

WASC 1996

'The Old  
Establishment'

by Brenda  
Buchanan

**THE  
NEWCOMEN SOCIETY**

**for the study of the history of  
ENGINEERING and TECHNOLOGY  
TRANSACTIONS**

**Volume 70, no. 2  
1998-99**



## THE NEWCOMEN SOCIETY

The Newcomen Society was formed in 1920 as a result of the James Watt Centenary Celebrations held in Birmingham the previous year. Its object is to support and encourage study and research in the history of engineering and technology, and the preservation of records, both technical and biographical. Although the Society takes its name from Thomas Newcomen (1664–1729), the father of the steam engine, its interests cover the whole field of industrial activities. It maintains close links with other organisations with like interests.

A free translation of its Latin motto could be:—‘That the future may learn from the past.’ The present growing national concern with scientific and technical education emphasises the value and interest of such study, which helps to foster appreciation of the humanistic content and value of technology, thus encouraging the student to view the past and the future as one live picture. The value of this study is now better appreciated in universities and elsewhere, and the field is continually growing.

The *Transactions* of the Society contain original and authoritative papers on many aspects of the history of engineering, technology, and industry, and particularly on the lives and works of the men who laid the foundations of our present industries. The headquarters of the Society are at the Science Museum, London, SW7 2DD. There are also Midlands, North Eastern, North Western and South West Branches with their headquarters in Birmingham, Newcastle-upon-Tyne, Manchester and Bristol respectively.

Meetings at which papers are read and discussed are held monthly from October to May, usually at the following places: the Science Museum Lecture Theatre, the Birmingham Museum of Science and Industry, the Tyne & Wear Archives Service, Newcastle-upon-Tyne, and the Greater Manchester Museum of Science and Industry. Visitors are cordially invited to attend. Papers from members, on any subject of technical history including modern developments, are welcome. Details of preparation and procedure can be obtained from the Executive Secretary.

Visits to places and items of historical interest are arranged from time to time; and there is a summer meeting in June or July lasting four or five days at some centre where places of interest are visited with help and guidance from local members and others.

Membership is open to persons approved by the Council who have at heart the furtherance of the objects defined above. Libraries and Institutions can join the Society as affiliated non-statutory members and are entitled to receive the publications of the Society but not to have a voice in the management of its affairs. The Executive Secretary would be glad to hear from any intending members, and to send them further particulars.

The subscription for Members in the United Kingdom is £30.00 per annum and for Institutions £36 per annum, this covers a copy of the *Transactions* published during the currency of the subscription. Members who notify the Executive Secretary of their intention to forego receipt of the *Transactions* pay £24.00 per annum. Students between 16 and 23 years of age may join as Associates; they receive the privileges of membership except the right to vote and *Transactions* for a subscription of £8.00 per annum. Members and Institutions overseas pay a supplement of £3.00 per annum on account of postal rates, bank charges and current exchange rates. Subscriptions are payable on election, and thereafter on 1 October.

All Members and Associates receive the *Newcomen Bulletin* which is published three times during the year.

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# Waltham Abbey Royal Gunpowder Mills: ‘The Old Establishment’

by

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## INTRODUCTION

Gunpowder and the explosives and propellants which followed it provided a form of energy which changed the world: it encouraged trade and helped to open up new lands; it provided a power beyond the previous limitations of the natural order and so allowed earth-moving mining and engineering to take place; and it set in train military conquest, the formation of nation states, and the building and maintenance of vast empires.<sup>1</sup> This was achieved through the development of many centres of gunpowder production, of which that at Waltham Abbey was crucial, for it was to become the pre-eminent powder works in this country and one of the most important in the world.

Gunpowder production began at Waltham Abbey in the mid-1660s and the powder mills remained in private hands until 1787 when they were purchased by the Crown. From this time the Royal Gunpowder Mills came to lead the way in the technology of explosives in Britain, an achievement reflected in its surviving structures through which we may trace the evolution of gunpowder making to its ultimate form in the late nineteenth century, with the development of new chemical explosives, especially cordite, running in parallel with these refinements. Production ceased during the Second World War due to the vulnerability to air attack, but after the war this became the principal research establishment for the investigation of non-nuclear explosives, providing a continuity of use which has ensured the survival of the site of the Waltham Abbey Royal Gunpowder Mills (WARGM) to the present day. After decommissioning in 1991 the Ministry of Defence undertook a decontamination of the site, so that access could be provided to this secret world.<sup>2</sup>

The visit by the Newcomen Society in April 1998 was the first such, and a privileged one in that the WARGM are not yet open to the public. Members will recall the mysterious and complex landscape which awaited exploration, with over 300 structures in varying degrees of soundness, 21 listed buildings, and a profusion of waterways; the whole surviving in a leafy parkland of 71 hectares. This rural landscape is not however simply a reversion to nature, indicating neglect of a de-industrialized site, but rather a sign of the strong link between gunpowder making and the countryside which survived into the era of the later explosives and can still be seen here today. Although initially an urban occupation, powdermakers had come by the seventeenth century to look for secluded sites in the countryside in which to conduct their dangerous industry with safety and security. They also wanted somewhere well-wooded to provide timber for charcoal (especially certain woods such as alder) and fuel, and to give protection from blast, with a good supply of water for production processes, power, and transport.<sup>3</sup>

The site at Waltham Abbey provided these advantages throughout its history, as a visitor as late as 1899 could testify:

waving avenues of poplar trees, and the ever-graceful alder, grow luxuriously everywhere. Instead of vast buildings, tiny bungalows are dotted here and there by the side of cool-looking canals, which seem to invite the heated wayfarer to absolute idleness. So peaceful, in short, is the scene that it is impossible to prevent an impression stealing across the mind that a mistake has been made in the locality, and that the Cordite Factory is miles away. In spite of all this, 23 tons of our Service explosive are floated down these placid weed-grown canals each week, a mass of latent energy of which the mind has hardly any conception.<sup>4</sup>

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Thus even in this very active phase of WARGM a fine balance was maintained between intense manufacturing activity and the natural environment within which it was taking place, a balance which will be reflected in the fact that the WARGM will not open to the public as a museum, but as an 'interpreted site'.

### SOURCES

It is the purpose of this paper to focus on the early history of Waltham Abbey Powder Mills and the technologies involved before 1787, when their purchase by the Crown was marked by the addition of the term 'Royal' to the title. Some of the evidence for these earlier years will come from published sources of research not previously drawn together, but much will come from engineering drawings by John Smeaton of the early 1770s; plans of 1783, 1801, and 1806; and a Report of 1806 by John Rennie. Although several of these documents lie beyond our chosen date, they can be used with confidence for they are essentially retrospective, referring back to features established before the change of ownership and perhaps even indicating how slowly that change-over took place. Of these documents the most helpful is the Report by John Rennie, not least because it was he who there invoked the term the 'Old Establishment' to describe the historic core of the works, thus providing us with an evocative name for the privately-owned powder mills. The Old Establishment included the site where gunpowder making was first established alongside the harp-shaped Hoppit Pool which has survived almost unchanged to the present day, together with the 'upper Set of Mills', probably dating from the third quarter of the eighteenth century, about which Rennie's advice was being sought and which he had therefore 'examined minutely'. By the time of his Report in 1806 there had been some development to the south of the historic site, but Rennie's specific exclusion of the 'New Mills below Waltham Abbey' allows us, like him, to concentrate on the Old Establishment.<sup>5</sup>

### MYTHS AND TRADITIONS

In seeking to establish the early history of gunpowder making at Waltham Abbey, two myths or traditions must be examined. The first, the story that the monks of Waltham Abbey engaged in this pursuit, has never been proved and must remain an attractive legend. It probably gained currency because the gunpowder mills are sited on land that once belonged to Waltham Abbey and because there was industrial activity here from mediaeval times, especially corn mills and woollen fulling mills.<sup>6</sup> Not all the stories about the contribution of religious figures are to be dismissed however, for it was the Taoist monks of China who discovered gunpowder in the 9th century AD. Their secrets filtered through the Islamic lands to the West where they intrigued scholars with enquiring minds, many of whom were clerics because they were amongst the few with sufficient time and learning to pursue such knowledge. From his base at nearby Oxford the Franciscan friar Roger Bacon became in the 1260s the first to set out the secret of gunpowder in his *Letter on the Secret Workings of Art and Nature, and on the Vanity of Magic*.<sup>7</sup> The recipe combined saltpetre, sulphur, and charcoal in particular proportions in a mixture which would explode 'if you know the trick'—if, that is, the maker used pure saltpetre; obtained certain woods for charcoal; incorporated the mixture thoroughly but refrained from compressing it unduly; and kept the powder dry. The subject is a matter of debate but it seems that, conscious of the dreadful power of gunpowder, Bacon devised a code for his recipe to prevent it becoming widely known. However, alternative sources allowed the knowledge to become available long before the code was broken earlier this century.<sup>8</sup>

The second unsound tradition concerns the activities of a merchant of Waltham Abbey, John Thomworth, whose purchase of 'saltpeter of Naples' and sulphur is recorded in the State Papers of 1562. This transaction has given rise to speculation that gunpowder was being made here in the mid-sixteenth century, but there is no evidence for this supposition. Thomworth was certainly a

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man of influence in Waltham Abbey, being the executor of the widow of Sir Anthony Denny who had acquired the Abbey and its lands in 1535, but he was also a man of influence at Court, as one of the Grooms of Queen Elizabeth's Privy Chamber, and it is probably in that capacity that he made these purchases on behalf of the Queen.<sup>9</sup> There were at this time, in the second half of the sixteenth century, very serious concerns about the supply of ordnance, both military and naval. The aim was self-sufficiency and efforts were made to buy in gunpowder making 'know-how' through, for example, the purchase in 1561 of the German captain Gerrard Honrick's secret recipe for making saltpetre<sup>10</sup> and the invitation in 1567 to continental powdermakers suffering religious persecution to bring their skills to England.<sup>11</sup> Also, until self-sufficiency was reached, merchants were encouraged to trade, both individually and in companies, for sulphur from the Mediterranean countries; saltpetre from the Baltic, the coast of North Africa and, after the East India Company had been set up in 1600, India; and for gunpowder itself from wherever it was available, especially through the entrepôts of the Low Countries such as Antwerp.<sup>12</sup> Thomworth was therefore more likely to have been a merchant than a gunpowder maker in the Lea Valley.

### DEVELOPMENT

Gunpowder making was in any case still, at this stage, largely an urban industry (Fig. 1). It was small scale, required little equipment and centred mostly on London, so that control could be maintained over manufacturers such as those at Ratcliffe who in 1580 were reported to the Privy

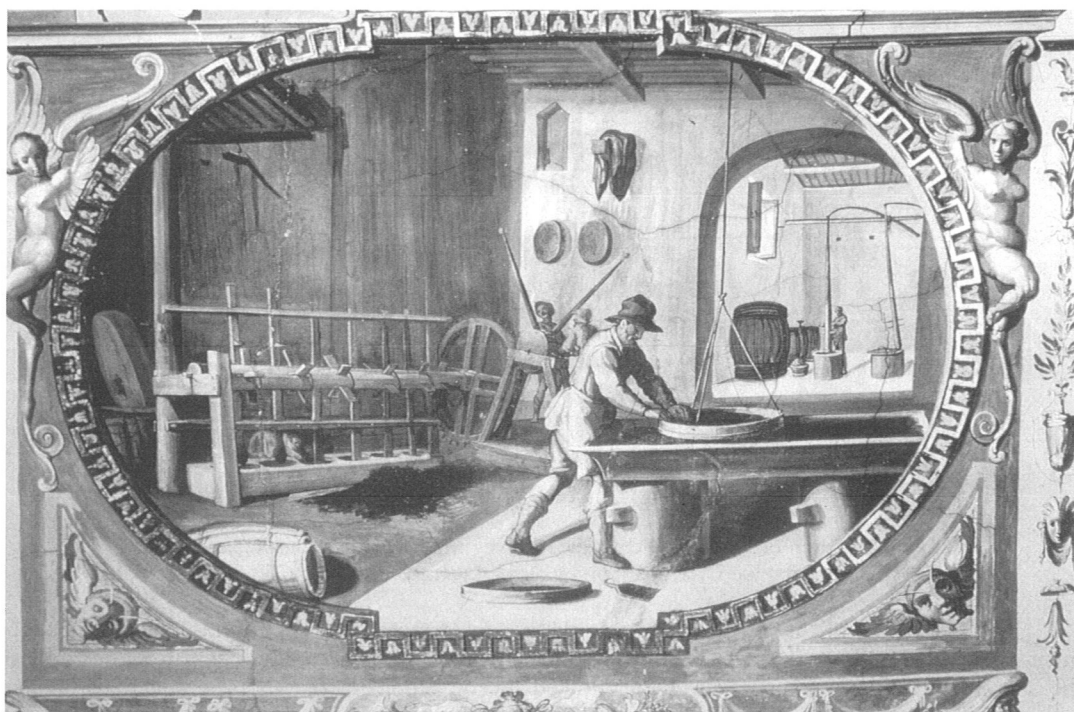


Fig. 1 Fresco by Bernardino Poccetti (1542–1612), Uffizi Gallery, Florence. In this urban setting, dependent upon manpower, the raw materials were probably prepared in the back room and then incorporated in the 'trough' with six mortars, by stamps operated by hand through a geared wheel and cams. The incorporated powder would be corned by the master workman at his table, pressed through a swinging sieve which could probably be exchanged for others in the workshop to produce grains of a particular size. Barrels, usually holding 100lbs, await the finished product. The edge runner on the left presents the tantalising possibility of future developments.

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Council for diversifying their activities by setting up a glass furnace at their gunpowder mill.<sup>13</sup> The deficiencies of the system were highlighted by problems at the time of the Spanish Armada of 1588 and this led to the granting of monopolies to certain suppliers such as the Evelyn family and, through them, to the development of rural centres of production on water-powered sites, outside London but within easy reach of the capital. As a result of these developments Surrey became the chief centre of the growing industry.<sup>14</sup>

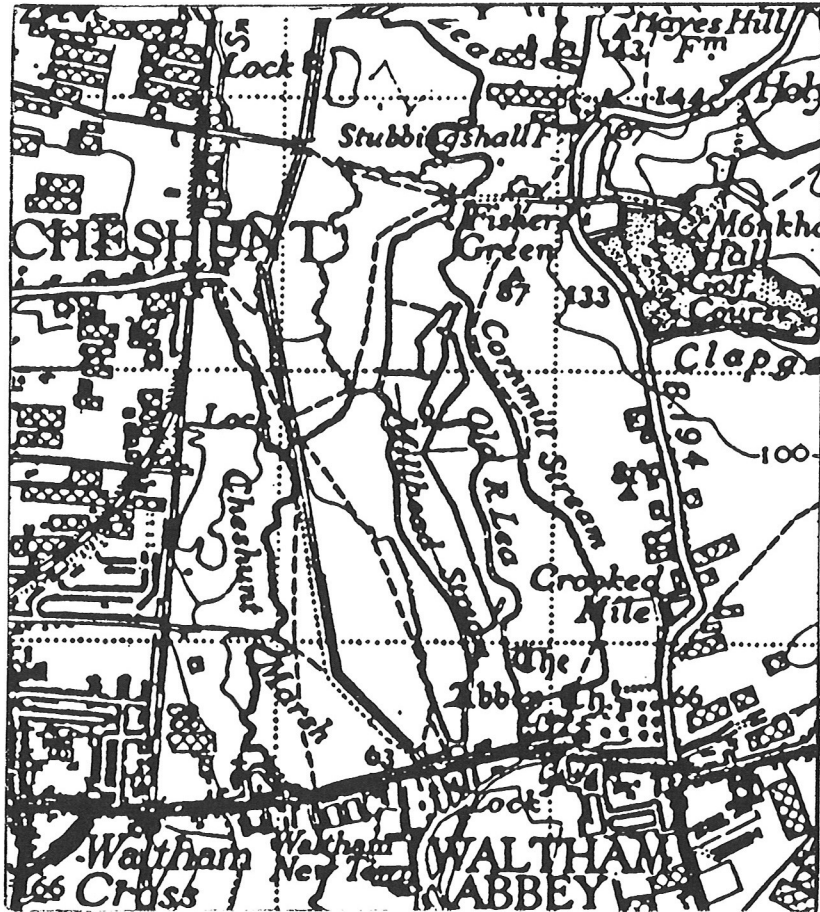


Fig. 2 Section of Sheet 161, Ordnance Survey Map, 1940 edition. Reproduced by licence from the Ordnance Survey. Grid reference centred on TL 378 011.

The Civil War of the 1640s broke this pattern and created the opportunity for the development of powder mills in the Lea Valley. The Parliamentary forces retained control of the mills in the south-east but, as an insurance, they allowed the development of others within their area of influence. The Lea Valley thus came to hold for a time one of the greatest concentrations of powder mills in the country, allowing Thomas Fuller, the perpetual curate of Waltham Abbey from 1649 until his death in 1661, to claim in his *Worthies* published posthumously early the following year, that more gunpowder was

made by mills of late erected on the River Lea, betwixt Waltham and London, than in all England besides.<sup>15</sup>

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Of the gunpowder mills on the River Lea, that at Sewardstone, producing powder from the 1640s, was the most important of the early ones, and that at Waltham Abbey, producing powder from the 1660s, the most important of the later ones. Other mills of this period where powder was at some time produced include four sites at Enfield (especially the Enfield Mills and Naked Hall Mills) and others at Tottenham, Walthamstow and Leyton.<sup>16</sup> By the early eighteenth century all except the Waltham Abbey Mills had gone out of powder production, either through conversion to other processes such as papermaking, or by ceasing industrial activity. This site alone therefore, out of all those in the Lea Valley, and indeed in the country as a whole, is able to claim the special distinction of having been in production as an explosives works for nearly 300 years and of maintaining that association until the present day.

### LOCATIONS AND PROCESSES

The location of the Waltham Abbey Powder Mills, like that of other defence establishments, was protected by the maps of the Ordnance Survey which carried no name and provided no details. This anonymity was helpful in the Second World War when only a stray German bomb landed here, and it still provides a useful function, for the absence of detail allows us to see the complicated system of waterways serving the site (Fig. 2). The River Lea was the basic source of water and power. It is shown here as the 'Old River Lea' because of the changes which have taken place in the course of its history. Until the cutting of the Lee Navigation (shown with locks to the west of the map) in 1770, it was used for navigation. Artificial channels or mill leats were created at an early date. On the east the Cornmill Stream was engineered, probably in mediaeval times, to serve the Abbey corn mill and later the pin factory there. To the west, the Millhead Stream had been constructed by at least 1590, for it is shown on a map of that date, serving a fulling mill. The position was further complicated by the engineering of the Horse Mill Stream which served in part as a drainage channel. South of the Waltham Abbey Mills these various waterways were united once more.<sup>17</sup>

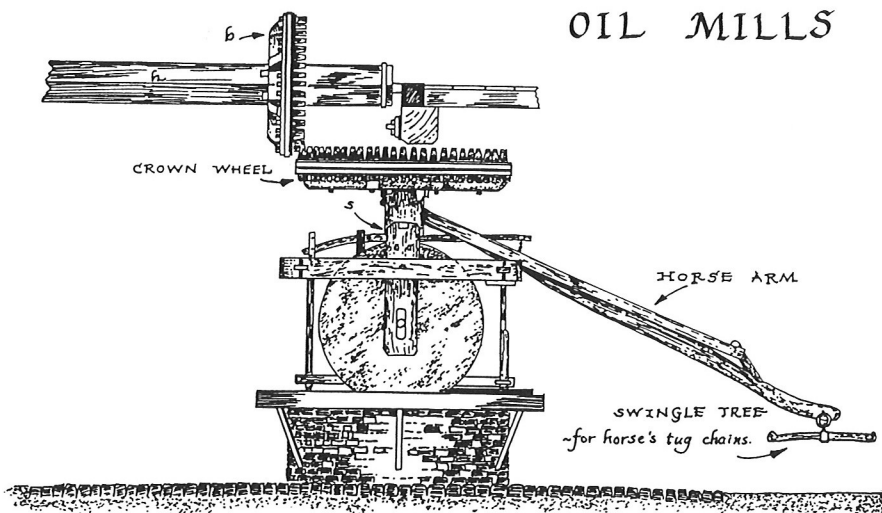
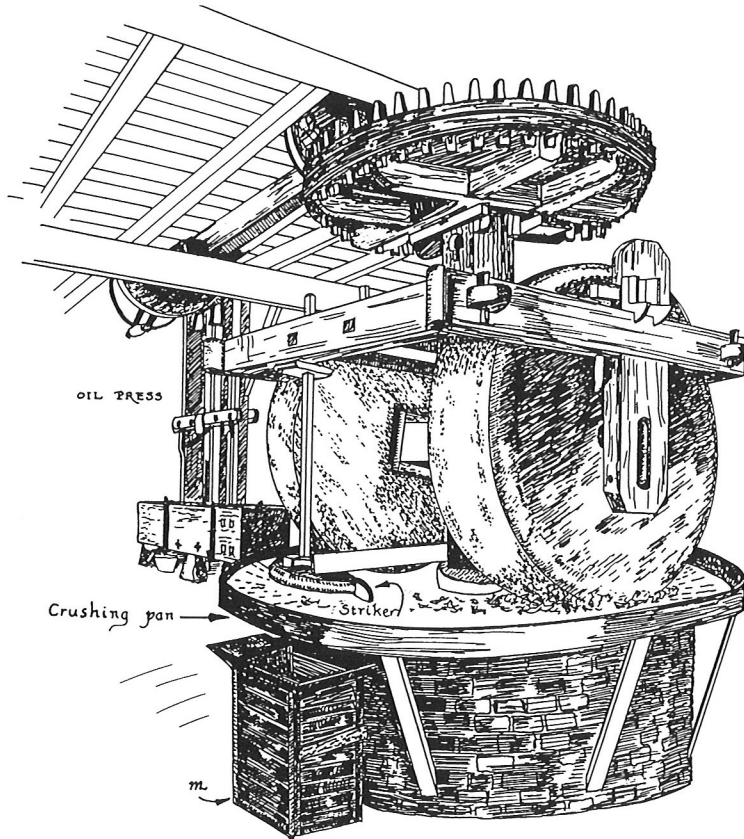
The fulling mill may at some time have become the site of an oil mill. Certainly there was an oil mill here before 1669, for a deed of that year refers to one that had been 'lately' changed into powder mills. The deed specifies:

All that Mill heretofore an Oyle Mill and now lately converted into two Powder Mills ... with all necessary outhouses for grindinge boylinge corninge & drying of powder ... now in the tenure or occupation of Samuell Hudson or his undertenants.<sup>18</sup>

All that was needed for making powder was here: outhouses for 'boylinge' or refining the saltpetre and sulphur; mills for 'grindinge' or incorporating the ingredients until they were thoroughly mixed; sieves for 'corninge' the resulting 'mill cake' to produce separate grains of powder; and some provision for drying, probably on trays, to remove the water added for safety during the preparations, before the powder was packed in barrels for ease of transport.

The conversion of an oil mill to a powder mill would have presented no difficulty, for the standard equipment found in the former would have included edge runners under which seeds were 'brayed' before being pressed to squeeze out the oil for food, lamps, and soap (Fig. 3) and such edge runners were to become standard equipment in powder mills for the incorporation under pressure of the several ingredients (Fig. 4). The similarity between the two processes was referred to in my earlier Newcomen paper when I introduced the evidence of Sir James Hope, a Scottish lead mill owner travelling in Zealand in 1646, who wrote in his diary of seeing '2 oyle milnes ... lyke unto our ordinarie poudre milnes ... consisting of tuo stoness turned upon edge'.<sup>19</sup> However that is the first reference known so far in Britain to the use of edge runners rather than stamps in the gunpowder industry; if there was indeed a transfer of function at the Waltham Abbey Mills in the 1660s, from braying oil to incorporating gunpowder, then this would provide a second early example of the use of edge runners in powdermaking.<sup>20</sup> Similar examples of this





OIL MILLS

Fig. 3 A Dutch Oil Mill, from John Vince, *Power Before Steam* (John Murray, 1985), p. 43. Reproduced by courtesy of the author.



Fig. 4 Edge runners in a restored incorporating mill, Chart Mills, Home Works, Faversham. Photograph provided by Arthur Percival.

adaptability in the use of equipment are growing in number—in Hanover for example, a powder mill established south of the city of that name in 1672 served other uses from the turn of the century, including that of an oil mill. Also when the ‘roll’ or edge runner mill, known in Germany from the Middle Ages but adopted more quickly by the wealthier Dutch, was introduced in north-west Germany, it was employed first in the manufacture of oils. Its use then spread to powdermaking where its advantages were thought to be those of *quality*, because the product was more homogeneous and better compressed than when stamped and *safety*, because the edge runners exerted a steady and consistent pressure rather than a pounding as in the stamp mills.<sup>21</sup> It seems however that at Waltham Abbey the stimulus behind the change from oil to powdermaking was the shortage of the latter during the Second Dutch War of 1664–67, when the officers of the Board of Ordnance were ordered to ‘impreſſe ſoe many Mills for ye makeng of gunnpowder for his Matie Service as they ſhall think fitt’. The urgency of these circumstances, which led in February 1665 to the signing of an Ordnance contract with Ralph Hudson, brother of Samuel mentioned above,<sup>22</sup> suggests that to meet this requirement edge runners may have been adopted from necessity rather than, as is more generally thought, because of their technological advantages.

From the 1660s prolonged, though intermittent, warfare created rich opportunities for powdermakers such as the Hudson family of Waltham Abbey. At the beginning of the Third Dutch War of 1672–74, Ralph Hudson secured a new contract from the Board of Ordnance which led to the establishment of additional powderworks at Hooks Marsh Bridge, north of the Waltham Abbey Mills, though these were of uncertain duration. On Ralph Hudson’s death in 1676 the business

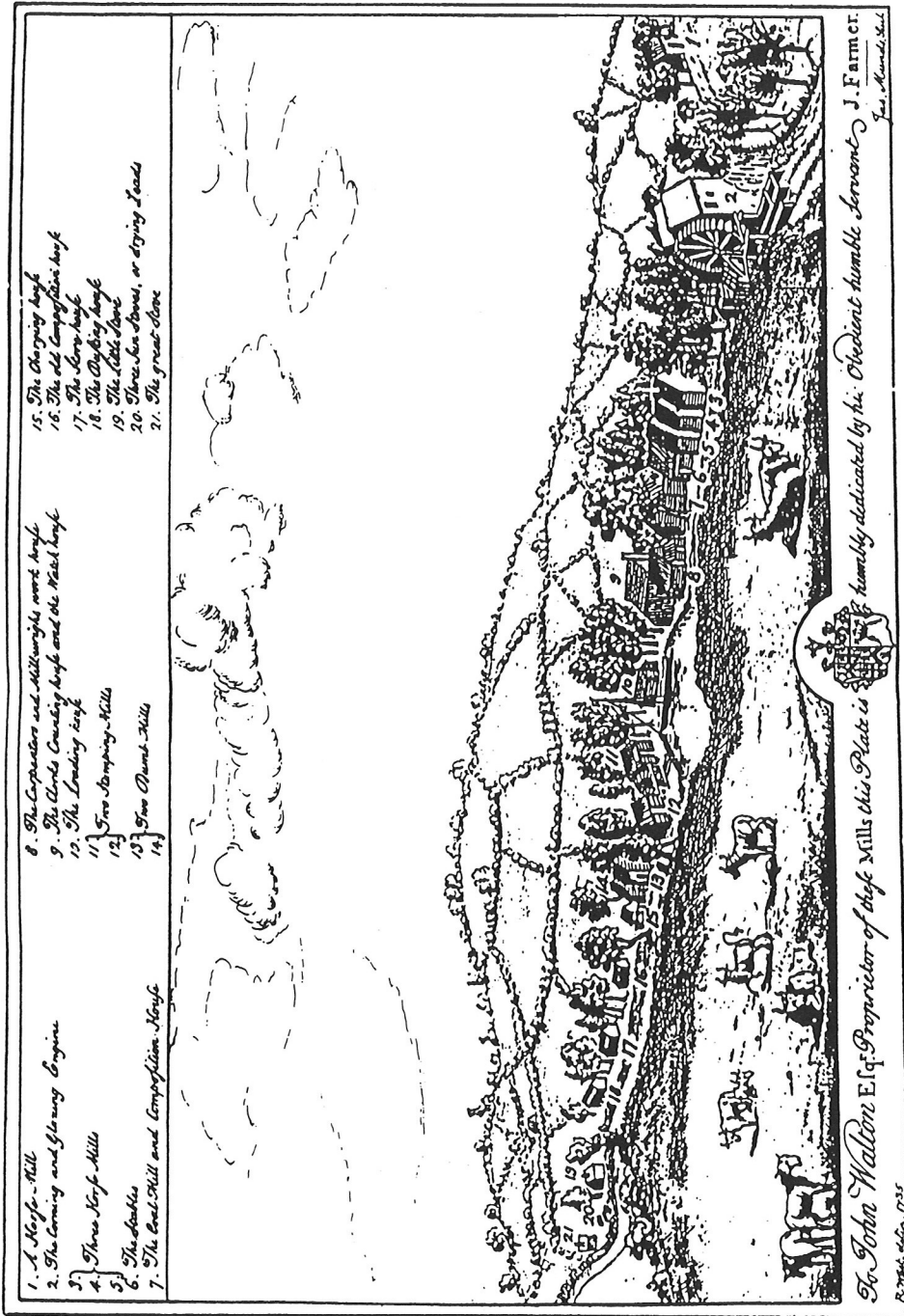


Fig. 5 Engraving of the Waltham Abbey Powder Mills by John Farmer, History of Waltham (1735), viewed from the west.

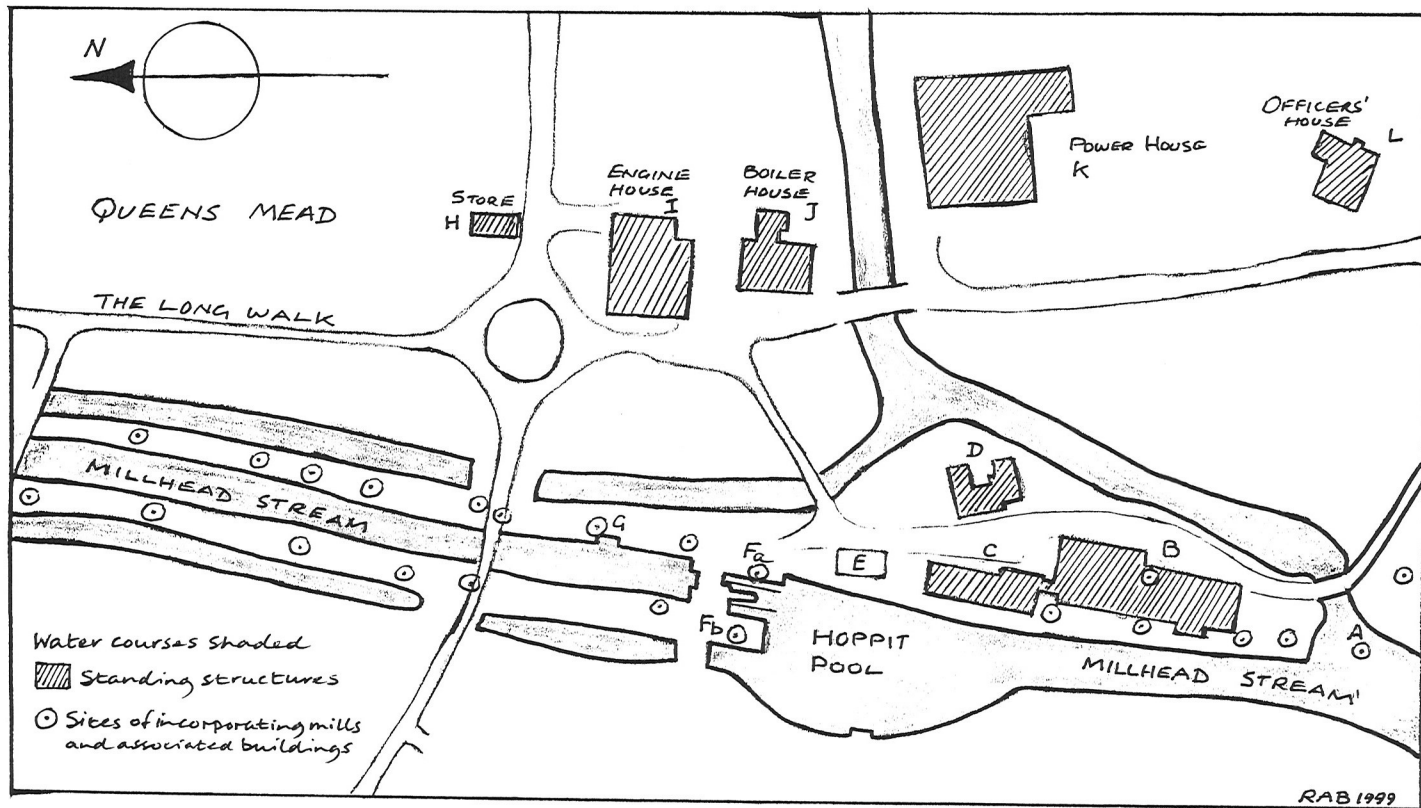


Fig. 6 Sketch plan of 'The Old Establishment' at Waltham Abbey.

A Site of Corning & Glazing Engine  
 B Modern Administration Block  
 C Saltpetre Melting House and the Mixing House

Drawn by R.A. Buchanan

D Walton's House  
 E Site of Loading House  
 F Site of the Head Mills  
 G Probable site of Smeaton's Mill.

passed to his brother Peter, who continued to receive contracts from the Board of Ordnance until it was discovered that in some cases powders of different quality had been packed misleadingly in the same barrel. Hudson blamed his workmen and the case was dropped, but he received no further orders and by the time of his death the works had been taken over by William Walton, who signed his first contract with the Board in 1702. In 1711 Walton died, but the family connection with the works continued and, contrary to the experience of other powdermakers who moved out of this business after the conclusion of the War of the Spanish Succession in 1714, they continued to be run successfully by William's widow Philippa and her descendants until bought out by the Board of Ordnance in 1787.<sup>23</sup>

It is to Philippa Walton's son John that we owe a significant piece of evidence about the early Waltham Abbey Gunpowder Mills, namely a topographical illustration in John Farmer's *History of Waltham* (1735) which provides a careful representation of the different buildings, and a key to their use (Fig. 5). In the following text, these features are identified by the prefix JF. Farmer's claim that these gunpowder mills 'supply the nation with great quantities of gunpowder, being esteemed the largest and compleatest works in Great Britain'<sup>24</sup> may be hyperbole, but the drawing itself presents us with what is probably the most accurate and best representation of a gunpowder mill of this period that is yet known. We are doubly fortunate that the detailed survey, undertaken by the RCHME after the site had been decommissioned,<sup>25</sup> allows us to locate in the present landscape (Fig. 6) some of the structures seen in Farmer's engraving. The features shown in Fig. 6 are identified in the following text by the prefix RAB. A comparison of the two drawings suggests that the present Lecture Theatre (RAB, B) stands at the core of this historic site, on the east bank of the Millhead Stream at the point where in 1735 Horse Mills (JF3, 4, 5) and adjoining Stables (JF6) would have been located. Here, after being refined, the saltpetre and sulphur would have been pulverized to a fine powder. Nearby was a Coal Mill and Composition House (JF7), where the charcoal would have been ground and the raw materials weighed and assembled (RAB, C). Also to be found in this central location was the workshop of the Carpenters and Millwrights (JF8) and the Clerks Counting House and Watch House (JF9), which were probably forerunners of the building known later as the Master Worker's House and now as Walton's House (RAB, D). Outside the Loading House (JF10, shown in outline as RAB, E) a vessel, forerunner of such Thames-going ships as the *Lady of the Lea*, awaits the barrels of powder it will carry to London.

In contrast to the horse-powered mills in which the ingredients were prepared, their incorporation would have taken place in two water-powered Stamp Mills (JF11, 12 & RAB, Fa and Fb), at the head of the leat serving the site and on either side of a large waterwheel. Further along the Millhead stream Farmer shows two 'Dumb Mills' (JF13, 14), which present our greatest problem in the interpretation of this illustration since the term is now unknown. Were they dumb because they were missing a vital part as a 'dumb bell' is minus its clapper? Or does the term come from the vernacular name for a wooded valley, a 'dumble'? Or were dumb mills equipped with edge runners which operated more quietly than the stamps? Or was there an over-capacity at the mills in this period of peace, so that these two were out of use and therefore silent or 'dumb'?<sup>26</sup> Whilst the last reason might be the most likely, the possibility that these mills were equipped with edge runners rather than stamps remains an intriguing one. Further along the line of the Millhead stream there was the Charging House (JF15) and the Old Composition House (JF16), the former a magazine where 'charges' could be stored safely whilst awaiting further processing, and the latter the workshop where batches of ingredients would be assembled for a preliminary mixing before incorporation under the pressure provided by stamps or edge runners.

At this stage Farmer's illustration shows a break in the production flow, for after incorporation the resulting millcake would have been returned to the southern end of the site, to the Corning and Glazing Mill (JF2 & RAB, A), to be corned by being forced through a sieve to produce separate grains, and then glazed by tumbling in a barrel to which lead had been added. This

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compacted the powder and imparted a sheen that would afford some protection to the grains, especially during transport. That these processes took place in the most impressive building on the site, a substantial mill with a large waterwheel, provides some indication of the importance of this part of the process. The location of this mill is also significant, for it suggests that it may have been the oil mill noted earlier and so perhaps also the first incorporating mill on the site. The sequence then returns to the northern end with a Dusting House (JF18) where broken grains and dust would be filtered from the corned and glazed powder; a Store Room (JF19); and various Drying Rooms including three small Sun Stoves (JF20) where powder was probably laid on trays to dry in the sun; and two more modern stoves, the Little Stove and Great Stove (JF19, 21), which were probably heated by hot air circulating from a stove placed outside the chamber for safety.

### SUPPLY AND DEMAND

In the mid-eighteenth century the smouldering rivalries between Britain and France broke out once more, and the fact that engagements were fought in Europe, North America and India, and at sea, gave the Seven Years War of 1756–1763 the distinction of being the first world war. The challenge to the Board of Ordnance of maintaining supplies was immense. This responsibility has previously been thought of only in terms of contracts signed and deliveries made, but the private correspondence of the Lieutenant and later Master General of the Board, Sir John (later Lord) Ligonier, shows the reality behind this. As early as the 15th October 1755, he was writing to his deputy Charles (later Sir Charles) Frederick, 'The Powder Runs In my head and [I] think all the Contractors ought to be summon'd and talked to, Pressed to work for the king, for I fear our Powder will go abroad if a Better Price is offered'. Two days later he wrote commenting on the reduction of the 11,000 barrels in store to 7,000, '... what a fatall thing might this prove to be'. And when things were going badly in the early phase of the war he wrote to Frederick on 9th February 1757, 'I don't know where it is proposed to find ammunition for the expedition army', and again on the following day, '... all the Expence and Hope of Success In this expedition is Gone for nothing Without this material'.<sup>27</sup>

In these circumstances of dire need, family businesses like that of the Waltons at Waltham Abbey (in the hands of Thomas and Bouchier Walton from 1757, following the death of their brother John) were well-placed to take advantage of the opportunities offered, though the motive may have been profit as much as patriotism. The problems were often considerable—in June 1757 for example, the Waltons lost some one-third of an incoming cargo of 20 tons of saltpetre when a barge sank between the warehouse in Rotherhithe and the mills at Waltham Abbey. By 1758 the needs of the Board were so pressing that the proprietors offered to work the Waltham Abbey Mills on Sundays but, despite this, they and several other powdermakers were unable to meet the targets set.<sup>28</sup> In an effort to diminish this reliance on private suppliers, the mills at Faversham were purchased by the Crown in 1759.<sup>29</sup> This experiment was not at first a success, perhaps in part because the Board wanted to use the mills to re-work its growing stocks of unserviceable powder stored at Greenwich, unloaded for example from ships which had been at sea. The result was that in that year only 7.3 per cent of the barrels from Faversham passed proof, whilst 81 per cent of those from Waltham Abbey did so, representing 3,199 barrels out of nearly 4,000 submitted. The Waltham Abbey powdermakers were not however immune to criticism and, in May 1759, they and certain others were rebuked for the inadequate corning which had left the powder with a high dust content, thus reducing the number of grains per barrel received.<sup>30</sup>

In 1760 and 1761 the strain on the Board of Ordnance and its Master General increased. In October 1761 the Board wrote to Ligonier to express their concern that, with the growing military and naval activity, the demand for powder was much greater than its supply. To help remedy the situation an offer was made, that if the manufacturers met their contracts they would for one month receive an advance of 5s per barrel, provided that 80 per cent of those submitted passed proof. Out

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of nine firms participating, only four met these conditions and of these the Waltham Abbey Powder Mills led the field. Their target of 400 barrels was also well ahead of their nearest rivals at 300 barrels. The Board continued with this monthly incentive and it seems that the Waltham Abbey proprietors sought to capitalize on this success, for they informed the Board in the spring of 1761 that they were building an additional mill,<sup>31</sup> although this may have been a replacement for one lost in an explosion in May 1760, when one workman was killed and another injured.<sup>32</sup>

Perhaps encouraged by their success in meeting the targets set, the Waltons made a request to the Board which provides a rare insight into their continuing private activities, for they asked permission to sell 250 barrels to London merchants for use in the Africa trade (by which West Africans were 'purchased' by barter goods such as gunpowder, often in kegs for ease of handling, and then transported across the Atlantic into slavery).<sup>33</sup> The advice of the Board to the Master General that, although the proprietors had supplied 25 per cent of all the powder passing proof, they could have produced more if they had not also been supplying private trade, suggests that these private sales had been going on for some time, with a consequent diversion of wartime resources, particularly saltpetre, away from the military and towards the merchants. In November 1761 the proposal was rejected. That outlet having been blocked the Waltons made a further proposal which was accepted—that they should produce exclusively for the Board for one whole year (March 1762–63), provided that they were allowed £1.5s 'for the workmanship per barrel'. The high rate of output continued, and in 1762 the Waltham Abbey Gunpowder Mills were leaders amongst the six establishments which that year produced more than ever before in the war. With peace in sight the pressure was relaxed; a request from Waltham Abbey that they should be allowed to supply the East India Company with 300 barrels was accepted, though this decision may also have owed something to the fact that, in the years 1760–62, Bouchier Walton was a director of that body,<sup>34</sup> thus providing a good example of the interlocking interests of the powder producers and the London mercantile and financial houses.<sup>35</sup>

## FURTHER DEVELOPMENTS

Production on the scale here suggested, for military and civil use, must have required a considerable extension of the facilities shown in Farmer's engraving of 1735. The Waltons' plan to build another mill in the 1760s has been noted; the outcome of that scheme is not known, but then in the early 1770s Bouchier Walton commissioned the millwright and engineer John Smeaton to design a watermill for the site—the drawings and notes suggest that two were designed and that one at least was erected. Other incorporating mills followed suit so that by 1783, as a plan of that date shows, a total of seven such mills had been built on the Millhead Stream. These were presumably constructed in response to civil demand and the requirements of the War of American Independence of 1776–1783, although it should be noted that it was largely the problems of supply in that conflict which led to the purchase by the Crown of the Waltham Abbey Mills in 1787. Plans dated 1801 and 1806 provide useful information on the layout, supplementing the report by John Rennie of 1806 already mentioned.<sup>36</sup>

The intensified use of the site in the third quarter of the eighteenth century is shown by the seven new mills in Fig. 7, where the relevant section of the 1801 plan has been selected for display because it is little different from that of 1783 but much clearer. The buildings at the lower part of the site show a remarkable continuity of purpose, though whether these were still those of the 1730s or new ones performing a similar function is not known. Here were still to be found the workshops, where the raw materials were prepared for incorporation, and the administrative offices, including the Grand Watch House and the Master Worker's House and Office. This last named is particularly interesting for, with the Mixing House and Saltpetre Melting House opposite, it is one of the few buildings of the Old Establishment which still survive (RAB, C and D), although these were constructed after the Board of Ordnance had taken over the works and Major William Congreve of the Royal Laboratory at Woolwich had been placed in overall charge.<sup>37</sup>

'THE OLD ESTABLISHMENT'

The water-powered stamp mills already examined in Farmer's engraving (JF11, 12) have a significance which goes beyond their own importance as an earlier method of incorporation, for they also provide a link within the Old Establishment between the core of the site and its northerly extension from the 1760s. It is likely that they were replaced by the two water-powered edge runner incorporating mills known as the Head Mills (RAB, Fa and Fb). In Farmer's engraving the stamp mills are shown either side of a large water wheel, at the southern end of a substantial leat. This leat, taken from the Old River Lea at Hooks Marsh Bridge (site of the subsidiary gunpowder mill mentioned earlier, built by Ralph Hudson in the 1670s) and marked on the plans of 1783 and 1801 as the Mill River though known later as the Millhead Stream, was crucial to the extension of the facilities within the Old Establishment. Here, between the 1760s and 1780s, there were built in their probable order of construction: the Head Mills, Smeaton's Mill, the Hoppit Mill, Queens Mead Mill, and the New Mills. By the time of the 1801 plan (Fig. 7) the New Mills had become

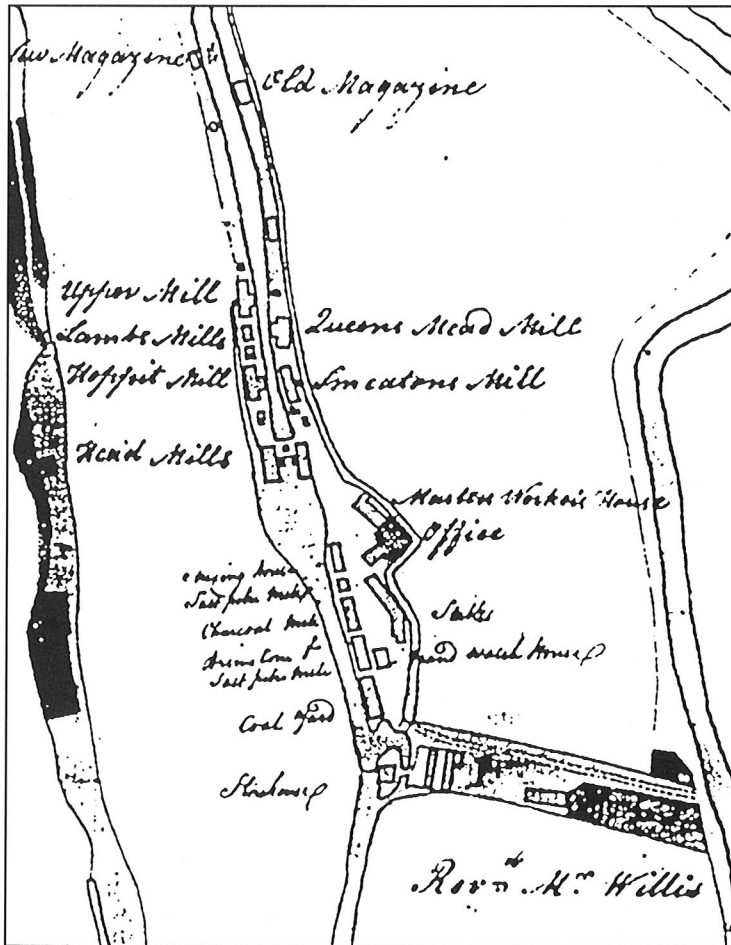


Fig. 7 Section of 'A Plan describing the whole of the land and its situation at Waltham Abbey belonging to the Board of Ordnance', 1801 (PRO, MR 580 [2], extracted from WO 78/2591). Reproduced by permission of the Public Record Office. The name below the Coal Yard so far defies interpretation, but may indicate the site of the corning and glazing mill.



## 'THE OLD ESTABLISHMENT'

separately identified as Lambs Mills and the Upper Mill and, by the time of Rennie's Report in 1806, the two Head Mills had become known as the West Head and East Head Mills. If as has been suggested the last-named were a replacement for the water-powered stamp mills shown by Farmer, this change-over was probably undertaken not only to achieve a greater efficiency, but also in anticipation of such mills being outlawed in 1772 in the interests of greater safety.<sup>38</sup>

### INTERPRETATION

The present condition of the upper part of the Old Establishment means that the identification of these seven mills and their supplementary buildings, such as the charging houses shown on the 1783 plan, must rest to some extent on conjecture, on a linking of the historical evidence from the several plans and Rennie's Report with any foundations uncovered by the RCHME's survey. The same is also true of the watercourses, not only the Mill River or leat which powered the incorporating mills, but also the tail races which carried away the waters, both often now overlain by later developments or filled in by rubble. Although now partially modified, the importance of the Millhead Stream must not be overlooked for it was vital to the extension of the facilities within the Old Establishment.

Little is known about the Head Mills, though there is a fresh representation of them in the plan of 1806 (Fig. 8) and recent photographs (Figs. 9, 10, 11). They may have been erected as a pair, because when Rennie undertook his survey of 1806 he noted that both had waterwheels of

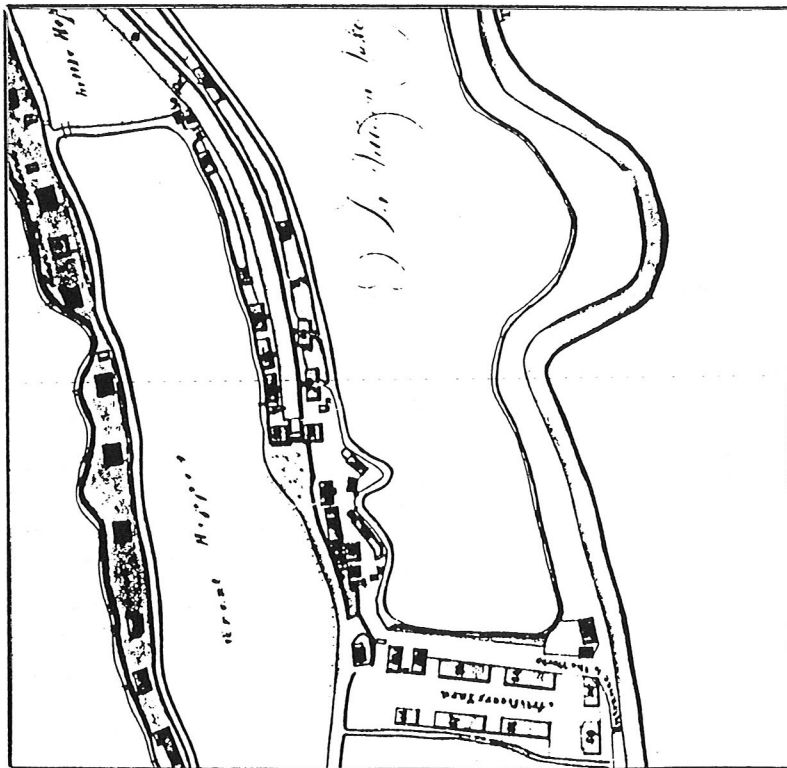


Fig 8. Section from a 'Map of the whole site including Lower Island', 1806 (PRO, MR 580 [3], extracted from WO 78/2591). Reproduced by permission of the Public Record Office.

*'THE OLD ESTABLISHMENT'*

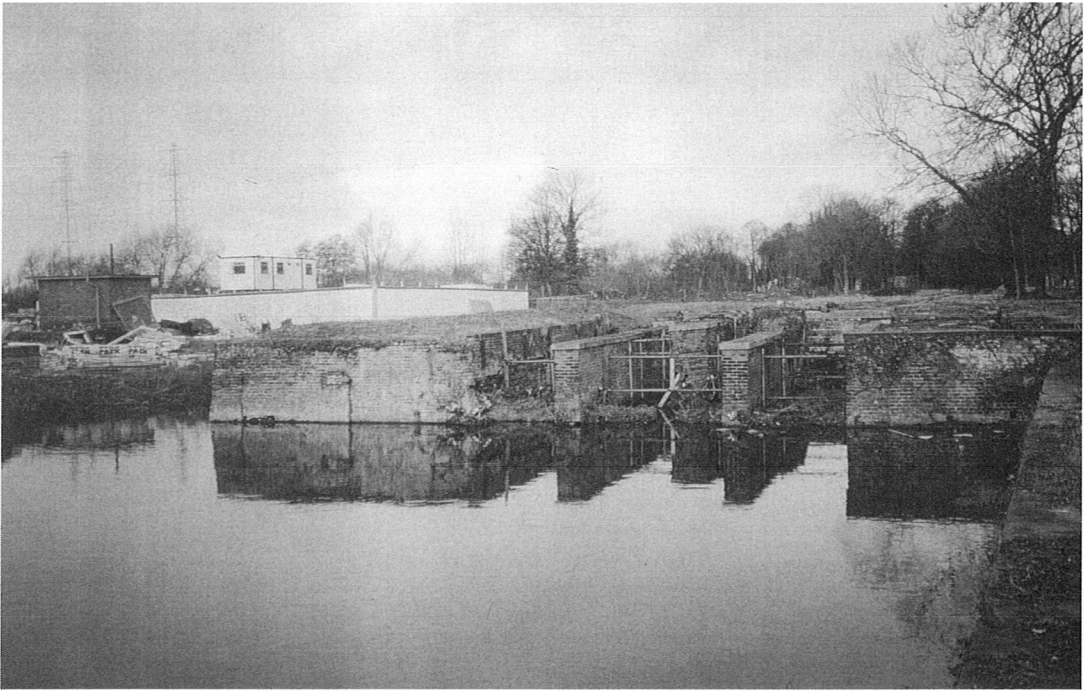


Fig. 9 Site of the twin Head Mills on the Millhead Stream, viewed from the Hoppit Pool. Photograph by R. A. Buchanan.

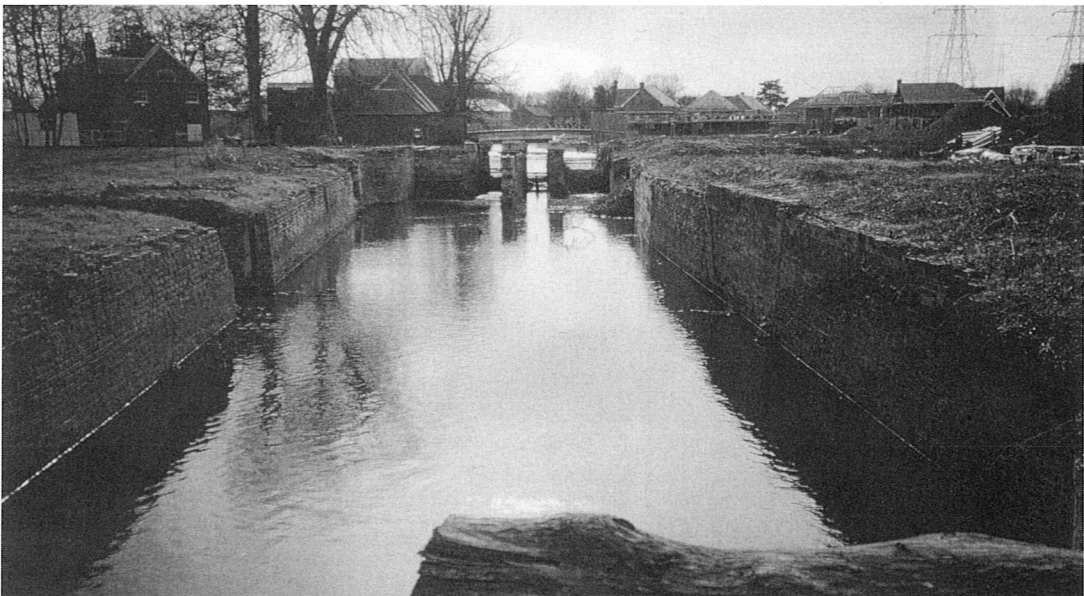


Fig. 10 Site of the twin Head Mills, looking downstream, with the site of the probable Smeaton's Mill clearly visible on the left. In the further distance see also the side of Walton's House, with the Saltpetre and Mixing Houses across the courtyard—all these are buildings of the later 1780s. Photograph by R. A. Buchanan.

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Fig. 11 Details of the site of the East Head Mill, showing a complex layering of pits and masonry. Photograph by R. A. Buchanan.

identical dimensions—15 ft diameter with a float 6ft 4ins wide. The 'floats' were the paddles on which the weight of the water fell in the case of low breast wheels, and the fact that Rennie refers to these, and to the general fall of water in the cases he examined as 5 ft 8ins, indicates that the incorporating mills at WARGM were then powered by low breast wheels (Figs. 12, 13). It is appropriate that the former clear illustration should come from a Newcomen Society paper on 'The Waterwheels of John Smeaton', for the design for the next mill or mills at Waltham Abbey was undertaken by Smeaton, who in the early 1770s also worked on schemes for powder works at Hounslow Heath in Middlesex and Worcester Park in Surrey.<sup>39</sup> Smeaton was commissioned by Bouchier Walton and responded with drawings for Waltham Abbey which, intriguingly, refer to more than one mill. Three of the drawings (Figs. 14, 15, 16) signed in 1771, refer to a plan for a mill on 'the West Side of the Mill Pond'. The flow of water shown in Fig. 14 confirms this intended location; the plan and upright drawings of Figs. 15 & 16 provide additional information about underdriven gearing in a large lined vault. The waterwheel designed to provide power for two sets of edge runners is shown by Smeaton with a diameter of 14ft and width of 6ft. The location of this mill is a problem. At a first consideration the most likely candidate on the west side of the mill pond is the Hoppit Mill, for the West Head Mill was built earlier and the Lambs Mill and Upper Mill both came later, appearing on the map of 1783 as the 'New Mills'. But by

## THE WATERWHEELS OF JOHN SMEATON

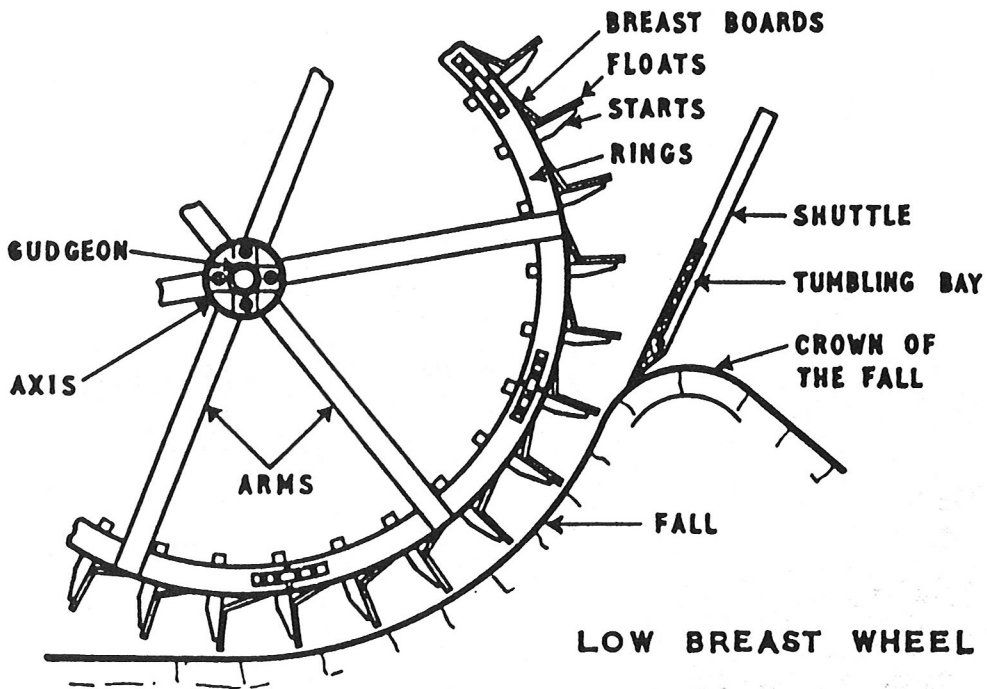


Fig. 12 Drawing by Paul Wilson showing the typical low breast wheel constructed by Smeaton. See Paul N. Wilson, 'The Waterwheels of John Smeaton', *Trans. Newc. Soc.* (1960), p. 28.

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Fig. 13 The surviving iron 'crown of the fall' at the intake to Smeaton's Mill on the Millhead Stream at WARGM. Photograph by R. A. Buchanan.

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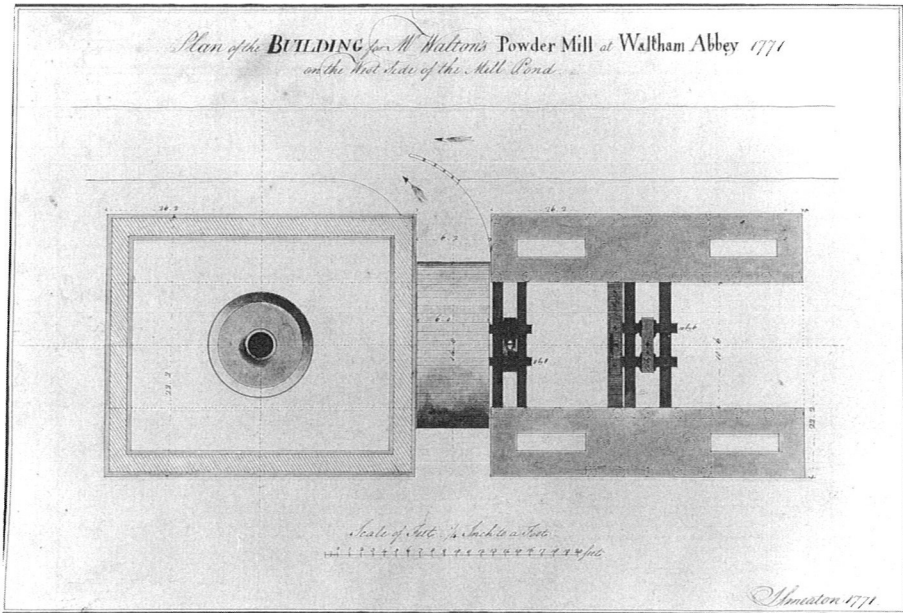


Fig. 14 'Plan of the Building for Mr. Walton's Powder Mill at Waltham Abbey, on the West Side of the Mill Pond', 1771, ink wash. See the *Catalogue of the Civil and Mechanical Engineering Designs of John Smeaton, 1741-1792*, (Newcomen Society, 1950), f.36v. Reproduced by permission of the President and Council of the Royal Society.

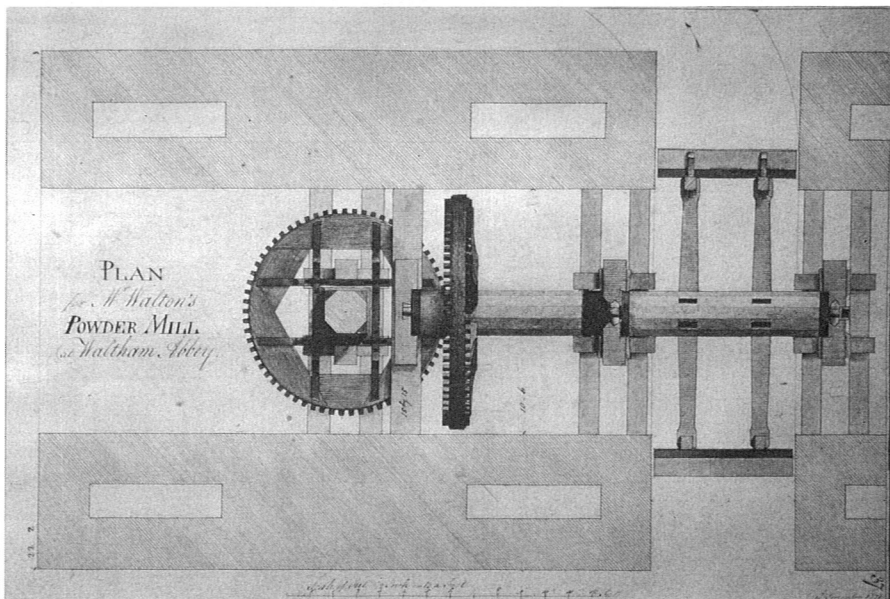


Fig. 15 'Plan for Mr. Walton's Powder Mill at Waltham Abbey', 1771, ink wash. *Catalogue*, f. 37. Reproduced by permission of the President and Council of the Royal Society.

'THE OLD ESTABLISHMENT'

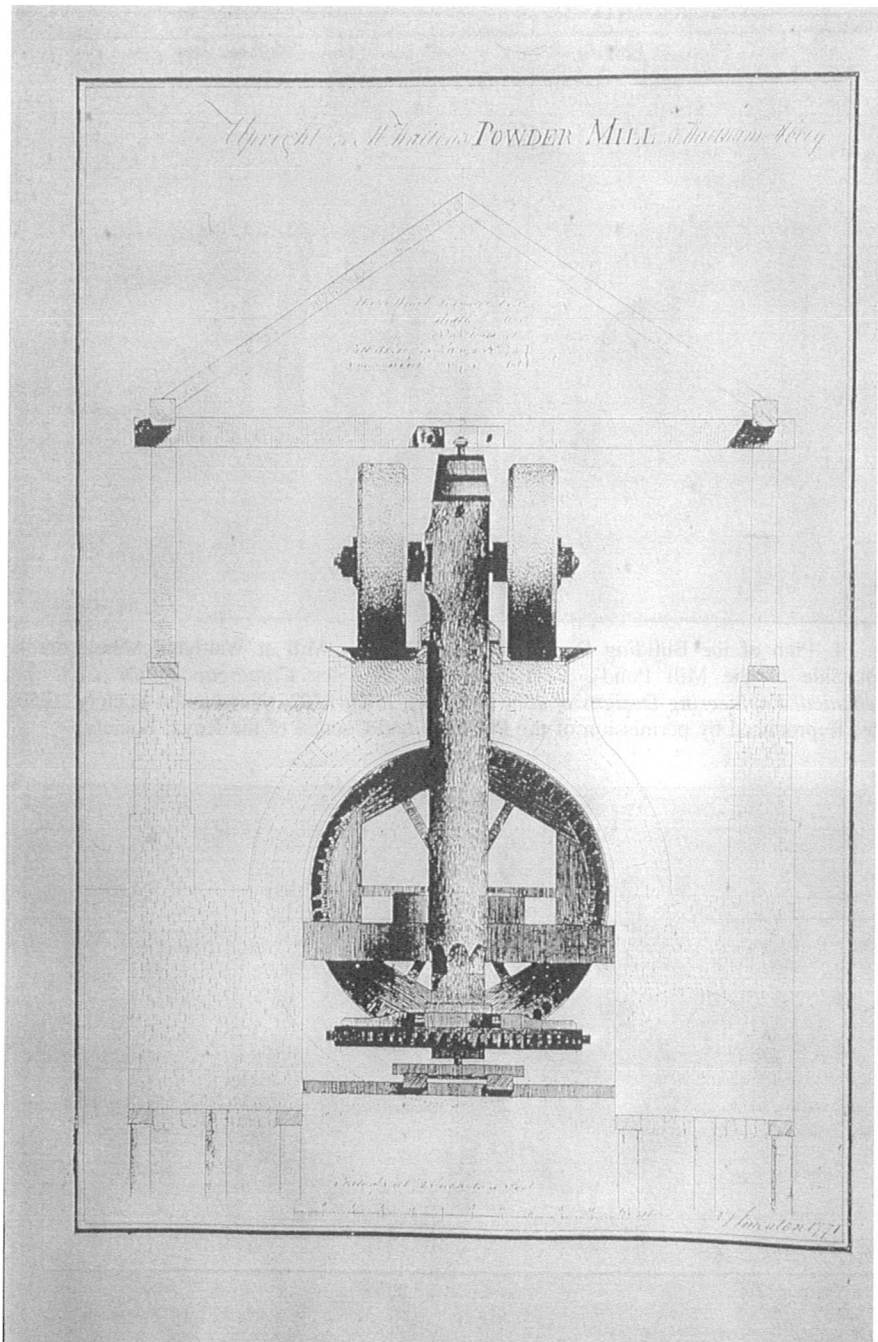


Fig. 16 'Upright for Mr. Walton's Powder Mill at Waltham Abbey', 1771, ink wash. *Catalogue*, f. 38v. Sectional elevation showing edge runners and underfloor gearing. Reproduced by permission of the President and Council of the Royal Society.

### 'THE OLD ESTABLISHMENT'

Rennie's calculation the Hoppit Mill wheel had at 15ft (with a float of 6ft 10 ins) a diameter greater than in Smeaton's drawing, so perhaps despite being designed for the west side, this mill was actually built on the east, and may be that long-known as 'Smeaton's Mill' (Fig. 6, RAB,G). However, the problem has not been fully resolved, for although according to Rennie's work the diameter of this wheel was at 14ft the same as in Smeaton's drawing, its float was at 6ft 11ins greater than the 6ft shown there.

Smeaton's second design for Waltham Abbey was unusual, for instead of a central water-wheel driving an incorporating mill on either side (a general pattern in the industry although only the Smeaton, Queens Mead and East Head Mill wheels are referred to by name by Rennie as working 'two pairs of Runners') there was what Smeaton called a 'double stack', with one set of edge runners driven directly and the other by a long shaft, with connecting gears at both ends (Fig. 17). If this design was ever built it would have required an unusual ground plan, of which there may be a hint in the representation of Lambs Mill on the plan of 1801, for this shows two separate buildings rather than the T-shape block by which the mills (other than the two Head Mills) are represented. But Rennie makes no reference to a 'double stack' and it is likely it was never built. He recorded the diameter of the waterwheel at Lambs Mill as 16ft 10ins with a float of 6ft 5ins. There remain for consideration only the Queens Mead Mill on the eastern bank of the Mill River, and the Upper Mill on the west. From Rennie's Report, the former had a wheel that was 16ft 7 ins in diameter with a float of 4ft 10ins, and the measurements of the latter were respectively 16ft 11ins and 5ft 11ins.

The seven incorporating mills on the Millhead are shown by the maps and plans consulted to have been served by a number of buildings in which other aspects of the work of production were carried out. There were for example two charging houses for the storage of the dangerous mix between processes, and a magazine to house the final product. Two 'running houses' are of uncertain purpose but may have been glazing houses in which powder grains were 'run' or revolved in barrels. It is a strange anomaly that according to the 1783 plan a hand-crank corning house had been built to service the new mills, but this may have been an emergency measure to make good the loss of the impressive 'Corning and Glazing Engine' of Farmer's engraving' due to an explosion in 1781 in which three men were killed and much damage done in the town.<sup>40</sup> By the time of Rennie's Report a successor had been built on a similarly impressive scale, for he recorded that the waterwheel had a diameter of 18ft (though the smudged figure in the Report might read 16ft), and a breadth of 4ft 11ins. Rennie notes that 'she' was not in operation when he saw 'her', but he was informed the usual rate of working was nearly four revolutions per minute.

Rennie's Report is important for the naming and description of the seven mills of the Old Establishment set up during the third quarter of the eighteenth century, and it also adds significantly to our understanding of the layout of the powder works at this time. His calculations, especially with regard to the critical dimensions of the waterwheels, have been quoted with confidence because this experienced engineer conducted a close examination of them. But the report is about more than measurement—it is a delight to read because it shows an expert addressing a problem, that of achieving maximum efficiency in the use of limited waterpower at an unusual site of manufacture. This was an important challenge, not only on the grounds of engineering and the prevention of any wastage of energy, but also on the grounds of powder making and the maintenance of continuity, for as the saltpetre, sulphur and charcoal were ground together under pressure in the vital process of incorporation which lasted for several hours, it was essential that any interruption or change of rhythm or pressure should be avoided, for this could affect both the safety of the procedures and the quality of the finished product.<sup>41</sup>

In order to avoid such interruptions some powder works would close down altogether in a dry summer month, taking advantage of this time to do the stocktaking.<sup>42</sup> Although there were at times problems of supply at WARGM, the question addressed by Rennie was not so much the vol-



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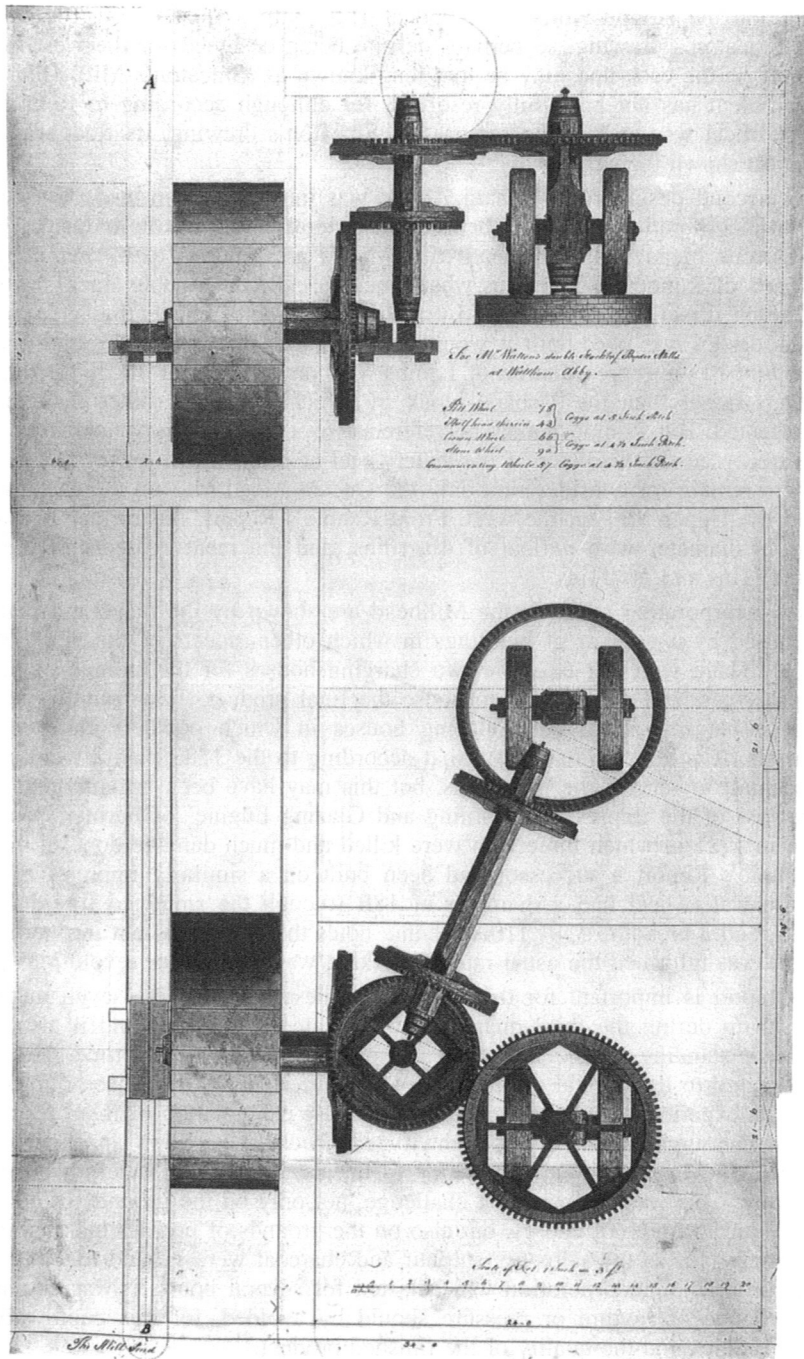


Fig. 17 'For Mr. Walton's Double Stack of Powder Mills at Waltham Abbey', [1771], ink wash. *Catalogue*, f. 33v. Elevation and plan of gearing. Reproduced by permission of the President and Council of the Royal Society.

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ume of water but inadequacies in its application. In his Report he noted that above Waltham Abbey the River Lea divided into three streams, of which that serving the Cheshunt corn mill had been 'stopped up' for some time, its water going to the gunpowder works and the Abbey corn mills, with the major share to the former. Despite the difficulties of calculating the flow of water, all fully explained in the Report, he reckoned that the powder works received about 76 cubic feet per second and the Abbey corn mills about 44 cubic feet per second. But he estimated that at the powder works a quarter of this power was lost because in order for the edge runners to make  $7\frac{1}{4}$  revolutions per minute (which is so generally mentioned that it must have been thought the most suitable for the task in hand) the waterwheels had to sustain a rapid rate of revolution—exacerbated by the impossibility of regulating the inflow of water to the floats due to the inflexibility of the immovable crown stones. He commended the late Mr. Smeaton's waterwheel as having the slowest movement ( $6\frac{3}{4}$  revolutions per minute), but even that was too fast. The Hoppit Mill wheel moved fastest of all with  $9\frac{1}{2}$  turns per minute (which makes it even more unlikely that this was a second Smeaton mill). To reclaim the lost power and increase efficiency Rennie recommended that the mills should all have identical wheels (16ft diameter being most suitable to the fall, with a 'proportionable' increase in the width of the floats), each making four revolutions per minute. This would be a difficult undertaking, but it could be achieved by bringing each mill up to standard as it came to need a thorough overhaul. As to the quality of the work done, Rennie recognized that the liability of gunpowder mills to damaging explosions meant that general construction tasks were not always undertaken in a 'perfect manner', but he stressed that moving parts, especially 'inside wheels', should be kept in good condition to reduce the risk of friction, for this could lower performance and raise the possibility of accidents. Rennie believed that if his advice was taken the mills of the Old Establishment could produce about 17,000 barrels per annum.

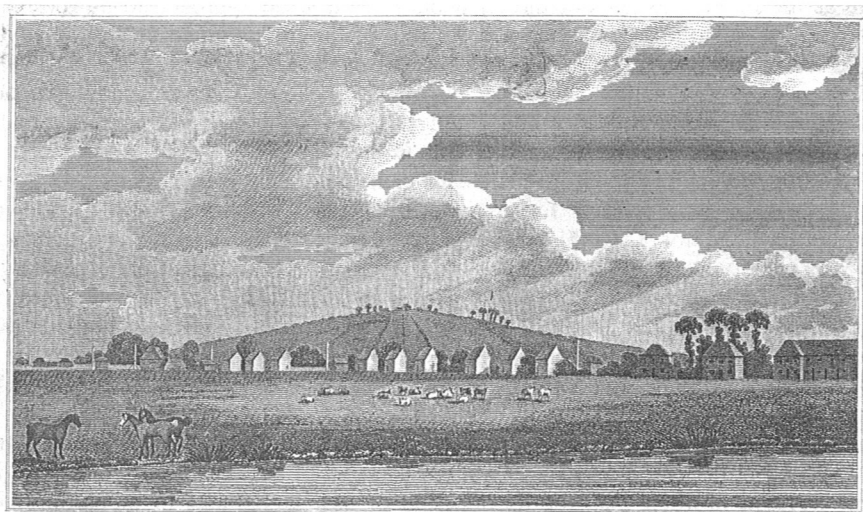
#### 'THE OLD ESTABLISHMENT': THE FINAL PHASE

As late as the middle decades of the eighteenth century the approach to powdermaking was still based largely on custom and practice and the rule of thumb, summed up by the advice of Sir Charles Frederick of the Board of Ordnance to the Bristol powdermakers in the early 1760s, that they should keep on trying so that they may hit on the most satisfactory method as others had done before them.<sup>43</sup> In some countries and amongst some businesses like firework making, this pragmatism continued over the years,<sup>44</sup> but in Britain the loss of the American colonies signalled the need for a new approach. The Ordnance Board came to realise it needed its own premises for research and development as well as for production, and the Waltham Abbey Gunpowder Mills were purchased in 1787 for £10,000. However, details of the deal were not completed until 1795,<sup>45</sup> which may be why, despite the professional approach of William Congreve and the growing interest in scientific aspects of the subject shown by members of the Royal Society, the Old Establishment survived almost in its entirety as the main centre of production until the end of the eighteenth century. There was some refurbishment of old buildings by, for example, the purchase of new mill stones; and some construction of new ones including the Master Worker's House, Mixing House and Saltpetre Melting House (Fig. 6 RAB, C and D & Fig. 18) already noted, as well as a number of drying houses and magazines; but it seems that the improvements undertaken by Congreve related more to the refinement and preparation of the raw materials and an improved testing of the finished powder, than the introduction of new techniques of incorporation. Indeed, the efforts by the Board of Ordnance to supplement the powder produced by the existing water-powered incorporating mills at the time of the French Revolutionary and Napoleonic Wars, had led to the retrograde step of introducing horse-power (formerly used only in the initial processes) as the prime mover of a new row of nine incorporating mills (Fig. 19). Rennie was critical of this system as a way of extending the works, concluding:

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Fig. 18 Walton's House is a rare survival from the early days of the Board of Ordnance at the Powder Mills, although the name and emblem on the wall are associated with the previous private owners. Photograph by R. A. Buchanan.



**POWDER MILLS, WALTHAM ABBEY.**

Published by S. Prichard 212, Abchurch Lane, March 25, 1806.

Fig. 19 'Powder Mills, Waltham Abbey', engraving by Ellis, reproduced in Dr. Hughson's *Description of London* (1808). Reproduced by courtesy of the Essex Record Office. It is likely that this drawing shows the nine horse mills criticised by John Rennie in his Report (1806). Note what may be lightning conductors, and the Board of Ordnance buildings on the right.

## 'THE OLD ESTABLISHMENT'

Of all the powers that can be applied to the working of machinery (except men) Horses are the most expensive and whenever another power can be obtained to work regularly, Horses should not be used. I have no hesitation therefore in advising that no more Horse Mills should be erected & that those which are now at work, should be laid aside as soon as other mills can be erected to perform their work. It appears from an account furnished by the Officers of the Royal Gunpowder Mills, that the expense attending the grinding of a given quantity of Cake by Horses, is fourteen times as much as by water.

Lastly in this survey of the Old Establishment, it comes as something of a surprise to learn from Rennie's Report that, far from being a place of closely-guarded secrecy and controlled entry, there was an unwelcome freedom of access to the powder works. He wrote in his penultimate paragraph:

In the Gun Powder Works at Waltham Abbey, there are common Footpaths which pass quite through the works, and they are in other respects, I may almost say, quite open to the Public. I beg leave humbly to observe, that such an Establishment should be entirely confined within itself & the public should have no access to it without leave. I therefore think that a Ditch & fence should be made round the works, and all public access should be denied without leave. The expence of such an insulating Ditch & fence would not be great, while many advantages would result.

It is pleasing to reflect that the wheel is come in full circle and the Waltham Abbey Royal Gunpowder Mills are now becoming a site to which 'public access' will no longer be 'denied'. But this account of the Old Establishment provides only the first instalment of a complicated history and members of the Newcomen Society (the first to benefit from freer access) should know that Rennie's concluding advice concerned steam power, for he had just heard that at Battle in Surrey Mr. Harvey was 'erecting a fourteen horse power steam engine to work some of his GunPowder Mills without the intervention of water'. He thought a similar course was not necessary at Waltham Abbey, but enquiries should be made as to the success of Mr. Harvey's experiment for it may be appropriate at other of 'His Majesty's GunPowder works'. Steam-powered incorporating mills were not to be introduced at WARGM until the mid-nineteenth century<sup>46</sup> but that, and other developments of the nineteenth and twentieth centuries, takes us beyond the scope of 'The Old Establishment'.

## NOTES AND REFERENCES

1. The background literature on this subject, especially the contributions made by Society members, was surveyed by the author in her earlier paper, 'The Technology of Gunpowder Making in the Eighteenth Century: Evidence from the Bristol Region', *Trans. Newcomen. Soc.*, vol. 67 (1995-96), pp. 125-159. Special reference was made to Oscar Guttman's two-volume account of *The Manufacture of Explosives* (London, 1895), to which a further note may now be added in the light of correspondence recently discovered in the papers of Rhys Jenkins, (Science Museum Library, Rhys Jenkins Papers, Box 46, folder 3). The letters reveal a generous exchange of information amongst these early scholars, see the Appendix to this paper.
2. The Waltham Abbey Royal Gunpowder Mills Charitable Foundation Trust was set up in March 1997 to safeguard the site in perpetuity, and to arrange for its management by an Operating Company. Substantial funds have been received by the Foundation from the Ministry of Defence and the Heritage Lottery Fund. The present author is one of four Foundation Trustees proposed by public bodies, and she is grateful to the Science Museum, by whom she was nominated, for the opportunity to be involved in developments at this important site.
3. Charcoal burning was carried on in the forests of Essex from at least the beginning of the fifteenth century, but the native trees were not best-suited for gunpowder making so plantations of lighter and more porous woods such as dogwood, alder, and willow were established at the Waltham Abbey works and on adjoining land. Until the mid-1790s the wood was charred in the traditional manner on a woodland 'hearth', but this 'pit-coal' was then replaced by the more effective 'cylinder-coal', baked in a

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- closed metal cylinder in the manner devised in the 1780s by Bishop Richard Watson. Local timber would also be used for the heating and refining or condensing of the two imported ingredients, saltpetre and sulphur. In the case of saltpetre refining, potash (potassium carbonate), another local forest and farm product of great importance, was produced in the county until at least the mid-nineteenth century. Victoria County History (VCH), *Essex*, vol. 2 (1907), pp. 372–375, 447–450. See also E Gray, H. Marsh & M. McLaren, 'A Short History of Gunpowder and the Role of Charcoal in its Manufacture', *Jnl. Materials Science*, vol. 17 (1982), pp. 3385–3400.
4. Frederick G. Engelback, 'Her Majesty's Ordnance Factories', *The Army and Navy Illustrated*, Part I (11 Oct. 1899), pp. 105–107.
  5. John Rennie, 'Report Presented to the Honourable Board of Ordnance, 18th September 1806', vol. 4 of Rennie's Papers (9th Dec. 1805—20th Oct. 1807), Archives of the Institution of Civil Engineers. I am grateful to the staff for enabling me to study this document. Other papers are held at the University of Edinburgh where Rennie was a student 1780–83. His biographer has concluded that this education enabled him to apply 'scientific theory, as well as practical experience, to the design of structures, and... to seek out the root causes of problems he encountered...'. Cyril T.G. Boucher, *John Rennie, 1761–1821, The Life and Work of a Great Engineer* (Manchester Univ. P., 1963), p. 7.
  6. VCH, *Essex*, vol. 5 (1966), pp. 162–5. Three corn mills were recorded in the manor of Waltham in 1086. By the early fifteenth century there was a fulling mill (recorded on a map of c.1590, Essex Record Office, T/M 125) on the site later occupied by the gunpowder works.
  7. Roger Bacon, *Epistola de Secretis Operibus Artis et Naturae, et de Nullitate Magiae* (Letter on the Secret Workings of Art and Nature, and on the Vanity of Magic), c. 1267. The proportions prescribed by Bacon were: Saltpetre 7 parts (41.2%); Sulphur 5 parts (29.4%); & Charcoal 5 parts (29.4%). Experiments were later made with a wide range of proportions and the standard military mix came to be 75–10–15. In mining and other civil use the proportion of saltpetre was usually lower. For the Chinese origins of gunpowder see Joseph Needham et al, *Science and Civilisation in China*, vol. 5, part 7, *Military Technology: The Gunpowder Epic* (Cambridge, 1986).
  8. J. R. Partington, *A History of Greek Fire and Gunpowder* (Cambridge, 1960), pp. 69–81, discusses the breaking of Roger Bacon's code by Henry W. L. Hime, *Gunpowder and Ammunition, Their Origin and Progress* (London, 1904), chapter 8. For a more recent critical review see Vernard Foley & Keith Perry, 'In Defense of LIBER IGNEUM: Arab Alchemy, Roger Bacon, and the Introduction of Gunpowder into the West', *Jnl. for the Hist. of Arabic Science*, vol. 3 (1979), pp. 200–218.
  9. W. H. Simmons, *A Short History of the Royal Gunpowder Factory at Waltham Abbey* (Controllerate of Royal Ordnance Factories, 1963), pp. 2–3.
  10. See A. R. Williams, 'The Production of Saltpetre in the Middle Ages', *Ambix*, vol. 22 (1975), pp. 125–133, for Honrick's recipe.
  11. Joan Thirsk, *Economic Policy and Projects* (Oxford, 1978). In 1567 the citizens of Maidstone invited craftsmen, including gunpowder makers, to settle in their town, p. 47.
  12. See my paper on 'Saltpetre: A Commodity of Empire', presented at the 26th Symposium of the International Committee for the History of Technology, Lisbon, August 1998, to be included in the forthcoming volume on the proceedings of the Gunpowder Section of ICOHTEC.
  13. E. A. Brayley Hodgetts ed., *The Rise and Progress of the British Explosives Industry* (London, 1909), p. 215.
  14. Richard W. Stewart, *The English Ordnance Office, 1585–1625. A Case Study in Bureaucracy* (Woodbridge, Suffolk, 1996), pp. 86–87. From 1589 almost to the Civil War, the Evelyn family maintained at various times the powder mills at Tolworth (also known as the Worcester Park Mills); at Wotton on the Tillingbourne; at Godstone near the village of that name; and possibly at some time at Kingston-on-Thames. See also VCH, *Surrey*, vol. 2, pp. 311–318 and Glenys Crocker ed., *Gunpowder Mills Gazetteer* (1988).
  15. Thomas Fuller, *The Worthies of England* (1662; new edit. introd. by John Freeman, London, 1952), p. 165. Fuller noted the danger of powder making, '...the mills in my parish having been five times blown up within seven years, but blessed by God, without the loss of any one man's life'. But this

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safety record could not continue and in October 1665 two deaths registered in the parish were of men ‘killed with a powdermill’, Simmons, *A Short History*, p. 6.

16. Keith Fairclough, ‘Early Gunpowder Production at Waltham’, *Essex Journal*, vol. 20 (1985), pp. 11–16.
17. A general survey of the complex waterways is provided by the VCH, *Essex*, vol. 5 (1966), pp. 165–167. On the Lee Navigation see John H. Boyes, ‘The River Lea and the Lee Navigation’ in R. Angus Buchanan ed., *Engineers and Engineering, Papers of the Rolt Fellows* (Bath University Press, 1996), pp. 1–26. G. B. G. Bull’s ‘Elizabethan Maps of the Lower Lea Valley’, *Geographical Jnl.*, vol. 124 (1958), pp. 375–378, is not as informative as the title suggests, but it does show Cheshunt Marsh and what must be the Small River Lea (both shown to the west on Fig. 2 of this paper), which formed a sometimes disputed parish boundary between Cheshunt and Waltham Abbey (or more accurately, the parish of Waltham Holy Cross).
18. Quoted by Fairclough, ‘Early Gunpowder’, p. 14
19. Buchanan, ‘Gunpowder Making in the Eighteenth Century’, pp. 145–146, quoting *The Diary of Sir James Hope, 24 January–1 October 1646*, vol. 9 (Misc. Scottish Hist. Soc., 1958), pp. 156–8.
20. The use from the 1720s of edge runners rather than stamps for the incorporation of gunpowder in the Bristol region was discussed in my paper ‘Gunpowder Making in the Eighteenth Century’, and although some earlier examples have recently been described by Glenys Crocker and Keith Fairclough in their article on ‘The Introduction of Edge-runner Incorporating Mills in the British Gunpowder Industry’, *Industrial Archaeology Review*, vol. 20 (1998), pp. 26–36, none of those cited shows the same continuity of use over the eighteenth century of the examples from the Bristol region.
21. Olaf Musmann, ‘Gunpowder Production in the Electorate and the Kingdom of Hannover’, in Brenda J. Buchanan ed., *Gunpowder: The History of an International Technology* (Bath University Press, 1996), pp. 329–350. For further comments on the advantages of edge runners see the written contribution by E. F. Clark to my Newcomen paper, ‘Gunpowder Making in the Eighteenth Century’, pp. 157–158.
22. Fairclough, ‘Early Gunpowder’, pp. 14.
23. Fairclough, ‘Early Gunpowder’, pp. 14–15; Jenny West, *Gunpowder, Government and War in the Mid-Eighteenth Century* (Woodbridge, 1991), pp. 209–210.
24. Quoted by Col. Sir Frederic L. Nathan, ‘The Royal Gunpowder Factory, Waltham Abbey’ in Brayley Hodgetts, *British Explosives Industry*, p. 318.
25. Wayne Cocroft & colleagues, *The Royal Gunpowder Factory, Waltham Abbey, Essex* (RCHME Survey, 1993), with a separate Collection of ‘Plans and Illustrations’.
26. I am grateful to Malcolm McLaren, formerly librarian at WARGM (MoD), for allowing me to use his copy of Farmer’s engraving, and for discussing the possible meaning of the term ‘dumb mill’. My thanks also to members of the Newcomen Society who have tried to shed light on this puzzle. We are also indebted to Dr. Ken Bascombe, formerly of WARGM (MoD), who organized an early archaeological investigation into the core of the site (*Post-Medieval Archaeology*, vol. 8, 1974, p. 132). An excavation near the mill head of the stream suggested levels of re-use by revealing that a bank which was probably late seventeenth century, made up of tile fragments etc., had been extended into the stream by a brick wall, probably of the late eighteenth century. A leat was ‘enclosed by planks backed by clay’.
27. BM Add. MSS 57318, Letters from Sir John Ligonier, 1754–7. This correspondence was quoted previously in a paper presented by the author in October 1995 at Fort Ligonier, Western Pennsylvania, USA, named in 1758 in honour of the then Commander-in-Chief of HM Forces. Ligonier’s long-standing connection with the Board of Ordnance has been noted. He was also MP for Bath.
28. West, *Gunpowder, Government & War*, p. 67, with reference to War Office papers of 1757 and 1758.
29. Arthur Percival, ‘The Faversham Gunpowder Industry’, 2 parts, *Industrial Archaeology*, vol. 5, nos. 1 & 2 (1968), pp. 1–42, 120–134.
30. West, *Gunpowder, Government & War*, p. 70. In contrast, in December 1761 the Bristol powdermakers learnt that they had been commended by the Board of Ordnance for ‘the Grain and Cleanness of the

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- Samples’ sent to London for testing, see Brenda J. Buchanan, ‘Meeting Standards: Bristol Powder Makers in the Eighteenth Century’ in Buchanan ed., *Gunpowder*, pp. 237–52.
31. West, *Gunpowder, Government & War* p. 73.
  32. *The London Chronicle*, 17–20 May 1760. On the Saturday morning one of the powder mills at Waltham Abbey ‘blew up’. One workman was killed and another injured.
  33. The role of the Bristol powdermakers and merchants in this trade was discussed at the February 1999 meeting of the Western Branch of the Newcomen Society, in a paper by the author on ‘Gunpowder Manufacture and the Bristol Slave Trade’.
  34. West, *Gunpowder, Government & War*, pp. 73–6.
  35. The exclusion of the provincial Bristol powdermakers from this metropolitan network is discussed by the author in ‘Meeting Standards’ in Buchanan ed., *Gunpowder*, pp. 237–252.
  36. 1783, ‘A Plan of the Powder Mills at Waltham Abbey and the Fishery on the River Lea the property of Walton Esq.’ (PRO Kew MR 593); 1801, ‘Plan describing the whole of the Land and its situation at Waltham Abbey belonging to the Board of Ordnance (PRO Kew MR 580[2] extracted from WO 78/2591); 1806, ‘Map of the whole site including Lower Island’ PRO Kew MR 580[3] extracted from WO 78/2591 PFN/555). See n. 5 for details of Rennie’s Report. Frederick Drayson’s *Treatise on Gunpowder* of 1830 (PRO, Supply 5/762) provides additional information; see also the account of the powder works in 1787, quoted by Simmons, *A Short History*, p. 27.
  37. The Office of the Ordnance developed out of the Royal Privy Wardrobe in the fifteenth century and had its own Board by the mid-sixteenth century, Stewart, *English Ordnance Office*, pp. 6–7. William Congreve (bart. 1812, d. 1814) was from 1783 the Deputy Comptroller of the Royal Laboratory at Woolwich, and from 1789 its Controller and also the Inspector of the powder works at Faversham and Waltham Abbey. He has been overshadowed by his son of the same name, who succeeded to his title and offices. The son’s rockets were spectacular but the father made a long-lasting and significant contribution to the production of high quality gunpowder at WARGM.
  38. 12 Geo. III c. 61 (1772). ‘...no Person or Persons whatsoever shall, for the making of Gunpowder, employ, work, or use, any Mill or Engine, worked with a Pestle or Pestles, and commonly called a Pestle Mill, upon Pain of forfeiting all Gunpowder manufactured therein, and also Two Shillings for every pound of such Gunpowder’. The mills of the parishes of Battle, Crowhurst, Seddelcomb and Brede, manufacturing ‘fine Fowling Gunpowder only’, were excluded from this order.
  39. The engineering designs of John Smeaton FRS, including those for these three gunpowder mills, are housed in the Library of the Royal Society. I am grateful to the Royal Society for the privilege of consulting these. See also Paul N. Wilson, ‘The Waterwheels of John Smeaton’, *Trans. Newc. Soc.*, vol. 30 (1955–7, pub. 1960), pp. 25–48, and Denis Smith, ‘Mills and Millwork’ in A. W. Skempton ed., *John Smeaton, FRS* (1981), pp. 59–81.
  40. Simmons, *A Short History*, p. 6. Smeaton made several reports on the navigation of the River Lea, especially as it affected the Waltham Abbey Powder Mills. That of 1771 refers to the ‘corning-engine weir’ in terms which suggest that the large mill was then still active. Obstructions in the water courses were to be cleared, and at the corning-engine weir an additional conduit was to be built, 10ft wide, its floor to be as low as that of the weir, with a draw-gate to enable barges to pass to the mills (Library of the Royal Society, *Reports of the late John Smeaton, FRS*, vol. 1, 1812, pp. 282–3).
  41. Guttman, *The Manufacture of Explosives*, pp. 198–201, noted that rifle powder was then (1909) incorporated for 5½ hours. The long period of incorporation meant the powder was mixed more intimately and its density increased—so that it could be pressed more easily, ignited more rapidly, and transported more safely. Although the causes of explosion were not fully understood, Guttman suggested they sometimes happened when the mill stopped, perhaps because ‘by the sudden starting and stopping sufficient mechanical vibration was concentrated in one point to produce explosion’, or because the steam engine or waterwheel made a small jerk after stopping completely, due to the valve of the former or the shutter of the latter not having been closed tightly.
  42. It was noted in 1801 at the Woolley powder works near Bath, that the annual stocktaking took place in June because then ‘...our Mills usually stand still for want of Water’, B. J. Buchanan & M. T. Tucker,

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'The Manufacture of Gunpowder at the Woolley Powder Works near Bath', *Industrial Archaeology Review*, vol. 5 (1981), p. 189.

43. Buchanan, 'Meeting Standards' in Buchanan ed., *Gunpowder*, p. 244.
44. See Begoña Bas, 'Fireworks for the Community: The Use of Windpower and Simple Techniques in Galicia' in Buchanan ed., *Gunpowder*, pp. 137–155.
45. O. F. G. Hogg, *The Royal Arsenal, its Background, Origin and Subsequent History* (Oxford 1963), pp. 1064–5, describes the poor condition of the works in 1787.
46. Cocroft, *Royal Gunpowder Factory*, p. 117.

## ACKNOWLEDGMENT

A first version of this paper was presented to the Newcomen Society on its visit to the Waltham Abbey Royal Gunpowder Mills (WARGM), organized by the author on 25 April 1998. It was followed by a paper on the later history of WARGM, presented by Wayne Cocroft of the Royal Commission on the Historical Monuments of England (RCHME) now part of English Heritage. I am grateful to Wayne Cocroft for his help on that occasion, and for kindly making available to me items of information arising in the course of the survey of the site by RCHME in 1993.

## APPENDIX

Letter from Oscar Guttman (1855–1910), international explosives engineer, to Rhys Jenkins. Science Museum Library, Rhys Jenkins Papers, Box 46, folder 3.

Rhys Jenkins (1859–1953) was an Examiner at the Patent Office (1884–1920), and President of the Newcomen Society (1923–25).

Oscar Guttman's major work was his 2 vol. *Manufacture of Explosives* (1895). He may not have completed the project mentioned here for he died whilst officiating at the Brussels Exhibition of 1910.

W. H. Hart was the author of *A Short Account of the Early Manufacture of Gunpowder in England* (1855).

The pen and ink drawings referred to were probably amongst those of the late 1790s from which a selection were shown in my previous Newcomen Society paper, taken from the volume edited by E. A. Brayley Hodgetts and entitled *The Rise and Progress of the British Explosives Industry* (1909). This was a collaborative effort strongly supported by Guttman, as shown by his letter of 6 March 1909 to E. W. Hulme of the Patent Office Library, and so it seems likely that he would have passed on the drawings in his possession to the editor.

See the text of Guttman's letter to Rhys Jenkins overleaf, p. 250.



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*Telegrams Grantable, London. Telephone N<sup>o</sup> 6309. Avenue.  
Code: A. B. C. 5<sup>th</sup> Edition.*

OSCAR GUTTMANN,  
M.I.M.S.T., C.E., F.I.C., F.C.S.  
CONSULTING ENGINEER & CHEMICAL ADVISER.

*60, Mark Lane,*

*London, E.C.*

10 th March 1909.

Rhys Jenkin Esq.,

Patent Office,

Birkbeck Chambers, W.C.

Dear Mr. Jenkin,

I am so hard driven with work and conferences etc. that I have been quite unable to call on you as I intended, and therefore must write you how extremely thankful I am for the most valuable and extensive notes, that you have been so good as to give me. I will have them copied out and return the original and then will embody them into the chronological account, that I have already started.

You will be interested to hear, that I have just received the loan of a manuscript book by the same Mr. Hart, who wrote a short account of gunpowder, giving hundreds of notes from year to year since 1558. Unfortunately he does not state the sources of his information, but perhaps in going through the book, you with your knowledge of detail might be able to point out at once, where the note was taken from. Perhaps also the Record Office will be able to assist since Mr. Hart evidently took his notes from papers in the Record Office. I have also obtained the loan of some papers and a number of pen and ink drawings of the apparatus used in the manufacture of gunpowder in 1796. As soon as I can find time, I will come and show these books to you and Mr. Hulme.

Believe me,

Yours very truly

*Oscar Guttman*

## NOTES FOR AUTHORS

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Books: R. A. Buchanan, *Industrial archaeology in Britain*. (Alan Lane, London, 1972), p.47. Only cite publisher if the book is still in print or in copyright.

Parts of books: R. A. Buchanan, 'I. K. Brunel, engineer' in *The works of Isambard Kingdom Brunel*, ed. Sir Alfred Pugsley, (Institution of Civil Engineers, London, 1976), pp.5-23. A subsequent reference to this work may be written R. A. Buchanan, *op.cit.*, p.21. If it is the following reference, use *Ibid.*, p.21.

Periodicals: N. A. F. Smith, 'The Pont du Gard and the aqueduct of Nimes', *Transactions, Newcomen Society*, vol.62 (1991), pp.53-80. Abbreviated journal titles may be used where they are in common use or where there are several references to the journal.

Newspaper reports: *The Newcastle Courant*, 8 Mar 1834, p.8, col.4.

Unpublished papers: Letter, Edward Pease to Thomas Richardson, 10 Oct 1821, Hodgkin Papers, Durham County Record Office, D/HO/C 63.5.

*Units of measurement.* Metric units should generally be used, following official practice in the UK, unless other units would be appropriate for historical reasons. Imperial units may be added in parentheses for the sake of clarity.



Dr. B.J. Buchanan  
13 Hensley Road, Bath, U.K. BA2 2DR  
Tel: 01225 311508

26 July 2000

Dear Lynne,

Just a note to say how well things went on Friday, and to thank you for your part in it. It was very encouraging to go round the site and see so much activity - I am sure our visitors were impressed by that. I don't think we

could have done any better, in the  
circumstances.

I enclose an offprint of my Newcomen  
Society article, which I thought you  
might like to have. Please accept it  
with my compliments.

All good wishes,

P.S. Could you let me  
have a couple of the  
new leaflets, if you have them handy?  
Many thanks, B.

Brenda.