'hardness' of chilled iron. Solve that issue, and steel would clearly be superior [April 19, 1878].

Table 7. Preliminary Results of Armor-Piercing Shot Trials

Round	Results
1	shot broke up on entering the plate. With the nose 8 1/2 in. and the body 4 3/4 in.
2	Nose completely through the plate and breaking away from the body in front of the stud holes
1	shot penetrated 10 1/2 in.
2	very nearly penetrated plate, with nose broken off in front at the stud holes but passed through the plate
1	stuck in plate by bulging, metal too soft
2	Point projected 1 in. beyond plate; head broke off but body remained intact
1	penetrated about 10 in, head separating from body, and body bulged out to about 10 1/2 in. in diameter
2	Much the same as the 1st, but making a crack at the bac of the plate some 8 1/2 in. long and about 1 in. wide
1	point through plate, which bulged 5 in. and opened crack 4 in. wide
2	similar to 1st
1	nearly through, but shot broe up in the plate, plate bulged with crack 23 in. long and 1 in. wide
2	very similar to 1st, but crack 14 in. long and 2 in. wide
1	remained whole, but bulged and stuck in plate, penetrated about 10 in, back of plate bulged with small crack

2	penetrated about 10 in, slight crack in back of plate with bulge 2 1/2 in, shot remained whole but diameter of body 10.22 in.
1 & 2	Both performed very similar -- hole perforated the plate of about 9 in. in diameter, with a large c. 23 in. disc being detached from the back. Shots were not broken or cracked. One passed through, the other nearly so.
1	Penetrated 11.9 in, back of plate bulged about 4 in. and cracked. Base of shot broke off, but rest remained intact but cracked.
2	Penetrated about 9 in, but impact slightly oblique. Slight bulge 2 - 3 in. at back of plate. Shot broke inot 3 pieces.
3	allowed by bad laying of gun for 2nd. Penetrated 10 3/4 in. and rebounded unbroken with gas-check intact. Back of plate bulged 3 in. with crack 2 1/2 in. wide.
1	Penetrated about 9 1/2 in. Base of shot broken into small pieces. Shoulder diameter increased to 10 1/4 in.
2	results not noted
1	Slightly oblique impact. Penetration about 10 1/2 in. Base broe up, but head entire. Back bulged 3.8in. With crack 1.5 in. wide.
2	Penetration about 8.5 in, with indent being widened to about 11.2 in. at mouth. Shot rebounded whole, but cracked through at nearly every stud hole. Back of target bulged 1 1/2 in. and craced slightly.
1	Penetrated so as to leave the base 2 - 3 in. short of the plate, front portion projecting through the plate. Part of chilled point broken off, and disc 23 in. wide detached from back of plate.
2	Penetrated so as to leave 7 1/2 in. of the front of the shot, with chilled point broken off, beyond back of the plate. Very large portions of the plate were torn and bent back. Striking velocity estimated at 1520 ft/sec.

During the annual 'show' at Shoeburyness on July 24, "the 9 in. muzzle-loading gun, with a 65 lb. charge, fired one Whitworth forged steel shell of 268 lb, and one cast steel shell of Cammell's at a 12 in. plate, manufactured by Messrs. Brown…"duplicating the conditions of the recent trials. "The Whitworth projectile, for some cause, failed to leave the gun with the usual velocity, and complete penetration was not obtained… The striing velocities of the two projectiles were about 1440 ft. and 1445 ft[/sec] respectively."

That both projectiles 'under-performed' in the same manner and to the same extent implies a common problem not associated with the projectiles; a problem with the powder, or a problem with the Woolwich gun, the latter being much more likely given the well-known tendency for 'self-inflicted injuries' and general lack of endurance. [July 26, 1878]

During some test shoots at Shoeburyness regarding the most effective general form of compound armor, some interesting results were obtained.

A chilled shot was fired at a compound plate with the steel face backed by wrought iron. The shot failed to penetrate.

A chilled shot was fired at a compound plate with steel backing the wrought iron. The shot easily penetrated the entire plate.

Captain English, R.E, suggested that a wrought iron cap be fitted over the chilled point of the shot. This was tried against a compound plate with a steel face and wrought iron backing, and the shot penetrated the plate.

The matter was left for further investigation, which seems to have never been taken up… [August 23, 1878].

Elswick Ordnance Works presented an experimental 6 in. breech-loading gun for trials. It weighed 3.9-Tons, and the bore was slightly longer proportionately than the 40pdr and 12 in. previously submitted, at 23 calibers. Rifling was poly-groove with an increasing twist, 1:91 to 1:38.

The gun performance was quite good. Mean initial velocity with the standard 33 lb. charge of pebble powder with a 70 lb. shell was 1962 ft/sec, and 2070 ft/sec with a 64 lb. shell. Against armor plate, the results were interesting, considering the recent trials of AP projectiles.

With a Whitworth steel projectile of 80 lb. and the standard 33 lb. charge, initial velocity was 1792 ft/sec, with the projectile passing through a 10 in. plate.

With a chilled iron projectile of 80 lb. and the standard charge, initial velocity was 1819 ft/sec; the projectile penetrated the 10 in. plate but broke up in the process.

With a Whitworth steel projectile of 80 lb. and the charge increased to 36 lb, initial velocity was 1887.5 ft/sec which produced partial penetration of 9.6 in. into a 12 in. plate.

A chilled iron projectile of 80 lb. and with the 36 lb. charge, an initial velocity of 1919 ft/sec produced partial penetration to 11.3 in, but the projectile broke up in the 12 in. plate. [November 1, 1878].

"The bursting of a gun on board the *Thunderer* at Ismid, on Thursday, the second inst, has caused dismay in the Government Departments. Apart from the loss of life which we have to deplore, confidence in our wrought iron guns has received a shock which will not readily be got over.".

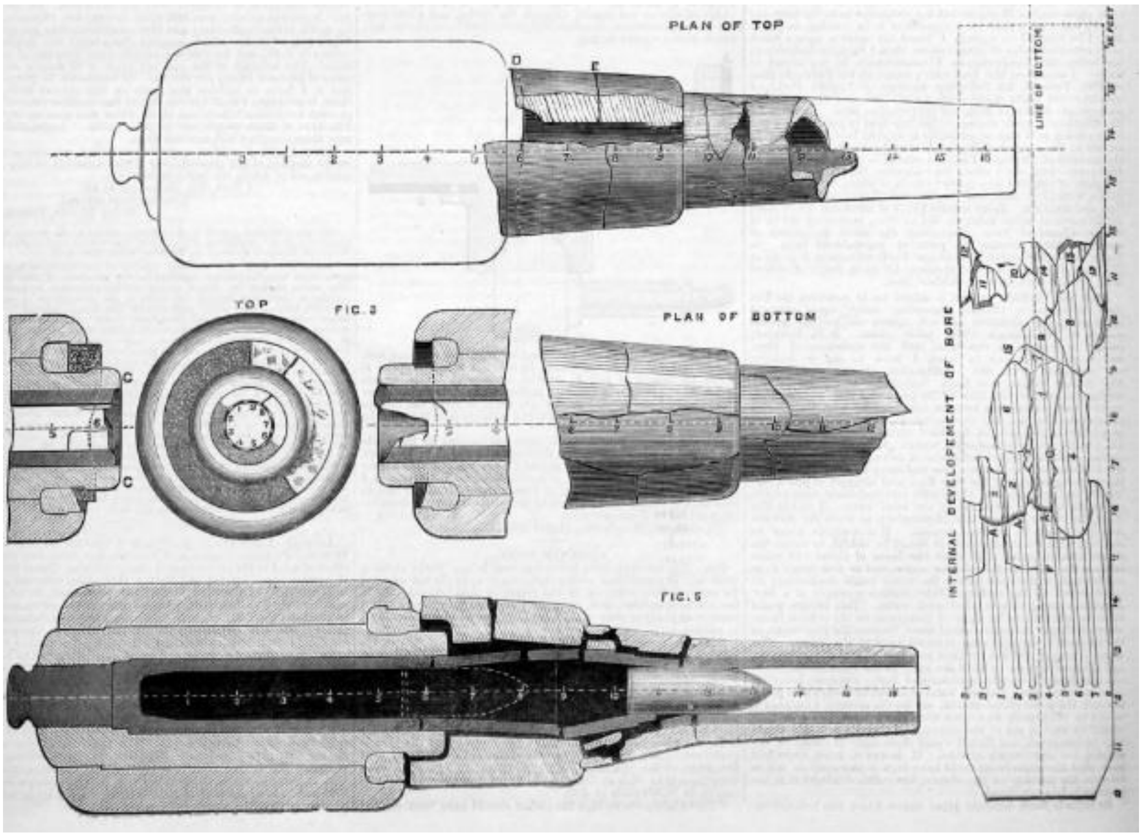

Fig 12. 38-Ton burst gun

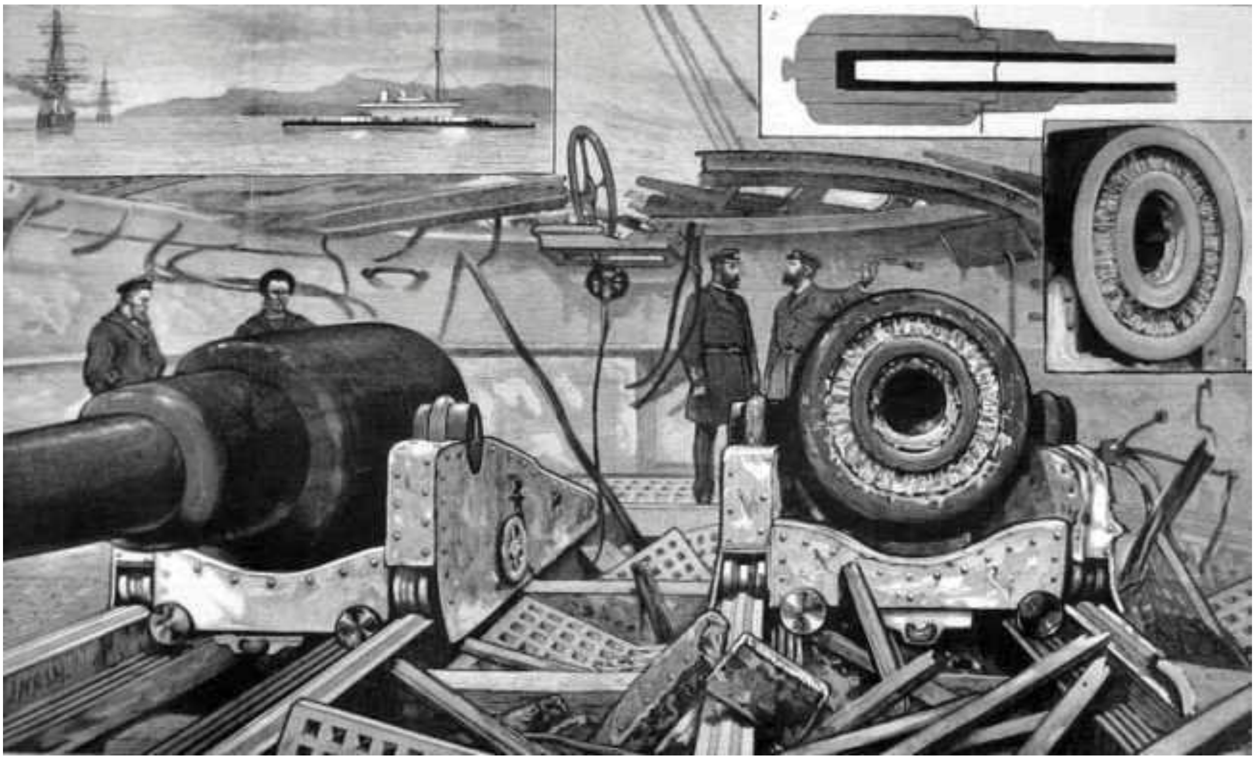

Fig 13. Explosion aftermath 1879 *Thunderer*

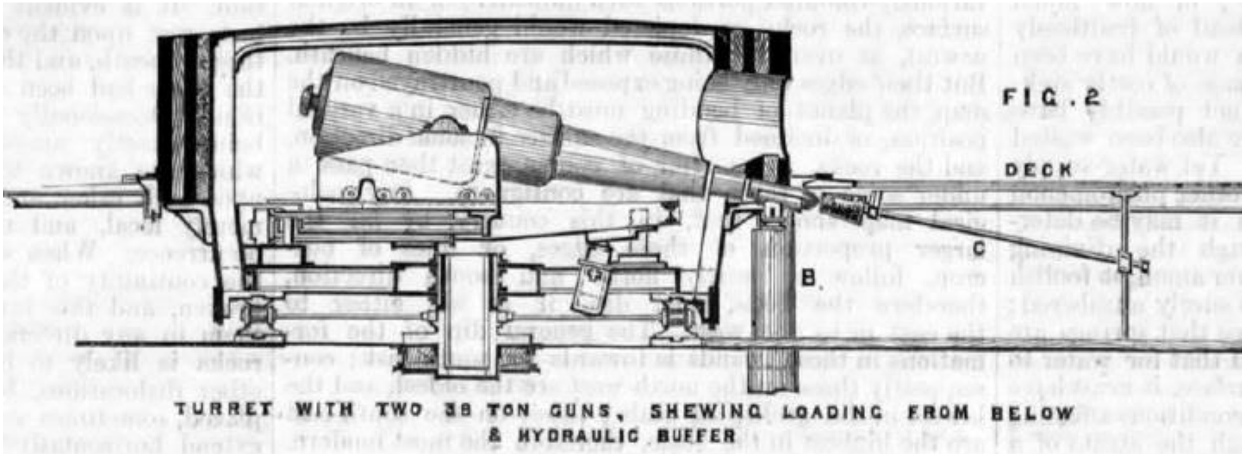

Fig 14. 38-Ton loading arrangements

This tragic incident spawned so many column inches of news and commentary in 1879 to easily qualify as one of the biggest stories in the last half of the 19th century. The reason for so much attention was, of course, the two great gun questions looming in the background; muzzle-loading versus breech-loading and wrought iron versus steel. It became a partisan issue to such an extent that the final official findings were not then, nor now, accepted.

What followed the bursting of the 38-Ton gun was an investigation at the Royal Dockyard at Malta, and another upon arrival in England, accompanied by an assortment of theories to explain what happened and why.

Thunderer was firing her quarterly target practice by firing each of her four guns by electricity simultaneously. One of the guns in the after turret had reported a fault, and did not fire in one salvo. Officers and men of the gunnery department reported seeing three shell splashes around the target, but other observers saw only two. The next salvo, the left-hand gun in the forward turret burst explosively.

Two main theories arose to account for the burst;

One is grounded in the known behavior of studded projectiles, the known tendency of the projectile to slip forward two or three feet when the hydraulic ram was withdrawn, the possibility of the charge also slipping forward leading to irregular ignition, and the known tendency of studded projectiles to jam in the bore. The charge was 85 lbs. of P2 and the Common Shell – fitted with a copper cup gas-check, weighed around 575 lbs. and contained a 38 lb 4 oz burster. Irregular ignition and/or a 'pressure wave' situation coupled with a jammed shell with the copper cup preventing any release of gas pressure, and the fine powder burster, would be sufficient to burst the gun. Or alternatively, the shell slipped forward, and the charge, ignited from the rear, would be propelled into the jammed shell, breaking cubes of powder into quick burning fragments and create a pressure spike. This theory would lay the responsibility squarely on the flawed loading arrangements and the myriad flaws in the 'Woolwich system.'

The other theory is counter-intuitive, and holds that the gun misfired in the round before the burst, and was inadvertently double loaded, giving a 110 lb. charge at the bottom of the bore, then a chilled shot, then the 85 lb. charge, then the shell. Evidence for this relies on a fragment of a stud which chemically matched the type used for shot, not shell, wedged in a groove. To prove this theory both viable and correct, the sister gun was sent to Woolwich to be double loaded in the manner conjectured, which, not surprisingly, burst the gun, and this became the 'official' explanation. Coincidently, acceptance of this theory absolves the 'Woolwich system' of any responsibility for a freak accident and human error.

The 'official' explanation has entered the history books as if it was proven fact, but it continues to be unsatisfactory [January 10 et.al, 1879].

Remarks by C.W. Merrifield, Esq, F.R.S. delivered to the Institution of Naval Architects:

"It is true that at the time the gun rifled on the French method was adopted [1865] in our service there was no system of breech-loading which could be considered as reasonably safe for large guns, but that has long since ceased to be the case; and even at that time I believe it would have been better to have expended a little inventive and experimental skill in endeavoring to produce a good breech-loader, rather than wasting labor in the attempt to cover and conceal the defects in muzzle-loaders actually introduced into the service…

"I think three points have now been established – first, that the existing service gun is a bad weapon; secondly, that it is of importance to replace it by a breech-loading gun; and, thirdly, that that gun should be rifled with a uniform twist… But I think it right to say that I am unable to accept the conclusion that the [*Thunderer*] accident was no fault of the gun. I believe it was entirely the fault of the gun, and that the only security against the recurrence of such accidents is to discard the present Woolwich gun in favor of a better system" [April 4, 1879].

On March 4th, Dr. Siemens read a paper at the United Services Institution, and in the ensuing discussion, General Young husband noted that "when the use of iron in coiled guns was decided upon, mild steel was not known."

This comment set off a firestorm in the pages of the Times. Mr. Henry Bessemer wrote that about 1858 the late General Eardley Wilmot, then superintendent of the gun factories in the Royal Arsenal, had for nearly two years investigated the question as to whether mild steel could be applied to the manufacture of ordnance; that General Wilmot had satisfied himself that mild steel was the best material for ordnance, and that a tender for the supply of steel…was sent in accordingly for casting guns in the Arsenal, when the Armstrong equipment was adopted and General Wilmot superseded.

Mr. Bessemer also stated that he has in his possession a small cannon made of mild steel in 1858, and that from 1858 to 1862 he had made to order 92 steel guns, one of which had well resisted tests of extraordinary severity in Belgium in 1859.

The debate continued without resolution. But The Engineer hit on the salient point of the whole discussion, "It is quite possible that steel may supersede wrought iron, and the explosive bursting of the 38-Ton *Thunderer* gun will doubtless weaken the ground on which wrought iron has been advocated…" [April 4, 1879].

On August 5 through 8, Krupp demonstrated numerous guns for the official military authorities of Belgium, Britain, Denmark, Holland, Sweden, Norway, Switzerland, Austria-Hungary, Italy, Spain, Portugal, Russia, Romania, Serbia, the Ottoman Empire, China and Japan.

One of the highlights of the occasion was trial shoots from the 40cm (15.75in) 71-Ton gun, and its smaller stable-mate, the 35.5cm (14in) 51-Ton gun.

For the demonstration, the larger gun fired a 778.5 kg (1716.5 lb.) chilled AP shell using a 205kg (453 lb.) charge to obtain an initial velocity of 505 m/s (1657 ft/sec). "The mean initial velocity of five rounds…variation in individual rounds was very small, the extreme difference…being only 2 ft. per second. The remaining velocity at [2500 meters, 2734 yards] was [434.5 m/s, 1425.5 ft/sec]. The [chamber] pressure was 3020 atmospheres (19.85 tons per square inch); the recoil 8.2 ft. The practice was very accurate…" with the eight rounds fired hitting the 6 ft. by 18 in. target. Range was not given, but presumed to be 2500 meters.

"The shooting therefore was exceptionally accurate, and the velocity very good. Most officers appeared to think that the use of prismatic powder insured greater accuracy than could be got with our pebble powder." [August 15, 1879].

Obviously, there was more involved than just prismatic powder, though that certainly contributed to the regularity of the initial velocity. Rigid production standards produced great equality of grain size and more uniform burn rate. Other factors included the enlarged chamber, the easy poly-groove rifling with a uniform twist of 1:45, more aerodynamic projectile nose shape – 2 crh as opposed to 1.5crh thus better retaining velocity -- and the Vavasseur copper driving and centering bands which eliminated windage and prevented the projectile from 'knocking about' in the bore.

The import of these results from Meppen, coupled with the results of experimental Armstrong breech-loaders, was certainly not lost on General Younghusband and his Committee on Heavy Guns.

"The recent Meppen experiments, the last firing of the 100-Ton gun at Spezia, and the appearance of the new Elswick 35-Ton gun, have elicited the fact that foreign Powers are likely to be armed with more powerful guns than ourselves unless we bestir ourselves. There is no use in shutting our eyes to this if it a fact. We think the following list of guns will bear out what we say. The pieces are arranged in order of power of penetration. We give the thickness of wrought iron that each gun should actually penetrate in preference to the number of foot-tons per inch of shot's circumference, because it is more easily grasped by the mind:--

1) Elswick 100-Ton muzzle-loading gun, 17 in. caliber, penetrates 37 in;
2) Krupp 71-Ton breech-loading gun, 15.75 in. caliber, penetrates 32 in;
3) Woolwich 80-Ton muzzle-loading gun, 16 in. caliber, penetrates 30 in;
4) Krupp 51-Ton breech-loading gun, 13.98 in. caliber, penetrates 27 in;
5) Elswick 35-Tn muzzle-loading gun, 11 in. caliber, penetrates 22 in;
6) Woolwich 38-Ton muzzle-loading gun, 12.5 in. caliber, penetrates 21 in;
7) Krupp 18-Ton breech-loading gun, 9.45 in. caliber, penetrates 20 in;
8) Woolwich 38-Ton muzzle-loading un-chambered gun, 12.5 in. caliber, penetrates 19 ½ in.

"But here it may fairly be questioned whether we are not connecting too much with the [enlarged] chamber and air space principle, especially as Krupp allows higher pressures in his guns than ourselves. May it not be that steel as a material, that breech-loading as a system, with its conditions as to close fittings of projectiles, etc, may have much to do with the matter?" [August 22, 1879]

News items of interest:

- Initial proof trials of the 80-Ton gun, bore 16 in. and with an enlarged chamber, were reported to have been a great success. With a proof charge of 445 lb. of P2 the initial velocity was 1657 ft/sec, with chamber pressure of 21.5 tons per square inch. This was equal to or slightly superior to the Krupp 40cm gun with a service charge of 443 lbs of prismatic powder.
- It appears that Sir Joseph Whitworth will not submit a tube of his compressed steel to the New Gun Committee.
- Sir William Palliser proposes to bore out the steel tube of a large Woolwich gun and then insert a very long loose coiled wrought iron tube, for submission to the New Gun Committee.
- The Italian Government has ordered eight 100-Ton breech-loading guns from EOC. This is seen as a 'vote of confidence' for the wrought iron coil system of gun construction.
- EOC test fired a new 300pdr 10 in. breech-loader on September 11th, and recorded a muzzle velocity of 2110 ft/sec. [September 19, 1879]

On January 30, 1878, the Turin Foundry cast the body of what would be a 45cm (17.72in) 100-Ton gun for the Italian Army, for coast defense purposes. This cast-iron body, 10 meters (32.8 ft) in length was accomplished using a variation of the Rodman 'hollow cast' water cooling process. The bore was to be lined with wrought iron, and the body reinforced with three layers of steel hoops. It was also a breech-loader, intended to fire a shot weighing 1000 g (2205 lbs). [October 17, 1879].

"Accuracy may be measured in two directions, namely, accuracy in range, and in lateral deviation. In range we cannot easily make a strict comparison between the 80-Ton [16 in.] and Krupp's [40cm]... It appears, however, that Krupp's accuracy in range is remarkable, while his lateral deviation...does not appear better than that of the 80-Ton gun... Now it may be said that variation in range must be charged to irregularity in the powder, whence it appears any superiority in accuracy of fire that may belong to the 71-Ton gun may be attributed to the fact that our pebble powder is inferior to the prismatic powder used by Krupp... Since the adoption of the system of imparting rotation wholly by means of a copper gas-check fixed on the base of the projectile [as was done by Blakely and many American Civil War designs], a muzzle-loading projectile stands in the peculiar position of having no windage in rear... On the other hand, the projectile, having no studs, must lie with its body resting on the grooves [the lack of centering noted in the Russian 1863 Trials]...a condition of things that appears unsatisfactory. Krupp's gun, being a breech-loader, has the advantage of comparatively easily admitting a tight-fitting projectile into the bore. Hence Krupp's projectiles have [Vavasseur's] copper ring on the shoulder, as well as a gas-check at the base. Nevertheless, projectiles have been made recently with no ring on [shoulder]...except that the [shoulders] have been made of within 0.012 in. of the same diameter as the bore of the gun... However this, like many other questions, indicates the advantage possessed by breech-loaders..." [October 17, 1879].

The end of 1879 saw the first gust of the 'winds of change' that finally brought an end to the anachronism of muzzle-loading ordnance, and eliminated one of the two remaining facets of Armstrong's legacy. Production of the 80-Ton guns for HMS *Inflexible* would bring fifteen years of erroneous concepts and bad decisions to an inglorious end.

Unfortunately, though, the process of acquiring the new breech-loading guns would not be rapid. The War Office remained responsible for providing the ordnance for Her Majesty's armed services. And as Captain H. Garbett, R.N. penned in 1897, Britain needed to make up for fifteen years of lost progress. Who was to build the new breech-loaders, using what materials and what method of construction, to what designs?

Only two firms had experience in building large breech-loading guns; Josiah Vavasseur's London Ordnance Company – though Vavasseur's own experience went back to 1863 – and Sir William Armstrong's Elswick Ordnance Company, which had only recently begun building experimental breech-loading rifles. The New Gun Committee would be required to discard the fallacious decisions of its forebears, and make the correct decisions with all dispatch.

1882

"...The Woolwich gun and that of Herr Krupp differ in many respects, some of them depending on the peculiarities of the respective systems of construction; for example, Krupp's [71-Ton] gun is a breech-loader, ours is a muzzle-loader; Krupp's is made of steel, ours of wrought iron, with a steel inner tube... Krupp's gun, however, has a bore 343 in. long, while our [80-Ton gun] has one of only 288 in. Hence in the former piece the gas has a longer time to act on the projectile before it leaves the muzzle...

"Now the dimensions employed in the 71-Ton Krupp gun could be actually adopted for a muzzle-loader in all respects with one exception, namely, that the projectiles for a breech-loader can be made with a windage reduced almost to nothing. The 71-Ton gun common shells, for example, have a diameter of 39.97 centimeters... This we look upon as a nicety, which is unsuitable to actual service conditions. It might, however, have been thought to have contributed to the admirable results obtained at Meppen, were it not for the fact that equally good ones were obtained with chilled projectiles possessing a diameter of 39.8 centimeters, implying a windage of 0.078 in, which nearly corresponds to our own service windage of 0.08 in. [This is essentially correct regarding the effect of windage, but the writer overlooked the impact of Vavasseur's copper driving band and centering band which are thoroughly effective gas-checks, but not suitable for muzzle-loading guns. Therefore, windage was an issue for Woolwich, but not for Krupp].

"To sum up shortly, then, it ought to be clearly understood that our 80-Ton *Inflexible* guns are old-fashioned pieces made for a special purpose, and as such cannot be expected to compete against guns of newer and better proportions. Further, that while great advantages are offered by breech-loading, and advantages which…increase with every increase in length, there is nothing in the success hitherto obtained by Krupp, splendid as we do not hesitate to call it, that might not be achieved by a wrought iron muzzle-loading gun…" [January 30, 1880].

"Public confidence in English guns could hardly fail to receive a great shock on the news received on Monday morning last that a 100-Ton gun had burst, while firing on board the [Italian ironclad turret ship] *Duilio*.

"The facts, as far as they have reached us, are as follows: a 100-Ton gun which had already fired many – thirteen and twenty-five have both been said…and which was undergoing trial in its turret on board the *Duilio*, has burst in such a way as to break the steel inner tube and cause the gun to come asunder behind the trunnions, which, with the fore part of the gun, remained on the carriage; the breech portion going back against the interior of the turret with sufficient violence to indent the inner steel skin and force the backing against the outside [of the] armor plates – which are 22 in. thick – s9 as to open two of them… The wrought iron coils built on round the inner tube are said not to be injured themselves, but drawn asunder… The gun had been loaded by hand with the following ammunition: a battering charge of 551 lb. [250 kg] of Fassano progressive powder and a 2000 lb. projectile. The steel tube is said to have yielded just at the base of the truncated cone leading from the enlarged chamber into the bore… The chamber is reported to be extended as if by an extraordinary pressure.".

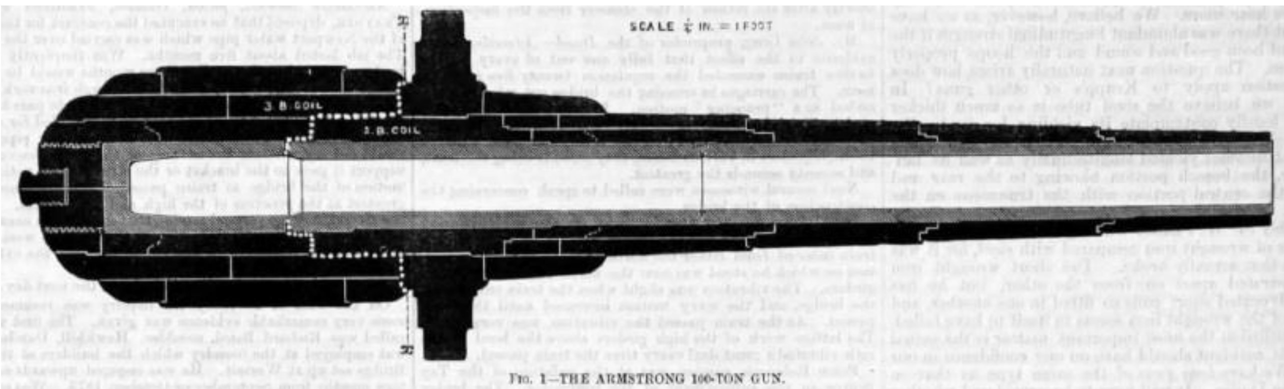

Fig 15. Armstrong Burst 100-Ton gun

'Asunder,' by definition means 'violently separated into pieces.' The result described in the admittedly second-hand information understates the extent of the damage to the wrought iron coils. The likely order of events provides an image of catastrophic failure. The gas pressure in the chamber extended and stressed the steel both longitudinally and circumferentially, which gave way at the weakest point at the base of the truncated cone. At that instant, the B coils gave way under vastly more pressure than they could possibly resist. That the separation followed the 'path of least resistance,' as if it were seeping rather than an expanding torrent, is not a surprise. But in the process, the iron would be bent and twisted from the stress. At almost the same instant the steel tube gave way, the resistance to the longitudinal pressure blew the after portion of the gun backwards. This release of pressure weakened the circumferential pressure, preventing what would surely have been an explosive burst. What this incident truly demonstrates is the simple fact that wrought iron coils cannot prevent or contain gas pressures sufficiently high to burst the steel inner tube [March 12, 1880].

"The powder question in all its aspects is just now a matter of peculiar importance, as affecting our monster ordnance. In saying this we refer not only to the size and quality of the so-called grains, but likewise to the construction of the cartridge and the mode of firing it. In the ramming of the cartridge a very safe powder may be transformed into a very dangerous one, by the crushing of the cubes or prisms, so as to convert large grain powder into small grain. The last round fired from the rent gun on board *Duilio* was subject to this peril, if we may accept the statement that the cartridge stuck in the chase and had to be rammed home with unusual force. But that is not all. When a cartridge is fired from an axial vent in the gun, it is just possible it may commence at the rear of the charge, despite those internal arrangements which are intended to secure a different result. It is well known that when a long cartridge is ignited at either extremity, particularly the rear, wave pressures are set up, far exceeding the normal force of the powder, and acting locally with extreme violence".

There had been little experimental work into the phenomena of irregular ignition, but what there had been was instructive. "For example, at Shoeburyness six weeks since, the pressure in the bore of a gun was increased from a normal of 18 to 30 tons by the substitution of 5 lb. RLG for 5 lb. Pebble 1 in a 105 lb. charge." This would be the rough equivalent of breaking up some cubes or prisms from too forceful ramming of the cartridge.

Elswick had experimented with a rear vent to ignite an un-tubed charge, and pressures were raised from a normal of 18 tons to 50 tons per square inch.

"What this force really amounts to is instructively shown by some experiments carried out at Woolwich with one of Mr. Vavasseur's steel guns, weighing 16-Tons, and having a caliber of 10 in. The projectile in each instance weighed 400 lb."

Table 8. Experiments with Vavasseur 10 in. 16-Ton Gun

Charge Weight, lbs.	Powder Type	WhereIgnited	Pressure atrear of charge, tons/square in.	Pressure atseat of shot, tons/square in.	MuzzleVelocity, ft/sec
70	Pebble 1	Centerrear	21	18	1412
			45	37,5	1455
			45,1	50,1	1436
75			c.45.1	59	1497
80			57,6	63,2	1541
	Pebble 2		25,1	24,8	1482
88			36,4	24,1	1514

The Italian Commission "...are driven to the conclusion that the charge was fired in such a way as to give rise to an abnormal pressure...they suggest a reduction of the present battering charge from 551 lb. [250 kg.] to 507 lb. [230 g.], which is to be made up in a cartridge with a tube to ensure the regular ignition of the powder." [April 3, 1880].

"Steel has superseded wrought iron so rapidly for manufacturing purposes generally, and has been found to possess such superiority, that the field left open for the latter bids fair to become very small. If steel is not only harder, and capable of resisting heavier strains, but is also more or less to compete with wrought iron in its own special functions of working well under the hammer, while owing to its capability of casting, it is cheaper on a large scale, it may well appear as if wrought iron might be expected to disappear before its rival, except for certain special purposes. In ordnance, however, wrought iron has as yet held its own wonderfully.

"On a question raised with regard to the amount of support afforded by wrought iron to steel we learn from Essen the opinion that Krupp's inner tubes, which are supported by steel, do not fail, but, that doubtless, compound guns will always do so, particularly in firing heavy charges, because the elastic limits being so different the steel tube will lose the support of the iron casing, and will naturally burst".

The impending design and construction competition of the New Gun Committee – soon to be superseded by a new Committee on Ordnance – while not limited in their investigations and trials, will likely be focused on the three main and most experienced gun construction operations; Armstrong's Elswick Ordnance Works, Vavasseur's London Ordnance Company, and the Royal Gun Factories/Woolwich. Their latest designs would no doubt be important to the Committee.

This gun, soon to be undergoing trials, weighed 11.5 Tons and had a bore length of 26 calibers. Though it was a compound gun of steel and wrought iron, it represented a departure from previous construction. The steel inner tube was both thicker and stronger, and the extent of wrought iron coil 'reinforce' was reduced. The breech piece was part of the steel tube. Longitudinal strength was entirely vested in the steel tube, as was a considerable amount of the tangential strength.

This piece, under construction so the weight is not known, was a typical Fraser designed compound gun, with extensive use of wrought iron coils to support the relatively thin steel tube. Though the breech piece itself was steel, and an extension of the steel tube, much of its structural support came from the iron coils.

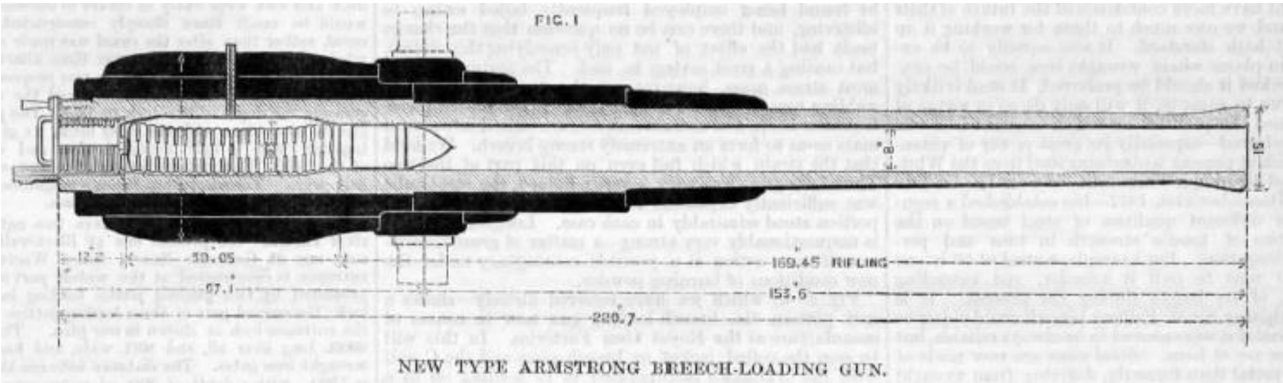

Fig 16. Newest Guns – Armstrong 8in

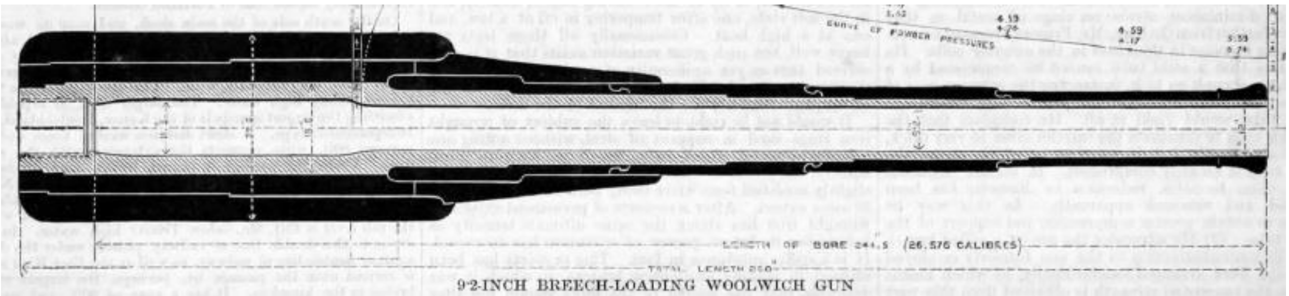

Fig 17. Newest Guns – Woolwich 9.2in

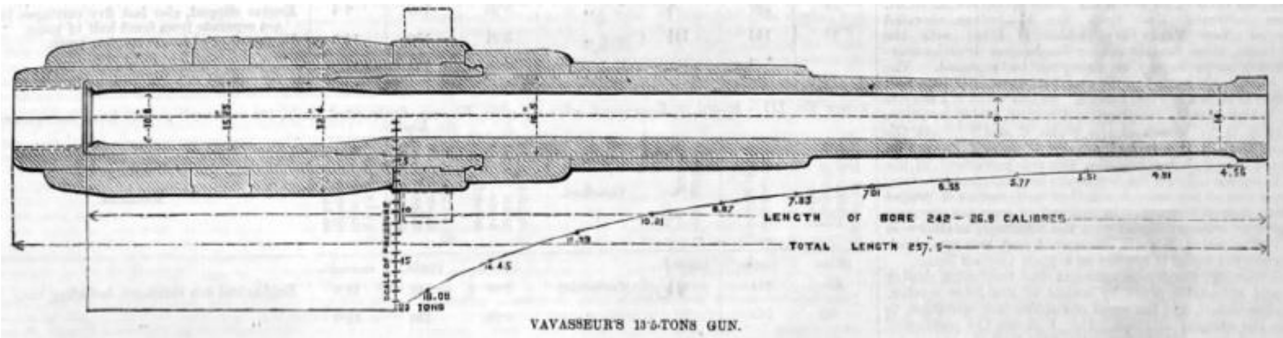

Fig 18. Newest Guns – Vavasseur 9in

The all-steel built-up gun up for consideration was Vavasseur's 9 in. 13.5 Ton gun of 26 caliber length.

"The principles on which steel guns have been built-up…are clearly stated by Vavasseur, and appear to have been consistently embodied in his guns from a very early date. They may be said as follows: the steel employed must have a high factor of elongation so as to possess the special qualifications of wrought iron in addition to a much higher tenacity.

"The steel ['A'] tube should be of nearly the same diameter from end to end, otherwise molecular disturbance is liable to be caused in cooling. In addition to which this form is better for production and working.

"The steel ['A'] tube should be supported by a long steel jacket, holding by means of shoulders behind the end of the inner tube and on the front part of the trunnion ring, so as to make it impossible to separate the breech from the trunnions, except by tearing through the entire jacket as well as the inner tube...The hoops over these only supply tangential strength.

"In breech-loading guns, the breech arrangement is fixed to the jacket, not the inner tube, it being considered that the latter should be saved from longitudinal strain in order to have its full strength to resist that in the tangential direction...Here will be seen...the features [of the all-steel] Blakely gun."

While the inner steel tubes of all three of these 'Newest Guns' are oil tempered, the jacket of the Vavasseur gun is 'lightly' oil tempered at a lower heat, to increase its strength, and all reinforcing jackets and hoops are shrunk on to obtain the proper initial tension.

Mention was made of a Krupp 9in (23.54cm actual) 14.5-Ton gun that had burst in the summer of 1879, by way of proof that all-steel built-up guns also fail. That model of construction, the C/68, came out of the August 1868 competitive trial with an Armstrong 9in, which, when using charges of prismatic powder proved superior in striking power and endurance. From the information available, that 11 year old gun burst forward of the seat of the projectile. The reinforcing hoops did not give way, and the inner 'A' tube was propelled forward while the breech was propelled to the rear. The likely cause was an old-style lead-coated projectile jamming in the bore, a not uncommon occurrence, judging by Russian and Krupp's own experience. [June 25, July 9 and July 30, 1880].

"The heavy breech-loader now in the course of its department trials in the Royal Gun Factories naturally excites much interest... The new gun weighs about 43 Tons. Its caliber is 12 in, and its length of bore about 26 calibers... In general appearance, proportions and character, the gun closely resembles the 9.2 in. breech-loading Woolwich gun... The gun was fired on Thursday, January 6th, with about 280 lb. prismatic powder...with a projectile weighing 703 lb, gave an initial velocity of 1830 ft. per second. The charge is being gradually increased – the pressure in the bore as yet about 16 tons on the square inch... The power of this piece then is very great, and we have not yet reached the maximum development. On the most recent trial a velocity of 1930 ft[/sec] was obtained with 300 lb. of powder, and a pressure of 19 tons on the square inch" [January 14, 1881].

In a freak incident, one of the first, if not the first, Armstrong 8 in. breech-loaders of 26 calibers, such as illustrated above, was irretrievably lost in combat. The piece had been sold to Chile, and armed the gunboat *Angamos* for operations against Peru.

"On December 9th she tried to sin the Peruvian corvette *Union*, firing twelve rounds of common shell, weighing 180 lb, with a 90 lb. charge of 'P' powder [undoubtedly Pebble 2, 1 ½ inch cubes], at 8000 yards at 12 ½ deg. elevation. On December 10th and 11th the same practice was repeated, the mark in this case the *Atahualpa* [formerly the monitor USS *Catawba*].

The sixth round was fired, and "the look-out man perceived the shot falling short, and turned around to call to the officer in charge saw that the gun had disappeared, leaving its trunnion hoop and trunnions only on the carriage. In rear lay the officer and the captain of the gun dead and mangled, an in the [unengaged] side of the ship was an aperture 8 ft. wide, through which the gun had evidently driven itself into the sea".

A number of factors contributed to this incident. First, a 90 lb. charge, 50% of the projectile weight, was very heavy, making the recoil quite violent.

Second, this very early construction differed slightly from the later versions. The powder chamber was slightly larger, and the trunnion hoop only 10 in. wide rather than the 17 in. of the later production. In consequence, the attachment o the trunnion hoop was less complete, and any support from the wrought iron coils, especially forward, was woefully insufficient against the strain involved.

Third, as an experimental gun, it had already been subjected to considerable strain prior to sale. 20 rounds of varying charge weights had been fired at Elswick. The chamber had already been elongated slightly, and the vent "enormously eaten away, and the metal forced so far up as to project at the outside end..." These may have contributed somewhat to the violent recoil.

And last, the carriage on which the gun was mounted had great compressive power for limiting the distance of the recoil. In other words, the carriage halted before the force of the recoil had been absorbed, and the gun tore away from the trunnion hoop and any resistance from the coil ‘reinforcement,’ rocketing across the deck, through the side planking, and into the sea [February 11, 1881].

“In his speech on March 3rd in the House, Mr. Childers spoke of the formation of the new [ordnance] committee in the following words:-- It has appeared that it would be desirable to recur to the advice of an independent Ordnance Committee, with functions somewhat differing from those of the former [Ordnance Select Committee]. It will consist of officers of the artillery, of the navy, and of the Engineers, with two eminent civil engineers; and while we hope to obtain from this committee technical advice of extreme value, we have determined not to run the risk of the disadvantages felt in connection with the old Ordnance Committee, and strictly to limit its functions to such inquiries and experiments as may be categorically referred to it by the Minister holding my office.’” [March 18, 1881].

The new 43-Ton gun began trials at Shoeburyness on March 16th. With a service projectile weighing 714 lb. and a battering charge of 286 lb. prismatic powder gave a muzzle velocity of 1850 ft/sec, with pressures of 17.3 tons per square inch.

One interesting feature in the construction of the gun may present major philosophical differences compared to both Armstrong/EOC and Vavasseur. Whereas the former appeared to increase the role of the steel inner tube, and Vavasseur sought uniformity in the ‘A’ tube from breech to muzzle, Fraser decreased the thickness from a point forward of the heavy ‘C’ coil to the muzzle, with a corresponding increase in the thickness of ‘reinforcing’ wrought iron coils [April 1, 1881].

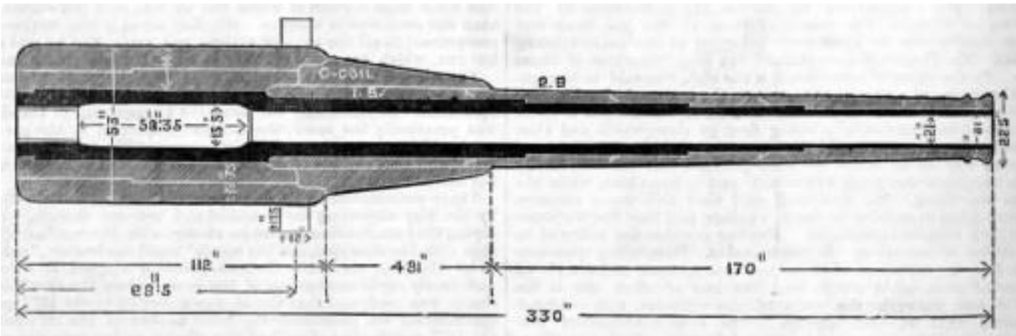

Fig 19. Newest Guns – Woolwich 12in

Elswick Ordnance Company has a 12 in. 43-Ton gun in the process of initial trials. While that piece is the same weight, caliber and bore length as the Fraser gun, significant differences exist. The powder chamber of the Armstrong gun has a diameter of 14.3 in. and a length of 87.43 in, compared to the Woolwich gun’s 15.5 in and 58.35 in. In terms of volume, the powder chamber is about 14189 cubic inches versus 11125 for the Fraser gun. This translates into larger charges for the Armstrong gun, but the trade-off is about 29 inches less rifled bore, or ‘distance traveled’ for the gas pressures to push the projectile.

With a 315 lb charge of prismatic powder and a 700 lb shot, initial velocity was about 1950 ft/sec. Increasing the charge to 325 lb. produced about 1970 ft/sec.

EOC was also experimenting with ‘steel riband’ [later known as ‘wire wound’] construction, with an experimental piece being built [July 29, 1881].

Sir William Palliser had requested the Secretary of State for War allow him to submit a new muzzle-loading gun for trials by the new Ordnance Committee. His rationale for the request was the strength shown by a converted gun the previous May at Erith.

That 7 in. gun, double loaded in the manner of the accepted theory on the cause of the bursting of a 38-Ton gun aboard the *Thunderer*, had demonstrated surprising strength.

The metal around the front of the forward charge was only 7.6 in. thick, composed by 2.8 in. wrought iron coiled inserted inner tube, and 4.8 in. of cast iron. The theoretical strength was 34 tons per square inch, but it had yielded under pressures of 44.3 and 47 tons.

Sir William proposed building a gun of 17 in. caliber, but using a casing of special steel rather than cast iron. The response from the Surveyor-General’s Department, dated 18 July, was direct.

"Sir, – I am directed by the Secretary of State for War to acknowledge the receipt of your letter of the 22nd ultimo, in which you submit remarks relative to the recent trials of your 7 in. rifle gun of 5 tons at Erith, and request permission to furnish a steel casing for a muzzle-loading gun, and that the barrel for it may be made in the Royal Gun Factories, in accordance with plans submitted on 21st May; and further that the trial of a gun composed of a casing and barrel as above may be sanctioned

"In reply, I am to acquaint you that Mr. Childers has carefully considered your request, but that he is not prepared to accede to it."

The era of the muzzle-loading rifled gun was well and truly finished. [September 2, 1881]

The *Revista General de Marina* for October gives a short account of the bursting of a Spanish cast iron gun lined with wrought iron coils while firing a shell. The piece was originally a smooth bore of 20 centimeters, lined and rifled, being then brought to 16 centimeters (6.3 in.) caliber. The firing charge was the service one of 6 kilograms (13.2 lb.). The gun appears to have yielded by blowing out the breech end, which flew to the rear. The piece also split longitudinally in a vertical line as cast iron pieces generally do. The [wrought iron] cup which formed the bottom of the bore was, of course, blown out to the rear with the breech, the coils into which it was screwed being unwound. The coils do not appear to have been rent, they seem to have held well together. The writer of the Spanish report considered that the longitudinal [pressure] was equally divided between the projectile and portion of the breech blown out, because there was little or no recoil…

"This gun must have yielded on the first commencement of explosion of the charge, and the weak place was determined by the crystalline structure at the angle of casting. It certainly yielded chiefly in a direction in which it would not receive additional strength from the wrought iron lining… It is, however, extremely uncommon for a gun to yield in this way. Generally, a gun has sufficient margin of longitudinal strength to admit of a considerable gain to be obtained by conversion. The coils appear to have behaved very well. It is difficult to say what strain was thrown upon the piece. The charge of 13.2 lb. is rather large; 12 lb. RLG is the largest charge we fire from out 64-pounder 6.3 in. wrought iron gun. The nature of the Spanish powder, however, is not stated. One thing appears certain, that the wrought iron prevented the whole gun from flying into fragments.".

The specific model of the original smooth bore gun was known as the '20cm No. 2 Rivera,' cast in considerable numbers by the Trubia Arsenal in the mid- and late 1850s, for the navy. The navy had resisted rifled artillery, accepting only a few Blakely patent construction 16cm pieces. So the fleet that fought at Callao on May 2, 1866, was armed almost exclusively with 20cm and 16cm smooth bores. Only upon the return of the fleet from the Pacific was the naval aspect of "the great modernization" seriously undertaken.

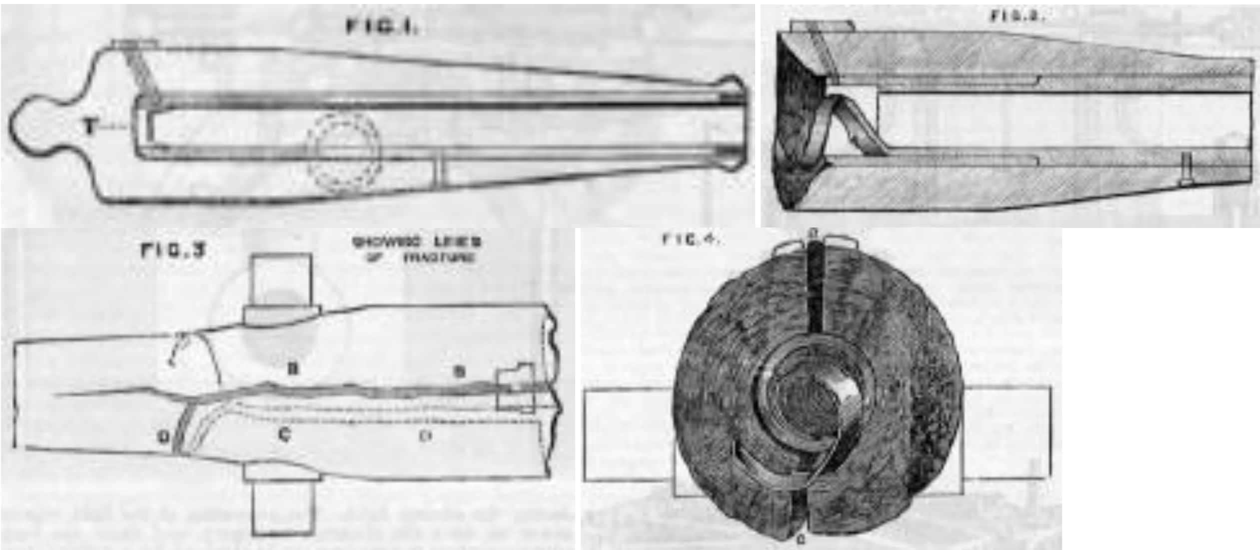

Fig 20. Burst Spanish Palliser

The preference of the naval authorities was to purchase large bore guns from foreign providers, and convert the well-regarded 20cm No. 2 Rivera in the Palliser manner. That type of conversion included the wrought iron cup at the bottom of the bore to protect the cast iron breech. In general terms, the 20cm No. 2 Rivera/Palliser conversion was so highly regarded that it was selected by Gonzalez Hontoria for conversion to a breech-loader as part of the M1879 system, losing its wrought iron coils to steel inserts.

For at least the previous twelve years, the primary powder for medium and large bore guns was prismatic black. Consequently, a 13.2 lb. charge should not have been excessive, and more closely resembles the strain of about 9 lbs. of RLG, a bit smaller than the service charge of a 64pdr conversion or Woolwich guns. [December 16, 1881]

On February 8, 1882, Col. E. Maitland, Superintendent of the Royal Gun Factories at Woolwich, delivered a paper on "Modern Ordnance" to the Society of Arts, London.

"Wrought-iron, as you are all well aware, is nearly pure iron, containing but a trace of carbon. Steel, as used for guns, contains from 0.3 to 0.5 percent carbon; the larger the quantity of carbon, the harder the steel. Since the early days of which I am now speaking, great improvement has taken place in the qualities of both materials, but more especially in that of steel. Still, the same general characteristics were to be noted, and it may be broadly stated, that England chose confessedly the weaker material, as being more under control, cheaper, and safer to entrust with the lives of men; while Prussia selected the stronger but less manageable material, in the hope of improving its uniformity, and rendering it thoroughly trustworthy. The difference in strength, when both are sound, is great. Roughly, steel is about twice as strong as wrought-iron.

"Prussia at first relied on the superior strength of solid castings to withstand the explosive strain, but at length found the necessity for re-enforcing them with hoops of the same material, shrunk on the body of the piece.

The grand principle of shrinkage enables the gun-maker to bring into play the strength of the exterior of the gun, even with quick powders, and to a still greater extent as the duration of the strain increases with the progress of powder manufacture... Now, as the duration of the pressure increases, owing to the use of larger charges of slower burning powder, it is evident that the more complete and effective will be the transmission of the strain to the exterior, and, consequently, the further into the body of the gun, starting from the bore, and traveling outward, does it become advantageous to employ the stronger material. Hence, in England, we had reason to congratulate ourselves on the certainty and cheapness of manufacture of wrought-iron coils, as long as moderate charges of comparatively quick burning powder were employed, and as long as adherence to a muzzle-loading system permitted the projectile to move away at an early period of the combustion of the charge..."

[The full text of the paper may be found in Scientific American Supplement No. 324, March 18, 1882. A review and commentary may be found in The Engineer, March 10, 1882.]

"We have now received the official report of Krupp's trials at Meppen... There were present at the experiments officers representing the following Powers: Germany, Austria [-Hungary], Belgium, Brazil, China, Denmark, Spain, Holland, Italy, Japan, Norway, Russia, and Sweden.

"...the following pieces have been fired this year: guns of 30.5 centimeters. (12 in.) and 15 centimeters (5.9 in.), each 35 calibers long, being examples of Krupp's new system, which is remarkable, firstly, for the adoption of heavy charges, reaching an amount of even and a half [times] the weight of a round shot [pounders] of the caliber of the gun; secondly for the employment of specially heavy and consequently long projectiles; and thirdly, for the great length of the guns.

"The 30.5 cm. and 15 cm. long guns were fired for accuracy, velocity and pressure on the bore...

"The principle dimensions are as follows:

Weight:	49700 kg. (48 Tons 18cwt)
Total length:	10.7 meters (35 ft.)
Bore length	9.77 meters (32 ft.)

"All projectiles...weigh 455 kg. (1003.1 lb.) and consequently vary in length...
Steel AP Shell: 3 ½ calibers, burster 11 kg. (24 ¼ lb.)
Cast iron Shell: 4 calibers, burster 22 kg. (48 ½ lb)

Steel Common Shell: 4 ½ calibers, burster 49 kg. (108 lb.)

Centering is affected by the metal [broadened shoulders] of the projectiles… The copper ring for rifling and [gas-check is around the base of the projectile].

"The charge is of prismatic powder channeled through and of 1.82 density… It is fired by self-closing tubes in an axial vent

"The 30.5 cm. long gun fired seventy-three rounds with varying charges and kinds of powder. The bore shows the commencement of scoring; otherwise it is almost uninjured, seeing that one can only detect enlargements of 0.1 mm. (0.004 in.). The results as to velocity and pressure, as well as accuracy, were good. The powder known as H 3.82, made especially for this gun, proved the best." Initial velocity was 1725.8 ft/sec, with pressure 18.3 tons per square inch.

"The 15 cm. gun…is constructed on the same principles as the 30.5 cm. gun… The dimensions…are as follows:

Weight:	4750 kg. (4 Tons 13 ½ cwt)
Total length:	5.22 m. (17 ft)
Bore length	4.8 m. (15 ft 9 in.)

"The projectiles are all the same weight of 51 kg. (112.44 lb.)…are as follows:

Steel AP Shell	3.35 calibers, burster 1.5 kg. (3.5 lb.)
Cast iron Shell	4 calibers, burster 3.4 kg. (7.5 lb.)
Steel Common Shell:	4 ½ calibers, burster 6.2 kg. (13.7 lb.)

"The results of firing were as follows: the bore was almost without scoring marks; highest result, charge 18 kg. (39.68 lb.), weight of projectile, 50.5 kg. (111.3 lb.), initial velocity 556.7 m/s (1826.6 ft/sec), pressure with Rodman instruments, 2585 atmospheres (16.95 tons), with English instruments, 2695 atmospheres (17.7 tons). The normal charge…is 17 kg. (37.5 lb.) with which the steel AP Shell…has an initial velocity of 538 m/s (1765.1 ft/sec). The mean pressure was about 2600 atmospheres (17.1 tons). The accuracy of the long projectiles was very good…" [October 6, 13 and 20, 1882].

"It is reported from Wilhelmshaven that on October 18th, firing took place to test the platform of a 28cm – 11.1 in. – gun of Krupp's mounted in Fort Heppens. At the second round the steel barrel of the gun burst… The charge was 58 kg. – 128 lb. – of [prismatic] powder, the largest employed in this gun. One fragment of the barrel, weighing about 1000 kg – 2205 lb. – flew to a distance of over 100 meters…"

This gun was an old type, possibly of the C/68 or C/72 pattern.

"At Shoeburyness, on Thursday, October 26th, a 6 in. new type gun – Mark II…that is a gun of 81cwt, firing a 100 lb. shot with a charge of 38 lb. of P2 powder – burst at about its 250th round, in front of the powder chamber. The breech is reported not to have been blown out, although fragments of the barrel were blown to a distance of 200 yards… The [Royal] Gun Factory gun has already been superseded by a pattern Mark III, weighing 2cwt more…" [November 3, 1882].

Necessity may have required the construction of compound breech-loaders even while the Ordnance Committee was deliberating on the best materials and method for construction, but the evidence suggests that these guns were no stronger or suitable to modern requirements than their muzzle-loading forebears.

Conclusion

On Friday, June 20th, 1884, Colonel Eardley Maitland, Superintendent of the Royal Gun Factory, Woolwich, delivered a paper entitled "The Heavy Guns of 1884" to the Royal United Service Institution. The full text and a commentary review may be found in The Engineer of June 27th.

"Any paper of Colonel Maitland's would command special attention, but several circumstances combine to give particular weight to this. Writing as Superintendent of the Royal Arsenal Gun Factory, with the Secretary of State for War in the chair, supported by the Surveyor-General of Ordnance and the Director of Artillery [and the First Lord and First Sea Lord of the Admiralty], Colonel Maitland's opinions are delivered *ex cathedra* in an unprecedented manner;

s9 much so, that we regard the reading of the paper thus as a bold move for the authorities to take, and one which is only justified by thorough confidence in their position.

"Colonel Maitland very handsomely acknowledged any good element taken from any system…" though conspicuous by their absence were Blakely and Vavasseur. In their review of the good Colonel's paper, The Engineer reacted to the oversight, and partially remedied it by noting, "…however, Vavasseur's name was not mentioned, we think it only fair to accord him credit for what appears was an important feature – indeed one which was mentioned as such by Colonel Maitland." And two years previously, the Colonel noted "the grand principle of shrinkage" and its important advantages at some length, which was the keystone of Blakely's ordnance.

J. Vavasseur and Company and the London Ordnance Works were primarily designers and builders of gun mounts, which were without doubt the best and most advanced of the time. Building guns was a secondary field of endeavor. From 1880 into early 1883, they were increasingly over-loaded with orders for gun mounts, as demand exceeded their production capacity, and crowded out design and construction of guns.

On February 27th, 1883, Josiah Vavasseur and Sir William Armstrong signed the documents which merged their companies. Vavasseur became a Director of the much larger business. In this capacity, he was in a position to greatly influence the design and construction of ordnance, and of course, gun mounts..Vavasseur's influence was immediate, as evidenced by the section images below.

The 6in M1881 of 26 calibers length was a typical Armstrong transitional compound breech-loader, with the breech mechanism attached to the inner steel tube. The diameter of this tube varied considerably throughout its length, 'reinforced' with wrought iron coils. As noted with earlier experimental breech-loaders, greater emphasis was placed on the strength of the steel tube, with the wrought iron covering less of the total length.

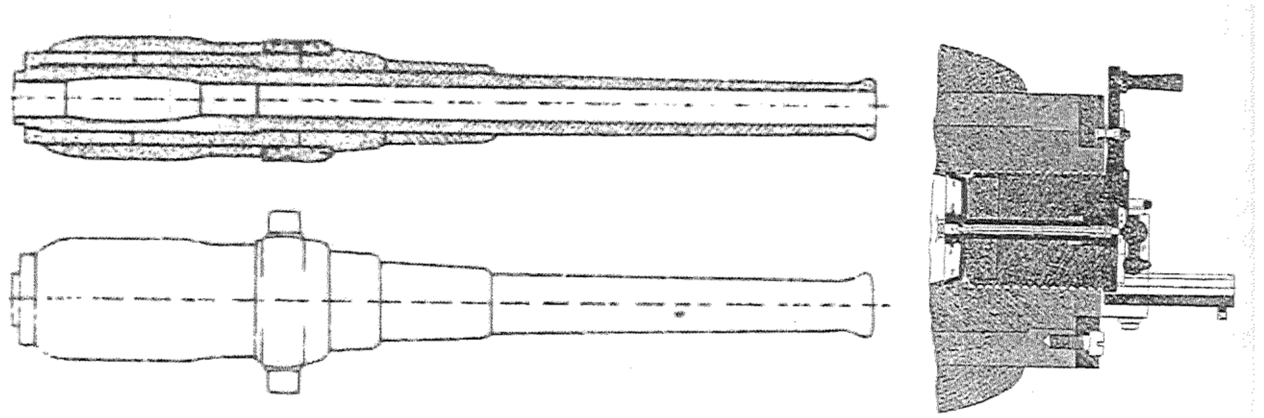

Fig 21. Armstrong 6in M1881

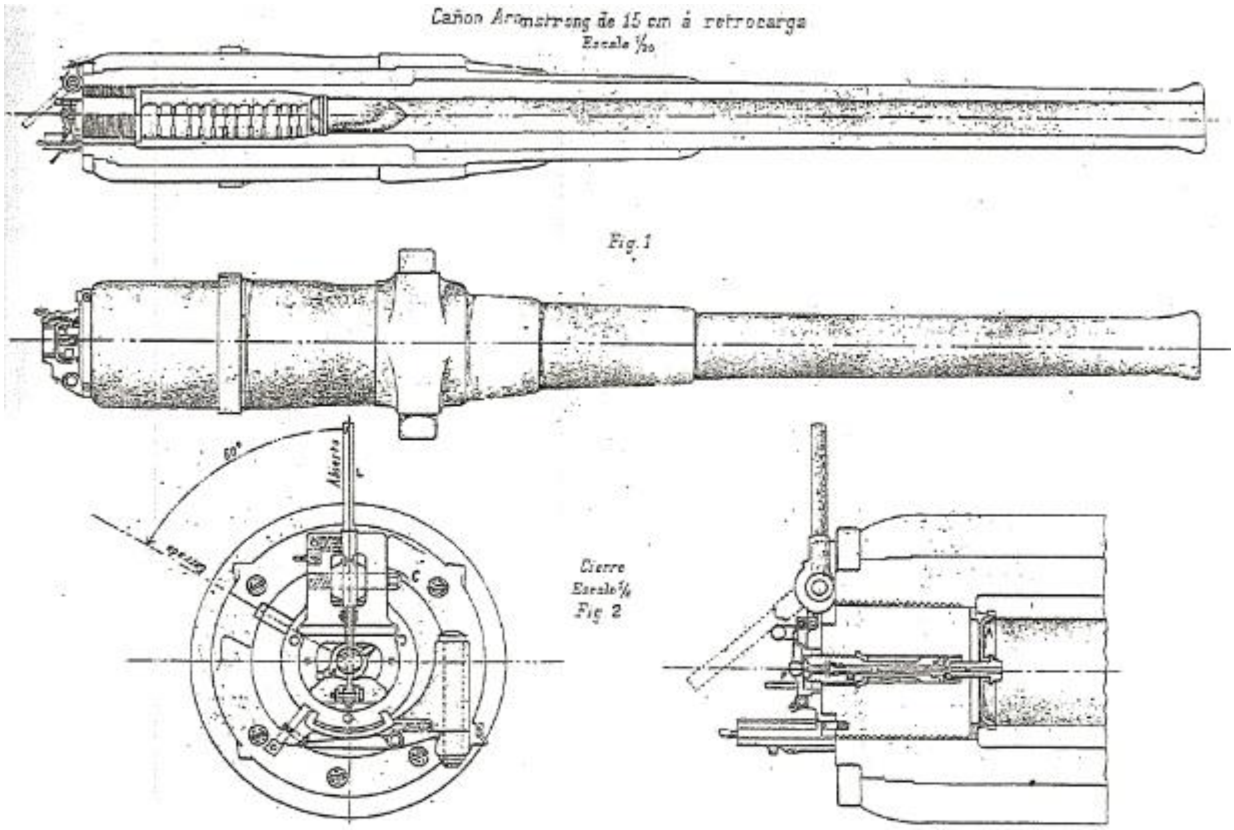

Fig 22. Armstrong 6in M1883

But the M1883 represents a major revision. The steel ‘A’ tube is generally thicker and of a more uniform diameter, though thinning under the steel jacket, and ending at the breech end of the powder chamber. The breech mechanism is attached to the jacket – or ‘B’ tube – which was shrunk on, and was also attached to the trunnion hoop, thus reducing longitudinal stress. This construction, not coincidently, compares remarkably well with the construction of Vavasseur’s 9in gun.

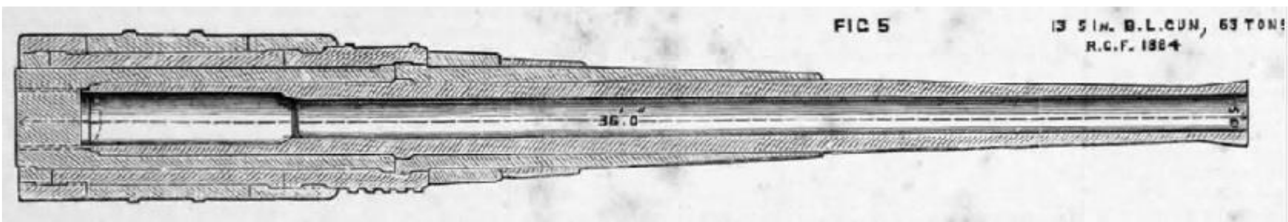

Fig 23. 13.5in design 1884

Not coincidently, this construction was adopted by Woolwich, as evidenced by the image of the 13.5in design Col. Maitland used as part of his presentation to RUSI.

Ultimately, there is an over-riding irony in the history of the twenty-five years which ended in early 1883. Both Armstrong and Woolwich began constructing ordnance utilizing the principles first developed by Captain Blakely, refined and evolved in both muzzle- and breech-loaders by Josiah Vavasseur, who received precious little credit for their advances in the art and science, yet whose contributions proved fundamental, invaluable, and correct.

Appendix F

Fraser System Construction

The Armstrong System of gun, as applied to muzzle-loaders, is illustrated by the image below. It consisted of a wrought iron coil as the inner, or ‘A,’ tube, open at both ends. This was closed by a wrought iron ‘cup’ or ‘shield’ (F) which ‘protected’ the solid breech piece (G), which in turn was screwed into coiled wrought iron jacket D, which extends forward to the muzzle. Over and beside this jacket are four wrought iron coils for further reinforcement, coil G being the trunnion coil. [Lines 'c – d' represent the fracture where the breech blew.] The gun was rifled on the Shunt system.

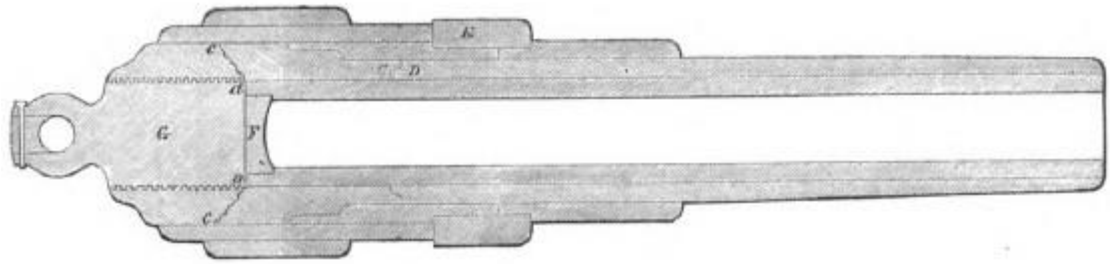

Fig 24. Armstrong 300pdr MLR

In April of 1863, when the 'divorce' between the Government and Sir William was concluded, both EOC and Woolwich were manufacturing the same guns to the same designs using the same materials and the same methods. Obviously, such a state of affairs could not stand for long, nor did it.

Mr. Fraser, then deputy-assistant-superintendent of the RGF, recognized that welds and 'blisters' were great weaknesses, and suggested that the quality of iron selected for forging the reinforcing hoops and jackets was actually too good; a somewhat lower quality iron that could be welded effectively and would not 'blister' would actually serve the purpose better.

At about the same time, Col. Campbell, realizing that the coiled inner tube was insufficiently strong and reliable, suggested that a certain type of iron, when cast, would be much stronger and reliable.

Both suggestions were taken up for experiments, and were successful. Implementation was immediate. EOC continued as before.

The next step, already mentioned, was the use of oil tempered steel for the 'A' tube. Fraser took that one step further by having the tube closed at the breech end, thus protecting the breech piece with steel instead of a 'cup' of wrought iron. EOC continued as before for several months before bowing to the inevitable.

The final step was to discard the jacket and many, labor intensive, coiled wrought iron hoops shrunk on at high heat to obtain initial tension. Fraser designed a system of mantles to fit over the 'A' tube. These were made of two layers of coiled wrought iron, each layer coiled in the opposite direction, and manufactured as individual 'pieces.' Fraser did not believe in initial tension, so did not shrink the outer layers on the inner layers. Rather, the four manufactured pieces ('A' tube, breech piece, mantle tube and chase – muzzle reinforce tube) were heated slightly and then assembled.

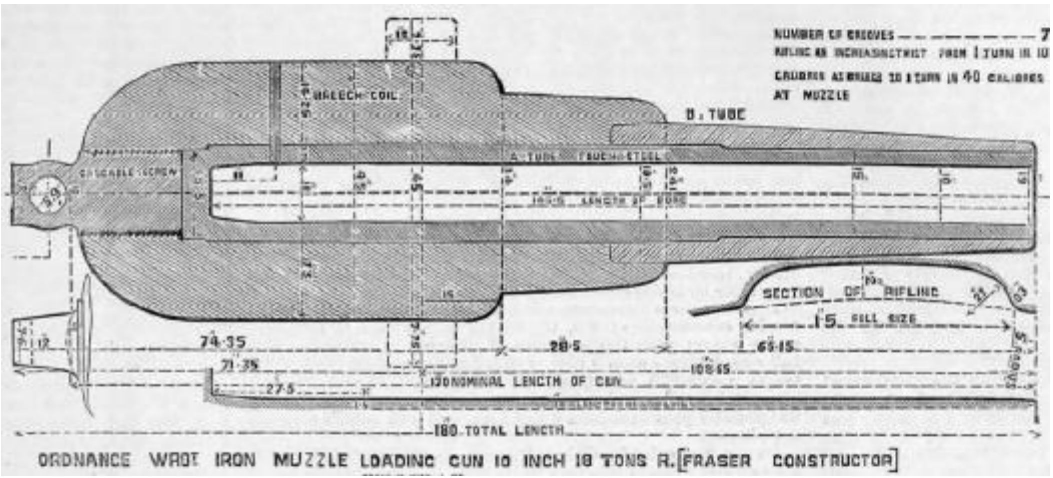

Fig 25. Fraser 10in MLR

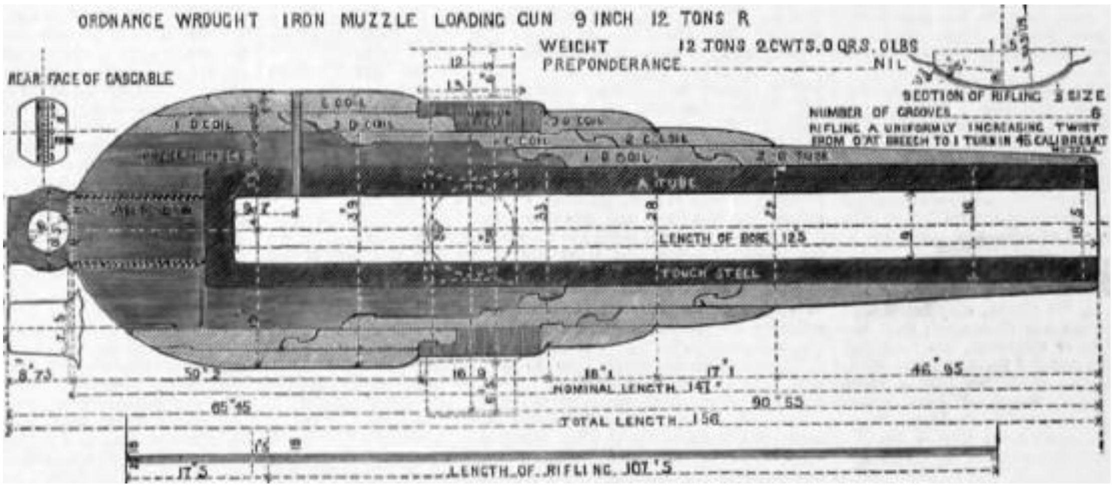

Fig 26. Armstrong 9in MLR

For purposes of comparison, an image of a contemporary Armstrong gun is included. Except for the steel 'A' tube, there is little difference between the 9in gun as displayed at the Paris Exhibition of 1867 and the 300pdr of 1862-3.

In the judgment of The Engineer Magazine, January 11, 1867, "That the guns of today are superior to those of a few years back only in two respects, they are able to stand heavier charges with certainty – in other words, they have more power of endurance – and they cost less money..."

Appendix G

On Rifling

Rifling is a hideously complex topic because of the number of factors involved and the necessity, and difficulty, of finding the best possible balance for effective shooting. Captain Lawrence L. Bruff of the Ordnance Department, U.S. Army, writing in 1896, gave an easily understood explanation if the concepts involved.

"If the [angle of the grooves] be constant for the whole length of the bore, the rifling or twist [expressed as a ratio of one revolution of the projectile in a certain length in calibers/diameters of the bore, eg. 1:30] is said to be uniform...The objection to uniform rifling is as follows:

"When the projectile starts from its seat, and during the first part of its path in the bore, the pressure of the powder-gas rises to its maximum, and the gun is subjected to the greatest stress at that time.

"With the uniform rifling, the angular velocity...is impressed upon the projectile at this time also. Hence, while the gun is subjected to its greatest stress, due to the starting of the projectile, it is also subjected to its greatest stress in giving rotation to the projectile.

"After rotation is once acquired, the stress due to this cause falls off very rapidly. Therefore, with the uniform rifling, both these stresses act together."

This is true as far as it goes, but there are two further considerations which must be considered. First, this combination of stresses takes place in the strongest area of the gun which, by design, is most capable of bearing the forces involved. And second, the amount of stress caused by the twist of the rifling is a controllable variable depending upon the resistance of the angle and the weight and length of the projectile involved. An 'easy' twist of, say 1:50, produces much less resistance, and hence stress, than 1:20. But to continue...

"If, however, the angular velocity...be imparted **gradually** to the projectile, it moves from its seat more readily and the strain on the gun **at first** is then diminished. When the powder [gas] pressures fall off along the bore, the twist...**gradually** increases, till it reaches its final value necessary to impart the angular velocity...to the projectile. In this case the stresses are more uniformly distributed along the bore, and the gun strained less at the **origin** of the motion, while the final velocity of rotation is the same.

"The twist in this case is called an increasing twist, as the [angle] increases **gradually** from the [seat]…To give steadiness of rotation to the projectile, the twist increases from the [seat] to a point about two calibers from the muzzle, and from this point to the muzzle is uniform."

"Studded Projectiles – This system was generally used for muzzle-loading projectile in Europe, and especially in England. The projectile was provided with studs made of soft metal, such as zinc or copper, to avoid wearing the lands of the rifling. These studs were arranged in two or three [rings] depending upon the length of the projectile, and at an inclination equal to the angle of the grooves. They were inserted into undercut holes in the projectile, and subjected to pressure, by which the soft metal was forced to fill the holes.

"The advantage of this system is that the projectiles are certain to take up the rifling motion.

"The disadvantages are:

1. The projectile must be adjusted to each particular twist; and if two guns have the same caliber but a different twist of rifling, different projectiles must be used for them.
2. **They cannot be used with an increasing twist.**
3. Owing to the relatively small number of studs, the pressure upon each is great, and they are liable to shear off. To avoid this they must be made stronger, and this necessitates increased depth and width of the rifling grooves, and a corresponding weakening of the gun.
4. The stud-holes in the projectile weaken the [body], and their irregular surface increases the resistance of the air to its motion.
5. Unless a gas-check is provided on the base of the projectile, the [windage will allow] the escape of the gas between the projectile and the bore erodes the latter.".

The original Armstrong shunt rifling used zinc 'ribs' along the projectile body, with zinc tabs to enter the grooves to provide the proper guidance for the projectile, and the twist was uniform. But in the 1963 Russian 8-inch gun trials, the zinc tabs proved too delicate for the large charges used, in spite of the uniform twist, and in at least one case caused the gun to burst in the chase nearing the muzzle. The Russians substituted copper buttons and centering buttons to prevent the shell shoulders from damaging the rifling. So the shunt projectiles were altered accordingly.

"It has been calculated by Captain A. Noble, late R.A., that the greatest pressure on the studs of a 10-inch gun, using a charge of 70 lbs, was reduced from 68 tons to 36 tons, by employing an increasing instead of a uniform twist. " This appealed to Sir William, so the shunt system was altered for increasing twist for Land Service 7in and all guns 8in and above. The grooves were widened in an attempt to accommodate the change in angle using the regular projectiles.

What Captain Noble and Sir William over-looked was the simple fact that MLRs, *per force*, have short bores in general, and the rifled portion 'distance traveled' from seat to muzzle is shorter still. To increase the twist from an easy 0:0 (no twist) or 1:100 or 1:90 down to 1:40 or 1:35 in a short distance under conditions of increasing acceleration is going to meet a lot of increasing resistance in the form of friction, and strain the gun to the chase approaching the muzzle where the stress tolerance is lower. There was nothing **gradual** given the amount of bore length available, and the 'steadying' final two calibers before the muzzle, it appears, were greatly reduced or dispensed with altogether. Mishaps caused by sheared studs, loss of 'centering,' weakened projectile bodies, premature shell bursts, jamming and various injuries to the bore would happen frequently.

Appendix H
Competitive Rifling Trials

In the autumn of 1864, the Select Committee on Ordnance initiated a comprehensive program of trials, designed by Mr. Anderson, assistant-superintendent at Woolwich, intended to determine the best form of rifling for service ordnance. After much sorting, the list of forms was reduced to four:

Commander Scott's well-known and extensively used centering system,

Lancaster's oval bore, with projectiles planed to fit mechanically,

Jeffrey – Britten's shallow-groove lead compression

The French *la Hitte* zinc button and rib

Conspicuous by their absence was Whitworth's hexagonal, Blakely's hook-slant, and Armstrong's shunt. This last, however, was eliminated early as its performance at 10-deg elevation proved inferior, producing a range of only 4050 yards, well short of the Lancaster, French and Scott rifling due to the resistance of the increasing twist, and inferior accuracy in general.

Identical guns were to be used, in this case the 7in 7 ½ Ton Land Service gun.

Identical standard charges of RLG were to be used 12 lb., 20 lb. Service Full, and 25 lb battering, and firing to be at identical elevations, 2-deg, 5-deg and 10-deg.

Identical garrison sliding carriages were to be used.

Projectiles were to be the standard 110 lbs.

The program consisted of twenty three steps;

1. Ten rounds for each charge, five with and five without lubricator, to establish initial velocities
2. One round with each charge at each elevation to establish a sighting mark
3. Guns to be laid directly on the mark, with no allowance for wind or deflection/drift, and fire ten rounds with 25 lb charges at 2=deg elevation.
4. Repeat for 5-deg elevation
5. Repeat for 10-deg elevation
6. Bores and vents to be carefully examined

7, 8, 9. Repeat with 20 lb charge

10. Bores and vents to be carefully examined

11, 12, 13. Repeat the practice at 2, 5 and 10-deg with 20 lb or 25 lb charges to confirm uniformity of range, afterwards carefully examine bores and vents

14. Practice as directed by the Committee
15. Ten rounds with shell and 25 lb charge at 10-deg elevation
16. Fifty rounds to test ease of loading, endurance, wear with 20 or 25 lb charges
17. Bores and vents to be carefully examined
18. Fifty rounds with solid cast iron ball
19. Bores and vents to be carefully examined
20. Repeat 16.
21. Bores and vents to be carefully examined
22. Practice at discretion of the Committee
23. Practice against armor confined to the guns preferred as a 'shot' gun (Table 9).

Table 9. Partial Results of Competitive Rifling Trials

Rifling	Charge weight, lbs	Projectile weight, lbs	Elevation, deg	Mean range, yards	Mean spread for range, yards	Mean deflection/drift, yards
Scott	25	110	2	1604,2	15,6	1,2
Lancaster	"	"	"	1589,8	28,8	2,0
Britten	"	"	"	1361,3	104,2	5,0
French	"	"	"	1499,8	52,4	2,0
Scott	"	"	10	4779,2	29,4	8,9
Lancaster	"	"	"	4605	26,6	6,6
French	"	"	"	4542,8	45,8	22,4
French	20	"	2	1386	35,4	0,6
Scott	"	"	"	1462	21,5	0,9
Lancaster	"	"	"	1455	27,3	1,9
Scott	"	"	5	2610,5	164,5	21,5
French	"	"	"	2429,5	237	27,5
Lancaster	"	"	"	2553	302	21,5
Scott	12	46,3	2	1331	328	23,0
French	"	"	"	1247	309	19,0
Lancaster	"	"	"	1147	221	19,5
Scott	20	"	0	1441	180	18,0
French	"	"	"	1351	1?6	13,5
Lancaster	"	"	"	1393,5	316	23,0
The Engineer						

Lancaster	25	110	2	1545	36	0,7
Scott	"	"	"	1604	15,6	2,4
French	"	"	"	1420	81,8	1,6
Lancaster	"	"	5	2803	32	2,7
Scott	"	"	"	2834	35,6	7,1
French	"	"	"	2788	41,8	4,9
Lancaster	"	"	10	4487	16,5	4,5
Scott	"	"	"	4779	31,4	8,9
French	"	"	"	4489	48,2	10,8
Lancaster	20	"	2	1380	34	2,1
Scott	"	"	"	1462	21,5	0,9
French	"	"	"	1386	35,4	0,7
Lancaster	"	"	5	2611	43	2,1
Scott	"	"	"	2741	44,7	3,3
French	"	"	"	2612	33,3	2,0
Lancaster	"	"	10	4353	54	9,2
Scott	"	"	"	4444	63,8	28,2
French	"	"	"	4210	46,2	14,6
Lancaster	12	"	2	1198	25,4	0,8
Scott	"	"	"	1213	21,4	0,8
French	"	"	"	1152	19,7	0,8
Lancaster	"	"	5	2287	57,2	1,2
Scott	"	"	"	2286	49,6	5,4
French	"	"	"	2219	54,5	2,8
Lancaster	"	"	10	3907	24,8	4,0
Scott	"	"	"	3909	109,8	40,7
French	"	"	"	3908	135,6	8,3
Lancaster	20	100	2	1433	33,7	4,2
Scott	"	"	"	1442	51,4	2,5
French	"	"	"	1348	127,3	7,5
Lancaster	"	"	5	2724	59,2	5,4
Scott	"	"	"	2630	45	1,6
French	"	"	"	2456	47,6	7,2

Rifling	Charge weight, lbs	Projectile weight, lbs	Elevation, deg	Mean range, yards	Mean spread for range, yards	Mean deflection/drift, yards
New Gun Modified'						
French	25	"	2	1446	19,9	2,0
French	"	"	5	2716	35,9	2,6
French	"	"	10	4573	23	6,3
French	20	"	2	1384	29,1	0,8
French	"	"	5	2640	27,4	3,3
French	"	"	10	4379	19,6	4,0

Private' Practice with sand filled shell

Rifling	Charge weight, lbs	Projectile weight, lbs	Elevation, deg	Mean range, yards
Lancaster	20	100	2 15'	1346
Scott	"	"	"	1380
French	"	"	"	1335
Lancaster	"	"	5 8'	2487
Scott	"	"	"	2557
French	"	"	"	2490

Lancaster	"	"	10 5'	4128
Scott	"	"	"	4119
French	"	"	"	4119

Final' Practise

Rifling	Charge weight, lbs	Projectile weight, lbs	Elevation, deg	Mean range, yards	Mean spread for range, yards	Mean deflection/drift, yards	MV	MV Ball
Scott	25	110	2	1585	17,7	3,7	1594	
French	"	"	"	1473	62,2	4,3	1529	
Scott	20	"	"	1473	18,1	3,7	1502	2162
French	"	"	"	1366	40,6	2,6	1444	2081
Scott	12	"	"	1213	19,7	0,8	1277	1827
French	"	"	"	1152	19,7	0,8	1254	1718

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Rifling Twist			Windage	Square in.
Lancaster	1:57.4	Uniform	Lancaster	2,955
Scott	1:42	Uniform	Scott	0,53
French	1:37	Increasing	Shunt	0,67
			French	1,36

Following the practice at 2-deg with a 25 lb. charge, it was determined that the lead at the base of the Jeffrey – Britten shot was unable to withstand the pressures of such a large charge, and it was withdrawn from the contest.

The soft zinc buttons of the 'French' projectiles also proved insufficiently strong to withstand large charges, and the gun was rendered unserviceable when the inner tube split. By all rights, that should have caused the rifling to be eliminated from the contest, as had the shunt and Jeffrey – Britten rifling had been. But the Committee exercised its authority under Article 23 of the program, and ordered a new supply of projectiles to be made, and a new gun. At the suggestion of Major Palliser, numerous 'gun-metal' (bronze) studs, arranged on Scott's 'self-centering' principles, replaced the zinc buttons, and the shot were finely turned rather than rough cast as were the other shot. This 'revised' projectile fired with great precision in subsequent trials. This should not have been allowed, let alone condoned, as the 'revision' materially, mechanically and philosophically altered the nature of the projectile and its relation to the grooves and rifling, and demonstrated a bias.

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Лебединая песня: Блекли, Брук и Вавассер. Часть 2

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Аннотация. Десятилетия 1860-х и 1870-х гг. характеризовались одной из самых глубоких технических революций, которые когда-либо видел мир, которая была охарактеризована как «Вторая промышленная революция». Эта революция затронула военно-морские силы мира не меньше, чем любого человека. В области боеприпасов железную гладкоствольную пушку, стрелявшую сферическими ядрами, заменила нарезная пушка. Первоначально для того, чтобы стрелять с большей точностью, она имела удлиненный взрывающийся снаряд, но вскоре для того, чтобы пробить броневую плиту, появился и удлиненный цельный выстрел. История этого периода упоминает многих конструкторов и/или производителей Великих Пушек. Но все-таки работа некоторых людей оказалась упущенной из виду.

Предлагаемая публикация, это продолжение истории капитана А.Т. Блейкли, исследуется также работа Джона Мерсера Брука, лицензиата, и его преемника Джозефа Вавассера. В контексте исследуется также вопрос постепенного отказа от использования системой Армстронга кованого железа и принятия стальных орудий британским правительством.

Ключевые слова: военно-морской, артиллерия, Блекли, орудие.

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