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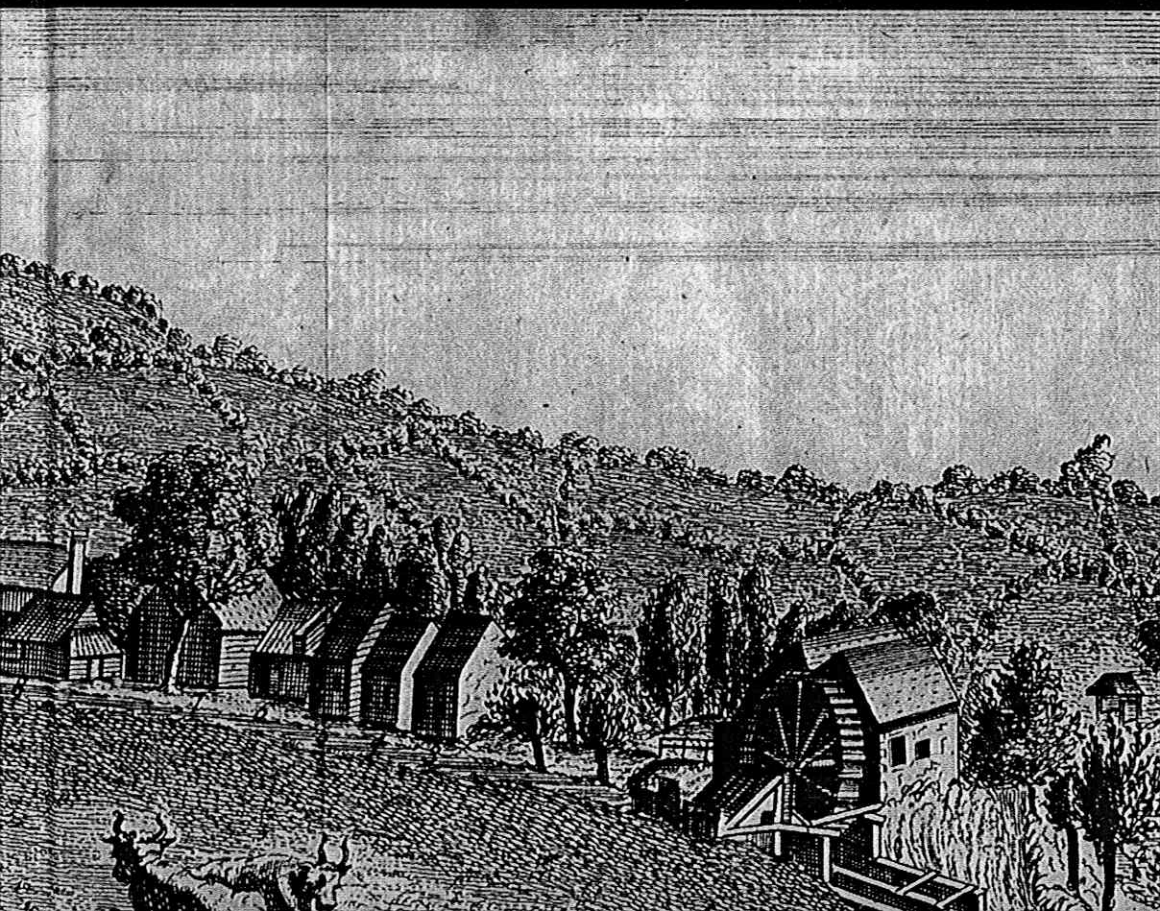
A Technological History

Edited by

Brenda J. Buchanan



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Chapter 6

The Barcarena Gunpowder Factory: Its History and Technological Evolution between the Seventeenth and Twentieth Centuries

António C. Quintela, João Luís Cardoso
and José Manuel de Mascarenhas

Introduction

There is documentary evidence of the use of gunpowder in Portugal since the reign of King Fernando (1367–83), and references to gunpowder makers are known from the middle of the fifteenth century. The Barcarena gunpowder works stand out among the primitive ones being built at the beginning of the seventeenth century. With overseas expansion their importance increased, although other factories were installed in the Portuguese overseas territories, especially in India and Brazil.

The technological evolution of the Barcarena gunpowder factory is here presented with special reference to the enormous works built by António Cremer (1729) and to the innovations introduced there by Bartolomeu da Costa at the end of the eighteenth century. The additions made later to the gunpowder factory and the use of new sources of energy are also mentioned – steam as well as hydroelectric and diesel engine power. The factory closed down in 1988 and in 1998 the Barcarena Gunpowder Museum was opened, the conception and constitution of which are described later.

The Manufacture and Use of Gunpowder in Portugal and the Overseas Territories

It is probable that gunpowder manufacturing techniques were introduced in the Iberian Peninsula by the Arabs, and that this mixture was used there for incendiary purposes during the thirteenth century or even earlier. The first

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mention of the use of pyroballistic weapons in Portugal was in 1381, towards the end of the reign of King Fernando I.[1] When Lisbon was besieged in 1384 these were surely used, although it is doubtful that they were employed in the Aljubarrota battle in 1385 since there is no reference to these weapons in the material seized then.[2] The first *factories* must have appeared at that time, but they may not have been more than small workshops or handicraft units.

The first known mention of gunpowder makers belongs to the reign of King Afonso V (1438–81), as well as the first provisions for storing gunpowder.[3] Letters from the king dated 1442 and 1443 refer to the gunpowder and saltpetre master Affonso Vasques, and another of 1466 authorizes the gunner Balthazar to look for saltpetre. The first prohibitions regarding the keeping of gunpowder in city houses and warehouses also go back to the time of this king. In his letter of 1470, reference is made for the first time to the Gunpowder Tower, as the place of compulsory storage for explosives.

Tapestries discovered in 1915 in the Spanish locality of Pastrana, representing the seizure of Arzila (Marrocco) in 1471, make a most important iconographic contribution to the understanding of the artillery used at the time of King Afonso V. On the tapestry representing the attack, eight cannons (two of which are geminate) can be observed along the perimeter walls, which are breached in front of those pieces. With the exception of a *collobreta* in bronze these are iron cannons, with the majority showing a *mantelete* (tilting wooden shield) for the gunners' protection. No armour was worn from the elbow to the hand, in order to increase freedom of movement and avoid that friction which causes sparks.[4] A gunner who is about to fire the piece appears to wear leather sleeves up to his elbows.

In the reign of King John II (1481–95) at least three masters of gunpowder making are known. The level of development of gunpowder production reached in this reign is described by André de Resende in a significant episode in *King John's Chronicle* (chapter LXII). In 1486, during the seige of Malaga, a port city of the kingdom of Granada, the Christian army ran short of gunpowder and the Catholic king and queen, Fernando and Isabel, addressed a request to King John II. He immediately sent a caravel with a great quantity of gunpowder and saltpetre to the fighting area, free of charge.[5]

The first gunpowder factories referred to in documents belong to the reign of King Manuel I (1495–1521). They were located in Portas da Cruz, the most eastern door of the old wall of Lisbon in the King Fernando period. Since gunpowder manufacture and the preparation of fireworks were then the responsibility of individuals called gunpowder makers and fire craftsmen, and since the artillerists also had to know this work, it is probable that other small manufacturing handicraft units also existed.

With the expansion overseas, gunpowder makers installed manufacturing units in several parts of the empire, with most of the documentary references coming from the reign of King John III (1521–57) and later periods. In the

first half of the sixteenth century there were known units in India: in Goa (Terreiro do Paço and Divar Island), Chaul and Bassein. In Brazil the first manufacturing units were most probably established in the main captaincies during the sixteenth century, although information is very scarce. At the end of that century there is news of Manuel de Padilha, master of saltpetre in Salvador da Baía and probably also gunpowder maker. The workshop of António Luis Santa Cruz, appointed master of gunpowder of the state of Brazil in 1613, was surely situated in Baía. On the Terceira Island (Azores), there was a gunpowder factory from the middle of the sixteenth century, and it is known that Mice Torres was one of its masters of gunpowder making. For a short time there was a unit in Ceuta.

At the beginning of the seventeenth century the quantity produced was far from meeting requirements, so other gunpowder factories were installed in the Portuguese overseas territories of Ormuz and Macao.[6] An important factory was built at the expense of the national treasury near Goa, in Panelim, during the government of Viceroy D. Francisco da Gama. It was finished in 1630 by Viceroy D. Miguel de Noronha, Count of Linhares. The output of this factory supplied satisfactorily all the Portuguese fortresses of eastern Africa and Asia as well as meeting private requirements. There is also information regarding seventeenth-century gunpowder works in Brazil, established in Salvador da Baía and Rio de Janeiro with António Matheus and Manuel Matheus, respectively, as gunpowder makers. Also in this period, a gunpowder works is known to have been installed in Angola between 1680 and 1694 by captain-engineer Luiz Mendes Henriques.[7]

From 1640, in the reign of King John IV (1640–56) who protected the gunpowder makers' activities, requirements increased abruptly due to the Restoration War. At that time there were several factories in Lisbon, which brought danger to the houses nearby and kept the inhabitants in constant fear. At least six factories are known to have been active in the city, working more than eleven mills, and there were three factories in the outskirts with over six mills, excluding Barcarena.[8] Among the Lisbon gunpowder makers of this period, Simão Matheus received a royal privilege in 1654 for having invented a type of mill driven by wind power. The mill house was fixed and the mill had a movable cap with four sails. This master also set up in 1650 a manufacturing unit in the city of Elvas, near the main theatre of operations of war against Spain. As a result of the risk that gunpowder workshops represented in Lisbon, the gunpowder makers began to transfer them out of the city, to the Barcarena area in particular. In 1681 a contract was signed between the state and the gunpowder maker Carlos de Sousa Azevedo, whereby a monopoly was established for gunpowder manufacture that led to the extinction of all the remaining private units except for the illegal ones.

Gunpowder towers are known to have existed in the city area of Lisbon. One of the oldest, near the factory of Portas da Cruz, is represented on a

design of the sixteenth century held in the Leiden University Library. This tower still existed in the seventeenth century, causing security problems in the area. In the last quarter of that century the tower of Lapa da Moura (Pampulha) was built. At the beginning of the eighteenth century an important tower was built in Beirolas. In 1748 that of Braço de Prata (Val Formozo) was constructed, and it is known that another tower existed in Pimenteira. Of special importance during the eighteenth century were the great works accomplished by António Cremer in the factories of Barcarena and Alcântara. But those of Conde de Villa-Nova and of Cartaxo did not flourish at this time, and of the factory of Salvador da Baía, the location and architecture are known from iconographic documents. It should be emphasized that between 1778 and 1807 the sale of gunpowder was undoubtedly a source of wealth for the Portuguese state.[9]

In the nineteenth century particular reference should be made to the creation in 1808 of the gunpowder factory of Rodrigo de Freitas Lagoon, in the suburbs of Rio de Janeiro. Its establishment was related to the transfer of the Portuguese crown to Brazil in October 1807, due to the invasion of Portugal by the army of Napoleon and the consequent French occupation of the Barcarena factory. The urgent need for gunpowder in many Portuguese overseas territories made Prince Regent John take this decision. He appointed Brigadier Carlos António Napion, who had been manager of the Barcarena and Alcântara factories, to execute the project. When the French armies withdrew, a royal letter dated 1811 indicated which overseas territories were to be supplied by the Barcarena and which by the Rio factories. The result was that the market for gunpowder produced in Barcarena was considerably reduced.

The Barcarena Gunpowder Factory from Its Origins until 1725

On the initiative of King John II a swordblade and firearms factory, 'the King's Smithy', was founded on the banks of the Barcarena stream in the later fifteenth century. It remained in operation until the end of the seventeenth century. As recent research has shown, the first gunpowder factory in Barcarena was built in the time of King Philip II (1598–1621, also Philip III of Spain), during the government of Viceroy Diogo da Silva Mendonça, Marquis of Alenquer.[10] Evidence from a codex in the National Library in Lisbon shows that the factory was constructed under the direction of the Italian architect Leonardo Turriano.[11] This fact was noted in a book by Manuel Severim de Faria, edited in 1655.[12] The four gunpowder mills were finished in 1618. Each had an edge runner that moved on a bed round a vertical shaft, driven by an overshot wheel (Figure 6.1),[13] a technical solution similar to that adopted later by António Cremer. The factory suffered several explosions, and in 1639 only one mill was at work, crushing the components of gunpowder.[14]

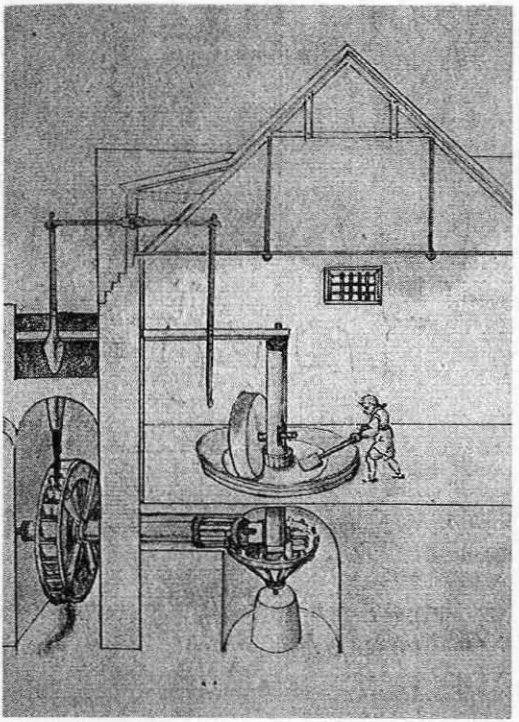

Figure 6.1 Leonardo Turriano's design for the gunpowder factory at Barcarena, 1622 (Codex 12892, Biblioteca Nacional, Lisbon).

The installation of the Barcarena gunpowder factory near a water course had the advantage of allowing the use of hydraulic power to drive the mills and later other equipment such as sieves and glazing machines. Although as noted the mills were initially equipped with edge runners, after 1640 these were replaced by pestles lifted by camshafts, working in stone mortars. It is known that in 1649 the pestles had bronze heads. This system of stamps was to be replaced by stone edge runners in the factory opened in 1729 by António Cremer.[15] Fourteen practically identical limestone mortars from stamp mills were used to protect the Barcarena stream bed from erosion, a little downstream from the weir by which water was diverted to the factory. Those mortars, shown on an old photograph (Figure 6.2), were later covered with a layer of concrete but it was possible to recover one for the present museum.

New mills were installed in Barcarena after the restoration of Portugal's independence in 1640. Due to the increasing demand for gunpowder, the latest of these belonged to private owners. By the warrant to manufacture gunpowder granted in 1679 to Carlos Sousa Azevedo, he assumed the obligation of rebuilding the Barcarena factory, and founding a new one in Alcântara on the site of the previous works. Under the contract of 1687 this

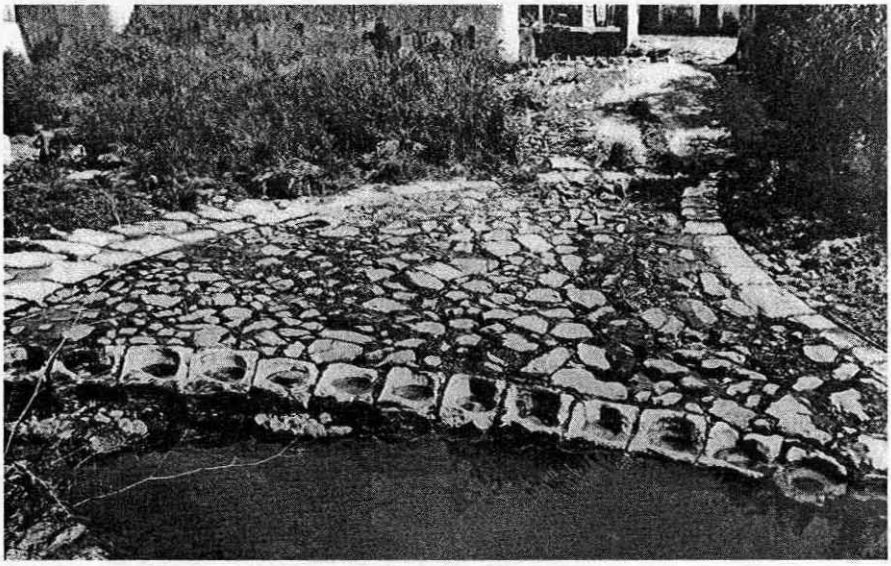

Figure 6.2 Mortars from the old stamp-mill workshop, used to protect the bed of the Barcarena stream (Oeiras Municipality).

gunpowder maker guaranteed an annual production of 120 tons for twelve years. The Alcântara factory, where five stamp mills were installed in 1690, was managed alongside the Barcarena factory, but the latter always kept the supremacy and began to be called the Royal Factory.[16] In 1695 the Barcarena factory and the King's Smithy were abandoned. A long lawsuit between the state and the then concessionaire led in 1725 to a competition for the public sale of the gunpowder factories. It was won by António Cremer, treasury general commissioner and ex-paymaster for the Dutch troops serving in Portugal.[17]

António Cremer's Factory: Historical and Technological Aspects

> On the 8th December the Barcarena Gunpowder Factory started to operate. António Cremer, Avowed Knight of the Order of Christ, Intendant and Administrator of this Kingdom's Gunpowder Factories, after having informed King John V that he had executed his royal orders and put to work the four edge-runner mills at the Barcarena Royal Gunpowder Factory, which he had brought from the Namur Province ... after the Mass and the blessing of the mills, the gates were raised and the water began to give them their first movement ... and some Foreigners having seen some European gunpowder factories confessed the superiority of this one for the splendour and regularity of the job ...[18]

This account shows how in 1729 the Barcarena Royal Gunpowder Factory was re-opened, initiating one of its peak periods of prosperity thanks to the efficient management of the Dutchman António Cremer, who had won the concession on 22 October 1725. By means of his contract of 2 March 1726 Cremer was authorized to create new mills, provided their superiority was proved in relation to the previous ones and that each year he converted 120 000 kg of saltpetre into gunpowder. He could establish other factories and '... nobody else could do it in public or in secrecy under penalty of confiscation ...'.[19] This clause is of great importance as it allowed commissioner Cremer a total monopoly of gunpowder manufacture. Having taken over the Barcarena and Alcântara factories, the new manager introduced great technical improvements in the manufacturing process by the use of imported limestone edge runners and beds, and in gunpowder testing. Cremer was granted the title of 'Intendant of the Kingdom's Gunpowder', for keeping gunpowder production and supply constant, and meeting the country's requirements.

António Cremer built the main structure of his factory on the left bank of the Barcarena stream, at a distance from the latter of around 30 metres. Edge-runner mills for crushing and mixing the components and incorporating the gunpowder were established, as these were considered safer than stamps with their risk of sparks and explosions. There were four mills, each with two limestone edge runners which moved on a horizontal bed of the same stone. These and other features, especially the apsidal-ended reservoir may be seen on the plan commissioned in 1775 by Martinho de Mello (Figure 6.3).

The edge-runner mills were driven by overshot waterwheels, powered by water taken from the stream and supplemented with that coming from underground sources, before being concentrated in the reservoir. The reservoir has an area of 860 square metres and the maximum volume of water stored is 690 cubic metres. To make it more watertight the bottom was lined with rectangular limestone slabs measuring *c.* 1.10 by 0.55 metres. Besides its functional aspect the reservoir offered a pleasant resting area, with small stone benches along its western wall. The waterwheels were fed through a channel along the exterior of the western wall of the factory building shown in Figure 6.3. This was at the level of the first floor in order to ensure a sufficient fall of water through four exits on to the top of the vertical wheels in the gallery below. After driving the wheels the water was returned to the Barcarena stream by means of two underground tunnels, associated with a small weir in the stream. The running of one or the other was determined by gates fitted on both tunnels: the first worked most of the time but was put out of service during floods in order to avoid water coming back onto the waterwheels; the second ran under a large drainage tunnel which met the Barcarena stream immediately downstream from the factory.

The waterwheels were installed inside a vaulted hemispheric chamber of careful construction, above which the vertical edge runners were located.

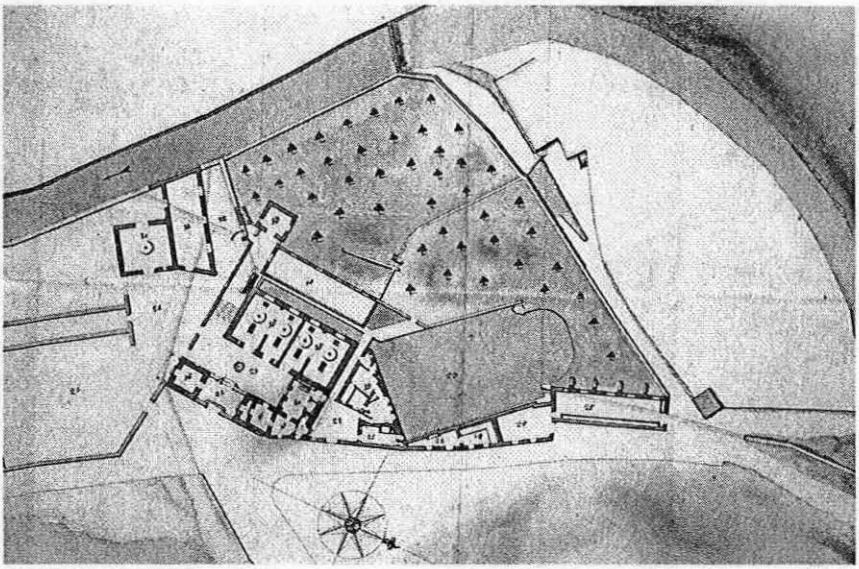

Figure 6.3 Part of a full plan (1.525 × 0.54 square metres) of Cremer's factory, showing the reservoir and four mills. Commissioned by Martinho de Mello, 1775 (Gabinete de Estudos de Arquelogia e Engenharia Militar, GEAEM).

These were driven by the rotary movement of the horizontal shaft of each waterwheel, transmitted by reduction gearing. The installation of these waterwheels and the method by which they were fed with water were, as will be seen, similar to those introduced by Turriano (Figure 6.1) in spite of the differences in the device by which the flow was regulated.

The use of animal traction when water was scarce is mentioned in a document of 1762.[20] Radial grooves in the paving slabs of two workshops in the main building show the importance of preventing the animals slipping as they provided the driving force.[21] In general the paving slabs of the four workshops are in a bad condition, with numerous fractures and fire marks, possibly due to the several explosions suffered by the building particularly the 1805 explosion. On the façade of the main building (Figure 6.4) there are two niches. These may have sheltered images of the patron saint of gunpowder makers, Saint Barbara, to whom a chapel was devoted at the northern end of the courtyard. This main building shows, particularly on the walls of the south-east corner, different stages of construction: a lower part which may correspond to the Turriano phase, and an upper part corresponding to Cremer's developments or to reconstructions after the 1805 explosion.[22]

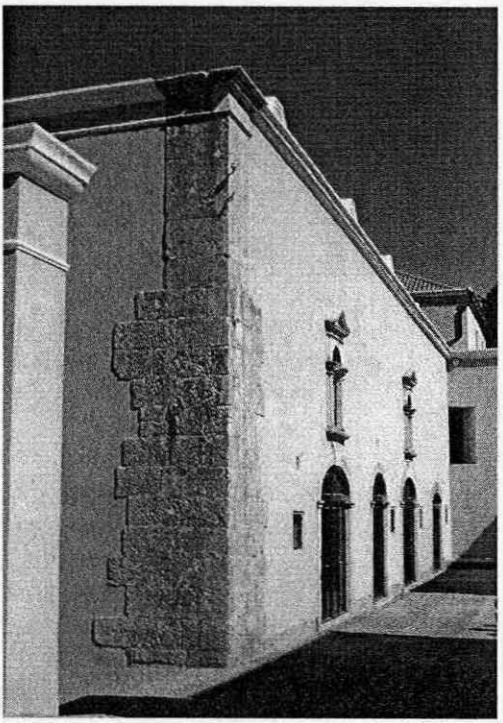

Figure 6.4 South-east corner of the main factory building, built by António Cremer and inaugurated in 1729. Photographed by the authors.

The light construction of the roof of the building is in contrast to the strength of the walls: this favoured the vertical movement of the blast in case of an explosion. To make night work possible there were four openings in the main façade in which thick fixed glass separated an oil-lamp lighting system from the interior of the building. The front exterior courtyard was lined with bricks placed in zig-zag formation to avoid the production of sparks.

Large storm water drains were constructed to avoid the accumulation of rain water and prevent it entering the building. The torrential conditions of the Barcarena stream, sometimes with very significant floods, must have been recognized by the builders, for the floors of the main Turriano/Cremer works and their later extensions were built much above the stream bed. The solid construction of the walls has been noted, with the squared stone generally reaching around 8 metres high. Amongst the auxiliary features that must have existed in Cremer's time were the workshops for crushing charcoal by means of edge runners, and for the corning and grading of gunpowder, and the drying courtyard where it was spread out on cloths placed on long benches.

The mills created by António Cremer operated for nearly two centuries. Gunpowder manufacture ceased here around 1925, at which time several new workshops were installed that, as will be seen, remained active until recently.

Technological Innovations by Bartolomeu da Costa

In 1774 there was a great explosion in the gunpowder drying courtyard. The then navy minister, Martinho de Mello, had the damage repaired, built two more mills as well as two reservoirs, and oversaw an increase and improvement of the workshops. Bartolomeu da Costa, the famous gunner who cast the equestrian statue of King José in the Terreiro do Paço square in Lisbon, played a very important role in the implementation of these measures.[23] He was charged with the technical direction of the factory sometime between 1780 and 1782, and in 1793 he became director, holding this position until his death in 1801. He reached the rank of lieutenant-general of the army and was one of the fourteen founders of the Lisbon Royal Academy of Sciences, established in 1779.

In order to decrease the risk of sparks which might cause the gunpowder to explode during its preparation in the mills, Bartolomeu da Costa introduced bronze edge runners and bedplates, moulded in the Alfeite Arsenal near Lisbon, to replace the earlier ones of stone. However, he kept one stone edge-runner mill, with its stone bedplate, to grind the sulphur and charcoal. Luíz Mardel mentions that in his time all edge runners and bedplates were made of bronze, or at least the beds and the rim of the edge runners.[24] Tomás de Morla wrote of these Barcarena edge runners, 'the millstones that go round are of wood covered with brass or bronze around and are hollow: to give them weight they carry within them loose bodies like bronze or lead spheres'.[25] These edge runners weighed much less than those of stone and had a smoother motion, lacking the irregularity caused by the differences in weight and width between the two stone edge runners at each mill. With these runners the preparation of the 'cake' was achieved in around half the time.

A replica of this edge-runner mill has been built and may be seen at the Barcarena Gunpowder Museum (Figure 6.5). It is as faithful to the original as is possible because it is based on a model, made in the factory to an approximate scale of 1/10, and now displayed undated in the Lisbon Military Museum. From this model with its wooden edge runners with metal rims and bedplate simulated by silver paint, the following estimates may be made of the measurements of the original mill: edge-runner diameter 2.00 m; first edge-runner width 0.44 m; second edge-runner width 0.38 m; vertical waterwheel diameter 4.00 m; waterwheel inner width: 0.60 m. These dimensions are not far from those represented on the building plan of 1910.[26]

Bartolomeu da Costa's new approach to the mills also included the construction of mechanisms mentioned earlier, by which the flow of water onto the vertical waterwheels could be regulated, thus varying the rotation speed of the mill. A useful illustration of this incorporating mill is now exhibited in the Barcarena Museum (Figure 6.6).

The regulatory mechanism consisted of a lever with a fulcrum fixed on the

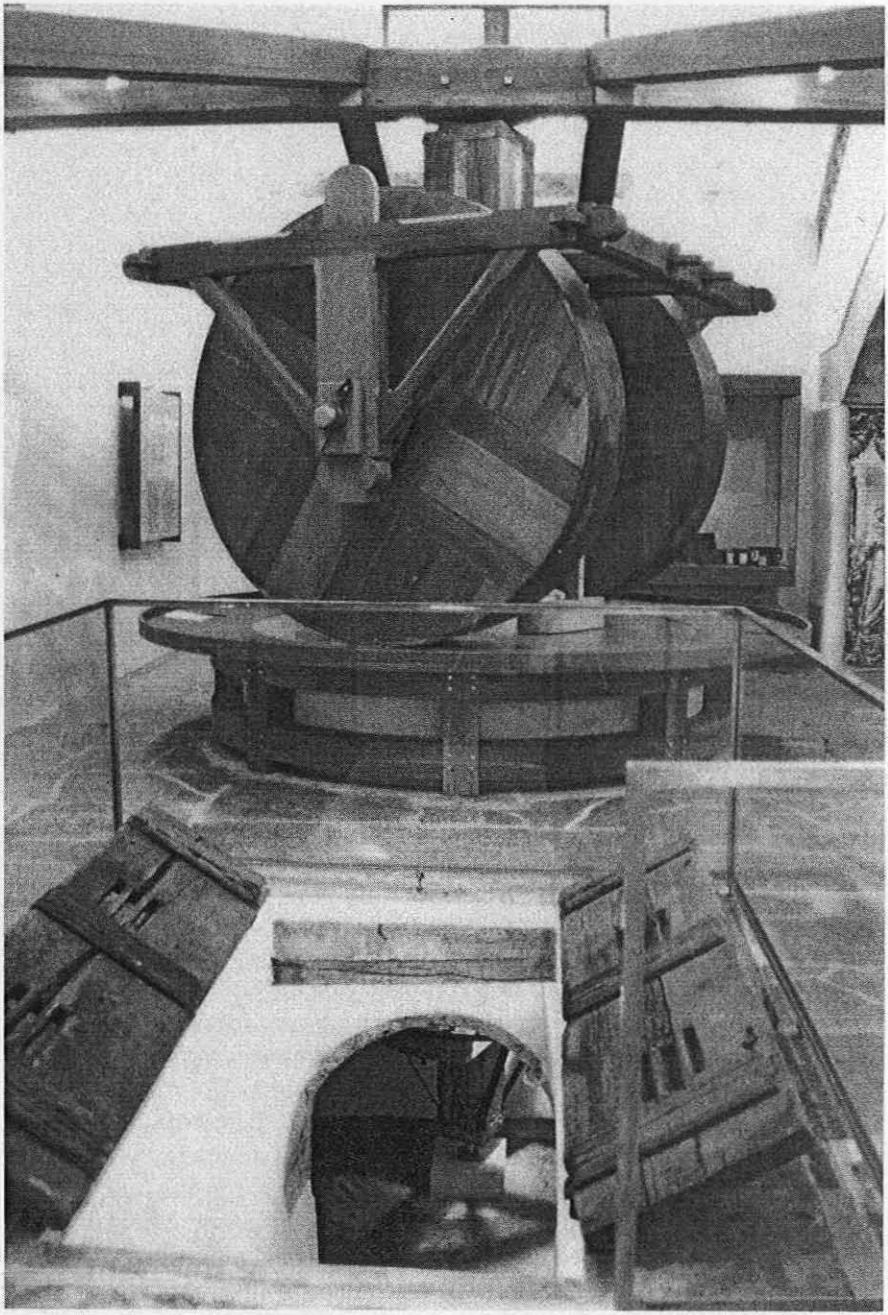

Figure 6.5 Edge-runner mill at the Museu da Pólvora Negra de Barcarena, rebuilt but with the original doors into the cellar. Photographed by the authors.

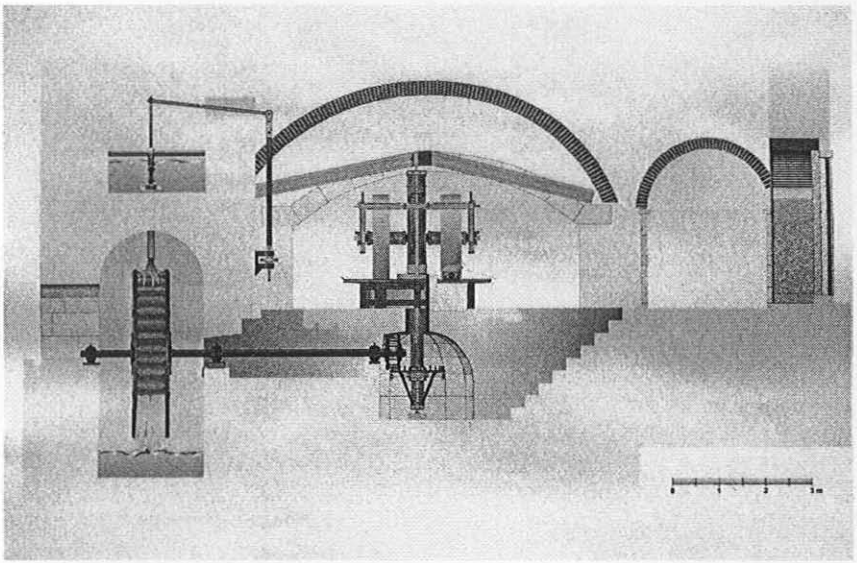

Figure 6.6 Diagramatic vertical section of the factory showing the control of the water supply to the edge-runner mill, which was later rebuilt at the Barcarena Gunpowder Museum. (Designed and photographed by the authors, digital drawing by J.M. Andrade Pereira).

mill wall, articulated at both extremes by vertical bars. The one operated from inside the mill moved that on the outside, which in turn transmitted movement to a sliding bronze plate set in a limestone block at the bottom of the water channel. It was thus possible to stop completely or to vary the entrance to the pipe taking the water to the waterwheel, and therefore to regulate the discharge. When the waterwheel feeder channel was recently emptied, the sliding plates of the various mills were found at the bottom of it (Figure 6.7).

The earlier scheme for the edge-runner mill at Barcarena adopted by Leonardo Turriano (Figure 6.1) had included a device similar to the type later constructed. Based on a lever operated by an upright bar in the inner part of the mill, acting upon an upright bar outside the building, the flow of water could in this case be stopped or freed by a cone-shaped plug.

Bartolomeu da Costa also built a machine to pulverize saltpetre, and another to mix the ingredients of gunpowder before going through the incorporating mill, which operated until at least 1855. It was worked manually and reduced the time spent on the preparation of gunpowder. He also introduced some innovatory safety measures to prevent fires and

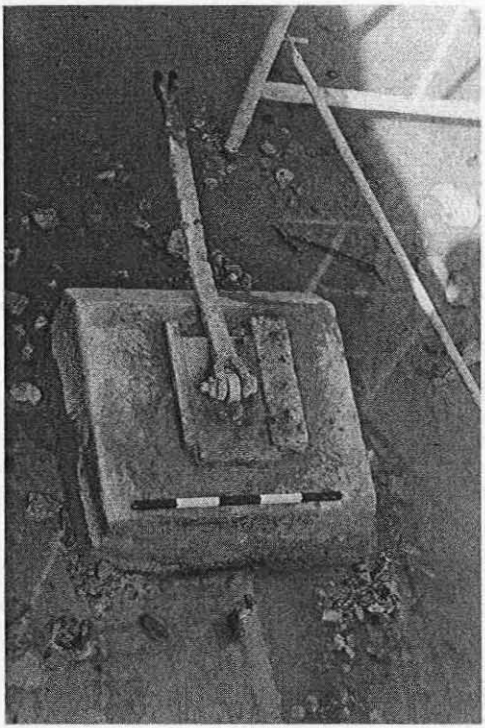

Figure 6.7 Bronze sliding plate in limestone block, found at the bottom of the water feeder channel and used to control the supply of water to the mill wheels. Photographed by the authors.

explosions. To avoid sparks in the factory, for example: the axles of all carts had bronze bearings; workers were obliged to use leather shoes over their own as the latter might have nails; all workshop doors had mats of esparto; and all workers were obliged to scrub their feet to remove grains of sand.

Under the management of Bartolomeu da Costa, gunpowder production at Barcarena reached a yearly average of about 315 tons, with a minimum of 123 tons in 1780 and a maximum of 606 tons in 1797. Martinho de Mello's work of restoration mentioned earlier had already allowed the average yearly production of 67 tons between 1753 and 1774 to rise to 158 tons in 1775 and 330 tons in 1776. According to information presented by Palmeirim et al. in 1855, the maximum reached in 1797 was not exceeded until at least 1853, and from 1801 to 1853 in only three years (1806, 1807 and 1820) was production slightly higher than 300 tons.[27]

The Enlargement of the Barcarena Factory

The later enlargement of the lower factory built by António Cremer is shown on a series of plans of 1817, 1883, 1918 and 1939.[28] That of 1817 shows the

first installations on the right bank, of a charcoal workshop and facilities for the proof mortar. On the left bank a further set of four mills, the upper factory, is shown in addition to and upstream of the four of Cremer's time, and close to a building with two mills shown on the full plan of 1775. The 1817 plan shows also the well-defined hydraulic system, with stream, weir, aqueducts and reservoirs, from which feeder channels led to the waterwheels. This system allowed the supply of water to the mills to be concentrated in the reservoirs during working hours. The other new buildings on this bank were mainly for carpentry, the storage of gunpowder 'cake' (for 'it was usual to take advantage of the winter waters ... and granulate gunpowder in the summer'[29]), barracks for sergeants and soldiers, kitchens, refectory, prison, and a hospital ward for people burned in gunpowder explosions.

Further information on the evolution of the gunpowder manufacturing operations and the equipment used is contained in the book by Palmeirim et al. (1855), already referred to. After several experiments the factory director, Carlos António Napion, adopted in 1802 the French manufacturing method, whereby the crushing and mixing of the components was done in wooden rotating cylinders before the preparation of the 'cake'. In 1813 charcoal and saltpetre were ground in cylinders set in motion by means of cranks. The sulphur was crushed in a stone edge-runner mill driven by oxen. By 1854, although the equipment for crushing, incorporating, corning and glazing was in different workshops, it was driven by the same waterwheels serving the machines alternately. This work most probably took place in the upper factory, where marks on the walls and in the ground corresponding to the extension of the shaft of the second waterwheel, counting from the north, can be seen.[30] The ingredients were crushed in barrels driven by a waterwheel, and their initial mixing was undertaken manually in a rotating barrel called a 'bear'. After incorporation, corning was carried out in cylindrical sieves moving around a horizontal axis. The granulated gunpowder was then taken to a large sieve set in motion by a waterwheel. From this time an effort was made for the different types of machinery to be installed separately. In 1854 the annual production of the factory was between 180 and 210 tons.

Steam power was introduced at Barcarena in 1873 for the operation of the edge runners. The 1883 plan shows a new saltpetre refinery on the left bank of the Barcarena stream and a significant increase of buildings on the right bank: charcoal making; a drying stove; Lefebvre granulators; sieves, grading and glazing equipment, operated by steam power until replaced by electric engines in 1924; and a building with eight rooms of equal size for hydraulic presses (for re-working the powder grains rejected in the processes of grading and dust removal, to form 'cake'). Amongst the installations appearing for the first time, the 1918 plan highlights the reservoir for feeding the steam-producing boilers, and the eight-sided boiler house where in 1924 the first

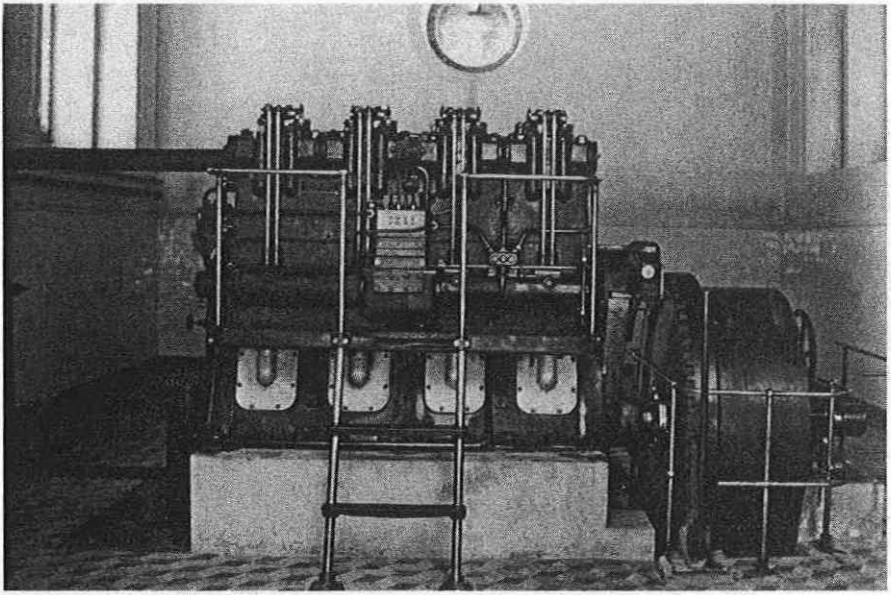

Figure 6.8 Diesel power station of 1929, with Deutz Winterthur engine and 86 kW dynamo. (Oeiras Municipality).

34 kW diesel power station was installed. The 1939 plan shows that besides this diesel power station, another one of 86 kW was installed in 1929 (Figure 6.8) as well as a hydroelectric power station completed in 1925 (Figure 6.9).[31]

The hydroelectric powerhouse received water from the waterwheel feeder canal of the upper factory mills, which ran through a covered channel for almost its whole course. It had two 50 h.p. horizontal-axis Francis turbines which activated three dynamos, two of 40 kW each and one of 5.5 kW used for electric light and auxiliary services. The electric powerhouses produced continuous (or direct) current to feed the electric engines of the four mills with their cast-iron edge runners (manufactured by Grusonwerk, see Figure 6.10), installed in buildings shown on the 1939 plan, as well as the calibrating and glazing equipment installed in the eight-room building shown for the first time on the 1883 plan. The continuous current allowed easier variation in the speed of rotation of the electric engines which operated the manufacturing equipment. The old water-powered edge-runner mills then stopped work, and the electric engines began to take their place and that of the steam engines operating other manufacturing equipment.

In 1972 there was a powerful explosion in the aforementioned eight-room building, which killed four workers and severely damaged the structure. Gunpowder then ceased to be manufactured there. In the 1940s the

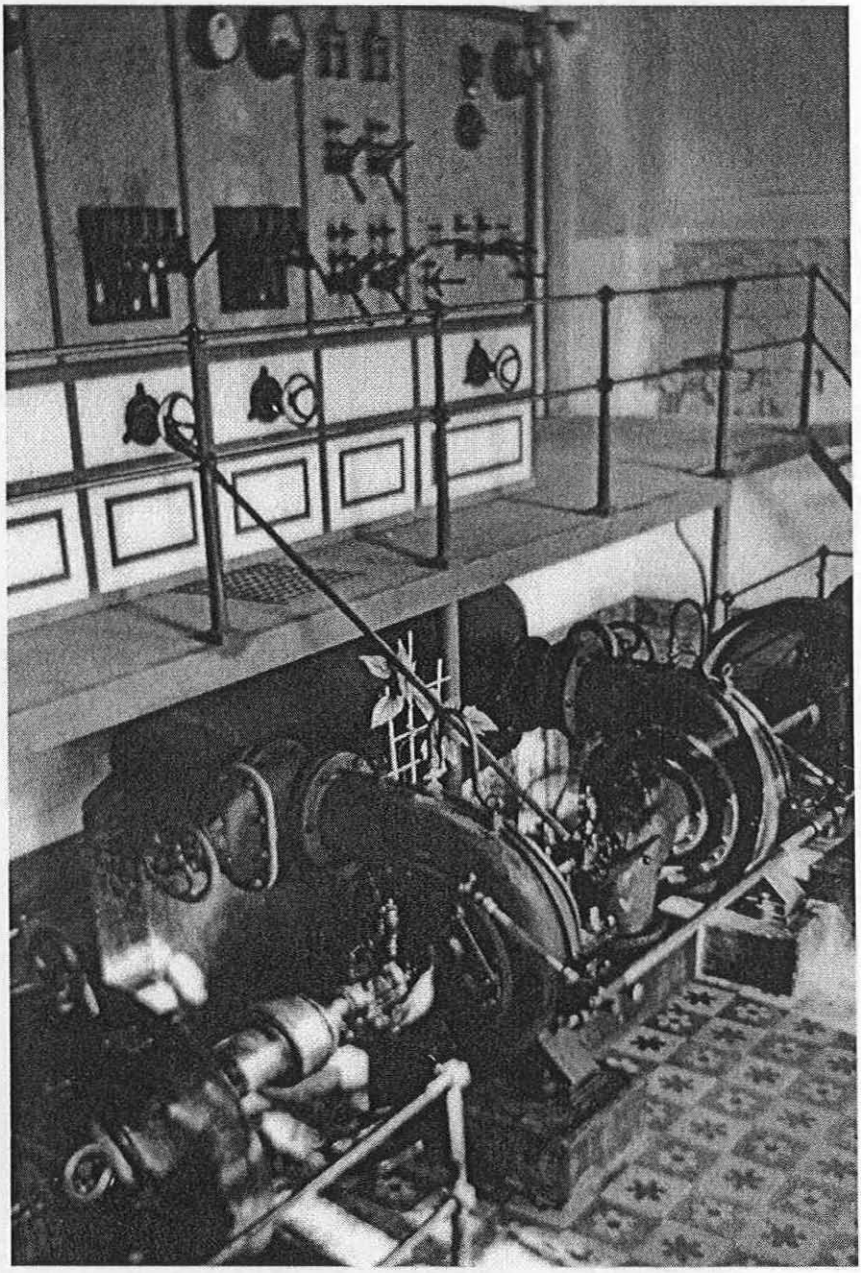

Figure 6.9 **Hydroelectric power station of 1925 with two Francis turbines of horizontal axis, geared to dynamos (Oeiras Municipality).**

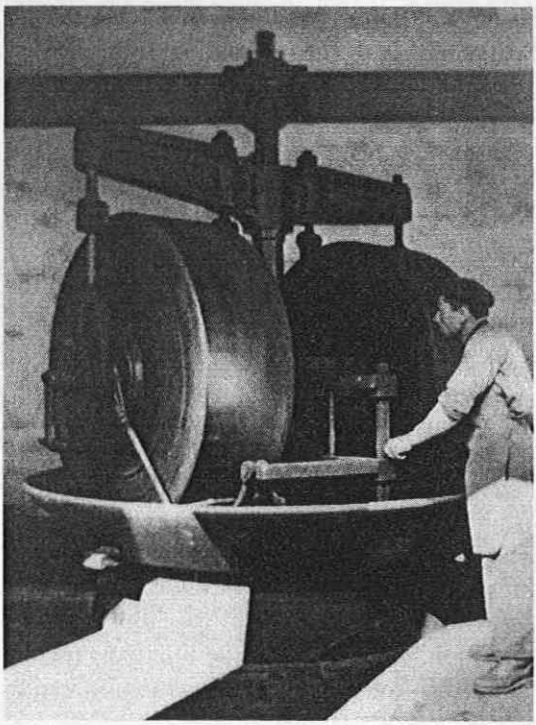

Figure 6.10 Grusonwerk cast-iron edge runners operated by electricity (Oeiras Municipality).

manufacture of nitro-cellulose and smokeless powder had been introduced in Barcarena and later the explosives for loading bombs for mortars, artillery and aircraft. The factory closed down in 1988.

Barcarena Gunpowder Museum

In view of the valuable historical and cultural heritage of the Barcarena gunpowder factory and the archaeological and industrial interest of the remaining installations and equipment, notwithstanding the dilapidations of the 1970s, the Câmara Municipal de Oeiras (Oeiras Municipality) decided to create a gunpowder museum. The aim of the museum is to illustrate the life of the industrial unit; document the gunpowder manufacturing processes and their introduction in Portugal; evaluate the Barcarena Factory, built under António Cremer's management and considered one of the first big industrial accomplishments of the country in the early phase of industrialization, 1720 to 1740; assess its social and economic importance; and promote the preservation and study of its assets as well as proceeding with the investigation of gunpowder manufacture in Portugal.

The Museu da Pólvora Negra de Barcarena (Barcarena Gunpowder Museum) is set out in four compartments of the main building of the factory, of approximately equal size and easy communication, which allows for it to be divided into four thematic centres.[32] Room 1 asks '*What is gunpowder?*' and so is an introduction to the museum. Room 2 presents the theme '*Weapons and gunpowder in Barcarena*'. It refers to the use of gunpowder in Portugal up to the eighteenth century and especially to its manufacture in Barcarena since the time of Leonardo Turriano. The importance of the manufacture of firearms in the 'King's Smithy' is also illustrated. Room 3 is dedicated to the theme '*The Barcarena Royal Gunpowder Factory of 1729*', built by António Cremer. This has as its main focus a replica of the edge-runner mills that were introduced by Bartolomeu da Costa in 1782, and the original doors leading into the crypt where the gearing system is installed. Lastly, room 4 is dedicated to '*The Factory in the nineteenth and twentieth centuries*' – the technological evolution of gunpowder manufacture, the energy sources, and the security and social and economic aspects of the works.

It is important to mention that within the extensive factory, installations and equipment used for gunpowder manufacture at different times still survive. Of particular significance are the four incorporating mills of the upper factory, similar to Cremer's, with their reservoir. There are also the buildings for the saltpetre refiner, the Lefebvre granulators, the four Grusonwerk incorporating mills, the two diesel electric generators, the hydroelectric power station, and the eight compartments where hydraulic presses, glazing machines, and calibrators had been installed. Other interesting features include the gunpowder drying courtyard, the water tanks for fire fighting, and the undergound galleries of the hydraulic circuits. With the exception of the upper mills building these are all situated in an open public area.

The factories built by Leonardo Turriano and António Cremer are unique in Portugal, and highly important within the worldwide context. Their significance is increased by the fact that they were constructed specifically for gunpowder manufacture. This, and the long association of the Barcarena gunpowder factory with the different stages of gunpowder making in Portugal, means that it has a high historical as well as heritage value.

Notes

1 Nuno Rubim, 'A Artilharia em Portugal na Segunda Metade do Século XV', *A Arquitectura Militar na Expansão Portuguesa* (Lisboa: Comissão Nacional para as Comemorações dos Descobrimentos Portugueses, 1994), pp. 17–26.

2 Gastão de Mello de Matos, 'Artilharia', in *Dicionário da História de Portugal*, vol. 1 (Lisboa: Livraria Figueirinhas, 1985).

3 Francisco Sousa Viterbo, *O Fabrico da Pólvora em Portugal. Notas e Documentos para a sua História* (Lisboa: Typographia Universal, 1896), pp. 11, 14; Maria Teresa C. Rodrigues (Coord.), *Livro das Posturas Antigas* (Lisboa: Câmara Municipal de Lisboa, 1974).

4 Nuno Rubim, *op.cit.*, note 1.
5 Francisco Sousa Viterbo, *op.cit.*, note 3, pp. 6–7.
6 José M. de Mascarenhas, 'Portuguese overseas gunpowder factories, with special reference to those of Goa (India) and Rio de Janeiro (Brasil)'. See chapter 9 of this book.
7 Francisco Sousa Viterbo, *op.cit.*, note 3, pp. 64–66.
8 António C. Quintela, João L. Cardoso, José M. Mascarenhas and Maria C. André, *A Fábrica da Pólvora de Barcarena e os seus sistemas hidráulicos* (Oeiras: Câmara Municipal de Oeiras, 1995), pp. 73–74.
9 A. Palmeirim, J. Monteiro, J. Almeida, J. Pimentel and J. Cordeiro, *Relatório sobre a fabricação e administração da pólvora por conta do Estado e seu comércio* (Lisboa: Imprensa Nacional, 1855).
10 Jorge Miranda, 'Fábrica da Pólvora de Barcarena (2003)', *Oeiras Jornal da Região*, **309** (2003), p. 5.
11 Leonardo Turriano, *Dos Discursos de Leonardo Turriano el Primero sobre el Fuerte de San Lorenco de Cabeçaceca en la Boca del Taxo el Segundo sobre Limpiar la Barra del Dicho Rio y Otras Diferentes* (Lisboa: Biblioteca Nacional, Codex 12892, 1622).
12 *Notícias de Portugal escritas por Manoel Severim de Faria. Acrescentadas pelo P.D. Jozé Barbosa. 3ª edição augmentada por Joaquim Francisco Monteiro* (Lisboa: Offic. de António Gomes, 1791), vol. I, pp. 129–130. As a result of the misinterpretation of these texts by A.Palmeirim et al. (note 9), references to the foundation of the Barcarena factory in the early sixteenth century have been repeated frequently, but incorrectly.
13 Francisco Sousa Viterbo, op.cit., note 3, p. 9.
14 Francisco Sousa Viterbo, *A Armaria em Portugal. Noticia documentada dos fabricantes de armas brancas que exerceram profissão em Portugal* (Lisboa: Typographia da Academia Real das Sciências, 1907), pp. 149–150.
15 A.C. Quintela et al., op.cit., note 8, p. 112.
16 A.C. Quintela et al., op.cit., note 8, p. 86.
17 A. Palmeirim et al., op.cit., note 9, pp. 17–18.
18 Fr. Claudio da Conceição, *Gabiete historico que a Sua Magestade Fidelissima, o Senhor Rei D. João VI em o dia de Seus felicissimos annos, 18 de Maio de 1818, offerece Fr. Claudio da Conceição* (Lisboa: Impressão Regia, 1820), vol.VIII, pp. 50–53.
19 A. Palmeirim et al., op.cit., note 9, p. 19.
20 A.C. Quintela et al., op.cit., note 8, p. 177.
21 António C. Quintela, João L. Cardoso and José M. Mascarenhas, *A Fábrica da Pólvora de Barcarena. Catálogo do Museu da Pólvora Negra* (Oeiras: Câmara Municipal de Oeiras, 2000), Figure 49.
22 A.C. Quintela et al., op.cit., note 21, Figure 17.
23 A.C. Quintela et al., op.cit., note 8, pp. 90–91; A. Palmeirim et al., *op. cit.*, note 9, pp. 23–24, 30–31; 'Breve Notícia da vida e dos serviços que prestou À Nação o Tenente General Bartholomeu da Costa', *Boletim do Arquivo Histórico-Militar*, **45** (Lisboa: 1975), pp. 209–263.
24 Luiz Mardel, *Polvoras, explosivos, suas applicações* (Lisboa: Imprensa Nacional, 1893), p. 70.
25 Tomas de Morla, *Arte de Fabricar Pólvora, Libro III, De la Fábrica de la Pólvora*, (Madrid: Imprensa Real, 1800), p. 62.
26 A.C. Quintela et al., op.cit., note 8, p. 179.
27 A. Palmeirim et al., op.cit., note 9, pp. CX–CXIX; 'Breve Notícia da vida e dos serviços que prestou À Nação o Tenente General Bartholomeu da Costa', *op. cit.*, note 23.
28 A.C. Quintela et al., op.cit., note 8, pp. 119–134.
29 A. Palmeirim et al., op.cit., note 9, p. 111.
30 A.C. Quintela et al., op.cit., note 8, p. 187.
31 Ibidem, pp. 125, 129, 132.
32 A.C. Quintela et al., op.cit., note 21, pp. 49–51.