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PRISMATIC
POWDER
MOLD


WASC 257

Technological change – pellet, pebble, prismatic, and brown powders

Profound changes beyond those of scale affected gunpowder production at Waltham Abbey RGPF in the second half of the nineteenth century. They are to do with the finished form in which gunpowder was produced, and the search for efficient combustion of charges for weapons of increasingly large calibre.

The technology of combustion – an international problem

In order to understand the significance of the development of different forms of powder it is necessary to unravel the complex technological background against which they were set. It is an international story, and serves to emphasise the role played by Waltham Abbey RGPF in the development of gunpowder technology and its importance in maintaining Britain's position as a great power.

As the principal supplier to the Services, Waltham Abbey RGPF produced a very narrow range of powders, in contrast to other government contractors who were also supplying blasting and sporting powders. In the mid-nineteenth century there was a range of grain sizes in Service use, the finer grains for muskets and rifles and the larger grains in cannons and mortars.[22] During the Crimean War the sole output of the RGPF was cannon powder, whose quality enjoyed a world-wide reputation.[23] On his visit to European gunpowder mills in 1858, Lammot du Pont made particular efforts to gain access to Waltham Abbey RGPF, 'where they manufacture nothing but cannon powder.'[24] He took away a sample of the new large-grained powder developed for use in Mallet's 36in (0.91m) calibre mortar, which he had watched undergoing trials at Woolwich.[25]

The difficulty of devising a suitable powder for large mortars and guns of ever-increasing calibres faced the powdermakers in all the state arsenals of Europe and America.

As charge sizes increased, two basic problems were presented to the powdermakers. First, if a large charge was ignited in the breech of the gun it could literally blow the gun to pieces. Secondly and conversely, complete combustion of a large charge of tightly packed powder might fail to occur if the igniting flame was not carried to the centre of the charge, thereby leaving some of the charge to be blown from the barrel unconsumed. The way in which the problem was addressed was to control the area of the burning surface, that is, the surface area of a grain of gunpowder in relation to its mass. Empiric knowledge had always favoured larger grain sizes for cannon powders. A scientific understanding of how a propellant burns was provided by the French scientist Guillaume Piobert; his law formulated in 1839 recognised that the burning surface of a discrete piece of explosive recedes in consecutive layers, comparable to those of an onion.[26]

Towards the end of the 1860s, with the adoption of Armstrong's breech loading guns, it became standard practice also to glaze the large grains with graphite to inhibit combustion.[27] How the powder was packed within a charge was also important in ensuring that enough interstices remained between the grains for the flame to pass almost instantaneously through the whole charge. The aim was to assure an increasing evolution of gases as the projectile travelled up the barrel of a gun, so that it reached its maximum velocity as it left the gun, while exerting the least pressure on the barrel.

It has been argued that Lammot du Pont's tour of Waltham Abbey RGPF and associated discussions may have sown the seeds of ideas that led to the development of his 'mammoth powder'.[28] In America, du Pont renewed his collaboration with Captain Thomas J Rodman, a soldier-technologist with the United States Ordnance Bureau. Rodman saw his research into large, 15in (0.38m), coastal and other large calibre guns as the study of an integrated system comprising the gun, the projectile, and the propellant. He conducted experiments in the 1850s to reduce the pressure exerted on the barrel by using circular, perforated cake cartridges of gunpowder of the same calibre as the gun. He found that such discs presented a minimum burning surface at the beginning of combustion, which increased as the holes enlarged with combustion and produced a greater amount of gas. Rodman's co-worker General Doremus later proposed large pellets of prismatic form, known as hexagonal cake cartridges, each perforated with cylindrical holes.[29] Elsewhere, Paoli di san Roberto experimented with compressed cartridges as early as 1852, by utilising the low melting point of the sulphur to bind the grains together. In other countries solutions such as sugar or gum arabic were employed to produce cartridges for use in large guns, while the Italians devised 'Fossano powder' or *poudre progressif*, which was regarded as extremely efficient.[30]

A parallel development, first introduced by the Belgians, was pellet powders, cylindrical in shape, 5/8in (20mm) in diameter and height, and with a slight hollow or indentation in their upper surface.[31]

The technology of production

Pellet powders

In 1858 a committee was set up at Waltham Abbey RGPF under the then Superintendent, Colonel W H Askwith, to investigate the problems of suitable powders for large calibre guns.[32] The discs or cakes produced by Doremus were evaluated but the results were irregular and unsatisfactory and this line of research was abandoned.[33] Instead, this committee advocated the use of pellet powders for large guns, and its final report in 1866 recommended systematic and extensive experiments with that form. Small-scale production was started with an experimental hydraulic press, constructed at the Royal Laboratory at Woolwich. Meanwhile, a new explosives committee under the new Superintendent, Colonel C W Younghusband, continued to deliberate over the rival merits. In May of 1869 Younghusband visited the state factories at Spandau in Prussia and Wetteren in Belgium to study machinery in use for pressed powders. He saw no advantage in adopting prisms rather than pellets; cylindrical pellets were chosen for the practical reason that they were regarded as being easier to press. Spurred on by the progress made by the continental powers, plans for a new engine and hydraulic accumulator house to serve the pellet press to be erected at Waltham Abbey RGPF were ready by December 1869 (Fig 3.19). A larger press than the one currently in use at the Royal Arsenal Woolwich was designed by John Anderson, Inspector of Machinery, and was installed and operational at Waltham Abbey RGPF by 1870.[34]

Even while these new facilities for manufacturing pellet powder were being installed, the explosives committee decided that the simpler form of pebble powders were to be adopted for use in large calibre guns. Whether through an administrative or a technical volte-face, pellet powders were apparently manufactured for less than two years at Waltham Abbey RGPF. This explains the conversion of the newly built pellet powder house (L149) into the Group E T-shaped incorporating mill in 1877–8. In 1870–1, 1451lb (658.17kg) of pellet powders were supplied to the magazines at Purfleet; in the following year only 370lb (167.83kg). Additional supplies of pellet powders may have been acquired from Curtis's and Harvey, who were manufacturing it by late 1869, but an enquiry to the magazines at Purfleet in 1881 revealed that no pellet powder was in stock.[35] Unsuccessful experiments were also conducted with pressed powder of a similar size but with hemispherical ends and a flat central band.

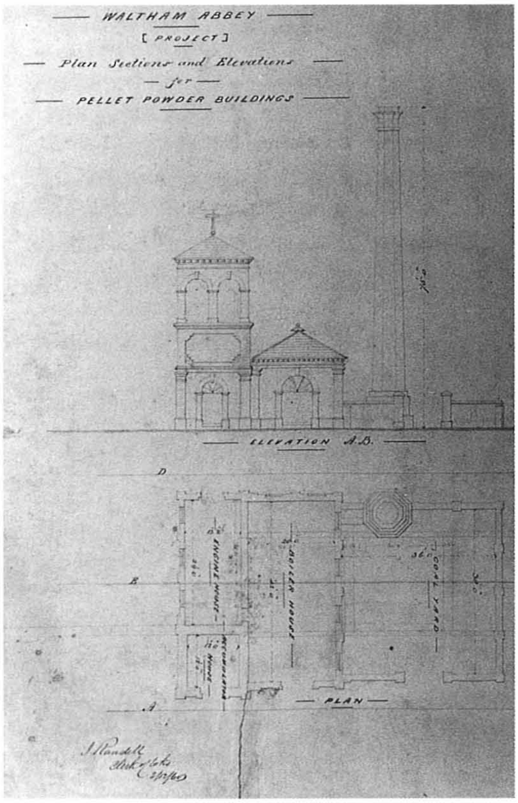


Figure 3.19 (left) RGPF Waltham Abbey. Design drawing for a Boiler, Engine and Accumulator House to serve a Pellet Powder Press, 1869; drawn up under the supervision of I Randell, Clerk of Works at the Royal Gunpowder Factory. (BB92/26360; © MoD)

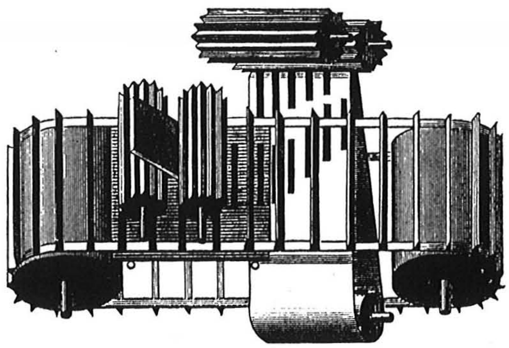


Figure 3.20 (top right) Morgan's Pebble Powder Cutter, 1872. (Guttmann 1895, 244)

Figure 3.21 (bottom right) Models of pebble powder. (WASC 263)

Pebble powders

Pebble powders at their simplest were little more than lumps of gunpowder cake. The earliest and simplest way of forming them was by breaking press cake with copper hammers and passing the broken pieces through sieves of the required size. In 1870 a system was introduced at Waltham Abbey RGPF whereby the square slabs of press cake were cut into strips and then into cubes with a copper knife. Using this method, it was estimated that a man could produce 150lb (68.04kg) of pebble powder per day. This process was improved on by a system, introduced by the Assistant Superintendent, Captain Smith, where a series of knives were arranged around a roller and cut a number of strips simultaneously. Smith's successor, Major S P Morgan, had by 1872 invented a machine consisting of two pairs of phosphor bronze rollers that first cut the powder into strips and then into cubes (Fig 3.20).[36] Pebble powders were classified as Class B or 'cut' powders, sometimes referred to as 'cubical' powders (Fig 3.21). Different sizes were experimented with, related to the calibre of the gun, and were assigned identification codes – 'P' powders were ⁵/₈in (20mm) cubes, while 'P2' powders were cubes of between 1–2in (30–50mm). The larger 'P2' types were hand cut, using a hinged blade similar in form to an old-fashioned paper guillotine.[37] After cutting the cubes were placed in glazing machines to remove their sharp edges, which might flake during transit.

Prismatic powders

In the wake of the Civil War in America there was little desire to engage in costly military research. The initiative in exploiting Rodman's important innovations passed to the Old World. A Russian military commission visited America during the Civil War and was introduced to Rodman's compressed powders. By 1866 Professor Wischingratzki had developed a cam press for manufacturing prismatic powder at the Russian state factory at Okhtinsky near St Petersburg. Subsequent trials at the Krupps' factory alerted the Prussians to this new type of powder, and after further trials in 1868 at the Tegeler range near Berlin confirmed the improved ballistic results that could be obtained from prismatic powder, it was adopted for use by the Prussian artillery.

Like pebble powder, prismatic powder varied in size according to the calibre of the piece it was to be used in or according to contemporary thinking on the optimum size. By the late 1870s a typical hexagonal prism might measure 40mm from corner to corner. It stood 25mm high and was pierced by a single central channel, 9.5mm in diameter at its base and 9mm at its summit (Fig 3.22). In the older forms it was pierced by seven holes, each 4.7mm in diameter at its base and 4.2mm at its summit. Large charges could be assembled by carefully packing the prisms so that the holes lined up with one another, ensuring the flame travelled in a consistent manner through the charge. This would not occur in a loosely packed charge. It was also found that all of the charge was consumed, whereas in pebble powders a large percentage would be blown out of the gun unconsumed. With their large initial burning surface, pebble powders created an initial violent jolt to the projectile, but subsequently a smaller burning surface reduced the available gas with an attendant fall in pressure; the converse was true with prismatic powders.[38]

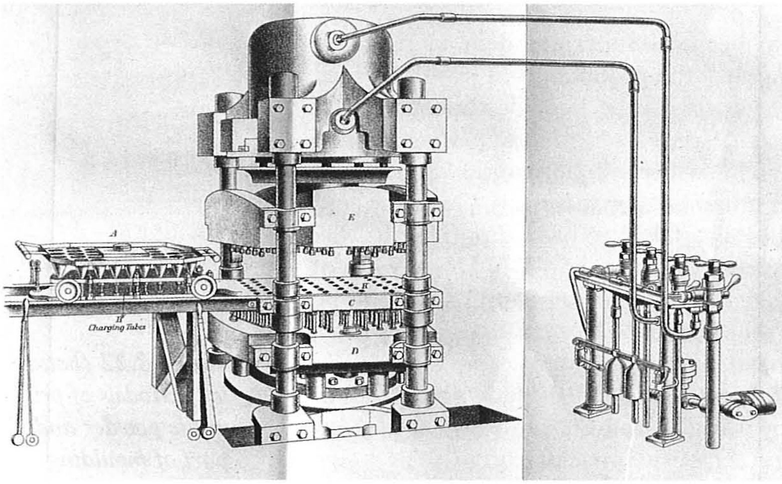
Britain persevered with pebble powders. In a major rebuilding campaign at Waltham Abbey RGPF in the late 1870s, nothing suggested an imminent intention to introduce prismatic powders. The extra capacity acquired at this time was entirely consistent with increased demands for pebble powders, including, for example, the construction of an additional drying stove (see Fig 3.60) to cope with the longer drying times required by pebble powders. But the explosives committee, now under the presidency of Colonel W H Noble (later to become Superintendent of Waltham Abbey RGPF), was set the task of enquiring into 'the production of powder which shall develop the maximum power of heavy guns with the least detriment to their endurance' and was clearly convinced by the widespread adoption of prismatic powders by the continental powers that Britain ought swiftly to follow suit.39 Samples of prismatic powders were requested from continental producers in Germany and Belgium, including Otto Heusser of Roensahl Pulverfabriken near Wipperfurth, Max von Duttenhofer of Rottweil Pulverfabriken near Hamburg, and F N Heidemann of Vereingte Rheinische-Westphalische Pulverfabriken at Cologne. Samples were to be delivered to the government magazines at Purfleet. In 1879 Colonel Hay, Superintendent at Waltham Abbey RGPF, also visited the factories at Wetteren in Belgium and Roensahl, Cologne, and Spandau in Germany. Prismatic powder manufactured in England by Curtis's and Harvey was also delivered to Purfleet for testing.[40] In 1885 they installed 'very heavy and expensive machinery' in their Leigh Mills at Tonbridge in Kent to manufacture government prismatic powder.[41]

Initially large quantities of prismatic powder were imported from Germany and this probably was the cause of the six-fold increase in the amount of powder imported between 1884 and 1885.[42] It became vitally important that Waltham Abbey RGPF should have the capability to manufacture prismatic powder, both as a producer and to provide government contractors with a specification and samples by which to judge their powders. In 1881 Duttenhofer and Heidemann were asked to undertake the manufacture of prismatic powder at Waltham Abbey RGPF for instructional purposes.[43] By 1882 new construction work and adaptation of pre-existing buildings show that preparations were being made to manufacture prismatic powder at Waltham Abbey RGPF. This work included construction of a wooden moulding house surrounded by a mass concrete traverse (Fig 3.23). This was perhaps in itself an experimental design, as another moulding house of this date was surrounded by a more conventional brick and earthwork traverse. It was probably also at this time that a press house constructed in 1879 (Fig 3.34) was converted to a moulding house.

Two types of press were adopted at Waltham Abbey RGPF to produce prismatic powders, hydraulic and cam presses. Those on the northern part of the RGPF were hydraulically operated and powered by the centralised hydraulic system. A variety of moulding machines were installed including one manufactured by Taylor and Challen of Birmingham, who had supplied a similar machine to China in the 1870s, and another by an unidentified manufacturer (Fig 3.24).[44] These machines moulded 64 prisms in one pressing, forming the perforations in the prisms by phosphor bronze rods which passed through the lower plunger. The cycle of charging, pressing, and unloading took about two minutes. The complexity of this press illustrates another factor in the advance of powder technology, namely a greater precision in machinery design as iron and steel replaced timber in their construction.

Figure 3.22 (bottom left) Models of prismatic powder and part of moulding machine. The annular ring on one prism distinguishes EXE prismatic and the circular hollow SBC prismatic. (WASC 257)

Figure 3.23 (bottom right) RGPF Waltham Abbey. Mass concrete traverse formerly enclosing two free-standing timber-framed gunpowder moulding houses. That on the left dates from 1882; the less well finished right-hand bay with its timber shuttering still visible was added in 1884. (BB92/26220)



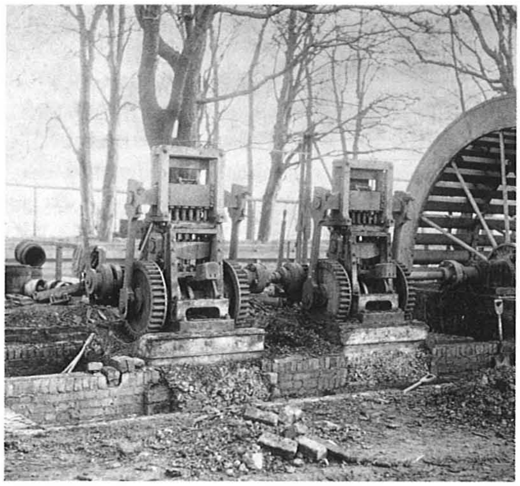


Figure 3.24 (left) Hydraulic prismatic powder moulding machine. From Wardell 1888. (BB94/8014)

Figure 3.25 (right) RGPF Waltham Abbey. Cam presses photographed after an explosion on 13 December 1893 in which nine men lost their lives. (BB94/8012; © MoD)

Cam presses for moulding prisms were first installed at Waltham Abbey RGPF in 1887. Compression in this type of machine was applied by means of a cam or eccentric on a shaft driven by water or steam power (Fig 3.25). This was similar to that devised by Professor Wischingratzki in Russia and had been widely used in continental factories since the mid-1860s. Such presses worked automatically, and very rapidly, pressing six prisms at a time. It was claimed that they produced a superior prismatic powder, because the eccentric generated an enormous pressure in a very short space of time. The resulting prisms displayed a very hard, smooth finish, which had the practical effect of reducing the initial pressure on ignition compared to prisms with a rougher finish from hydraulic presses.[45] Elsewhere in Britain cam presses were little used. Enquiries by the Explosives Inspectorate after an explosion in 1893 at Waltham Abbey RGPF revealed that only six manufacturers were using them, in three cases for pressing mining cartridges. John Hall and Son reported that they had been the first to use the principle about 20 years earlier at their Oare Works at Faversham; the works at Chilworth had been using four since 1886. Curtis's and Harvey at Hounslow, after investing £2000–£3000 in 1890 on two cam presses, considered them too dangerous to operate and abandoned them shortly afterwards.[46]

Brown powders

The early prismatic powders manufactured in England in the early 1880s used traditional black powder to form the prisms. The leading German manufacturers J N Heidemann and Max Duttenhofer, in seeking to mitigate the effects of large explosive charges on the breech mechanism of the guns, altered the composition of the gunpowder used in the prisms by substituting lightly carbonised rye straw for traditional wood charcoal. The resulting powder was termed brown or 'cocoa' powder from its reddish brown hue. In addition to securing a slower evolution of gases, a further important characteristic of brown powder was that it produced little smoke, which dispersed very quickly. This was a significant military benefit for the comparatively large quick-firing guns and machine guns that were being introduced specifically to combat small and swift-moving motor torpedo boats. The new slower burning powders were themselves also a factor in a return to breech-loading guns in British service in the 1880s.

The British Government was aware of these developments from 1882 and the Superintendent of RGPF secured details of manufacture on condition of secrecy.[47]

In 1884 trials took place with brown powder supplied to the British government by the Rottweil and Rheinische-Westphalische factories. It was reported early in 1885 that the Russians were also experimenting with brown powders supplied from Germany, and full-scale manufacture of brown prismatic powders began at Waltham Abbey RGPF later in 1885.[48]

No major changes of buildings or layout at the RGPF accompanied this important development. Ensuring an adequate supply of rye straw was a considerable concern. Throughout the summer of 1885 advertisements were placed in the agricultural press. One in *The Field* in July of 1885 asked 'which are the largest rye growing districts near London, and in which towns could information be obtained as to supply and cultivation, also any names of local persons or officials to whom inquiries might be addressed, also foreign sources of supply?'. The enquiry was hidden under a cloak of secrecy by the signature 'SALIX', no doubt a witty allusion on the part of the Superintendent to the fact that willow had previously been the preferred source of charcoal for large calibre guns.[49] This may have been an attempt to conceal Britain's interest in brown powders from rival powers, although it was common knowledge in Germany and indeed some rye straw was imported through Rotterdam. Alternatively, it may have been a commercial ploy to prevent a sharp rise in the price of rye straw. In 1886 the specification for formal government acceptance of prismatic brown powder stated that the prisms should be 24.8mm in height with a hole 10mm in diameter. The proportions for the ingredients were also varied so that it contained 79 parts saltpetre, 3 parts sulphur, and 18 parts charcoal. Special forms known as EXE and SBC, distinguished by an annular ring and a circular hollow, were manufactured using mixtures of carbonaceous substances that at the time were not divulged (Fig 3.22).[50]

The development and manufacture of brown prismatic powders brought some additional requirements for hydraulic pressing. Yet this represented the final evolutionary form of gunpowder technology as applied to propellants. Despite the advantages of significantly reduced strain on the breech of a gun and reduced smoke that brown powders had brought, gunpowder was now an outmoded technology. The technological breakthrough made with chemical explosives within the next decade would almost replace gunpowder as a source of propulsive energy (see Chapter 5).