THE ROYAL GUNPOWDER FACTORY

Drawn and Engraved by Ellis.

For Dr. Hughson's Description of London.

POWDER MILLS, WALTHAM ABBEY.

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THE ROYAL GUNPOWDER FACTORY
WALTHAM ABBEY.

There is little doubt that a gunpowder factory had been established at Waltham Abbey long before the earliest documentary references. The factory had come into the ownership of a John Walton and in 1787 he sold it to the Board of Ordnance since when, until only recently, it was used by the Government for the defence of the realm. The factory was enlarged to cope with the demand for gunpowder during the Napoleonic Wars and between 1803 and 1853 the Board bought a further 140 acres on the banks of the River Lea. The mills were water-powered and to protect the water supply to the factory the Board also bought Cheshunt Corn Mill in 1805 and four years later the Waltham Abbey Corn Mill. Production of gunpowder had reached 20,000 barrels a year in 1809 but this was reduced to 1,000 barrels in 1819 before dropping further. The establishment gave employment to 250 people in 1813 but this dropped to only 34 in 1822 and the Board of Ordnance reduced their production capacity by selling the Royal Gunpowder Factory at Faversham in 1824 and nine years later the Irish factory near Cork at Ballincollig.

In 1860 the factory had 32 pairs of incorporating mills which ground together a 'green charge' of saltpetre, sulphur and charcoal to make black powder. Many of these mills were water powered but by that date some were already steam driven. At various states of its manufacture the powder was carried from house to house on an internal canal network in various sizes of small boat. For this work the factory had fifteen covered boats in 1869, varying in size between 21-feet and 30-feet and 5-feet 11-inches to 8-feet-6-inches in width: they also had sixteen open boats at various places around the site for carrying coals, wood, stores as well as acting as ferryboats. Although there was a plentiful supply of timber to produce charcoal all other ingredients for black powder had to be brought to the factory. It also had a limited magazine capacity and the finished explosives had to be transferred from the factory to the magazines at Purfleet and woolwich as soon as practicable. This work was carried on by the barges and in 1869 the factory had two such craft, which being built for working the River Lea, were much less seaworthy than the broader beamed barges in private ownership or those based at other Government establishments built for use in the estuary.

ROYAL GUNPOWDER FACTORY.

THE 'OLD ESTABLISHMENT'.

The distinguished engineer John Rennie (1761-1821) coined the phrase 'The Old Establishment' in his 1806 report on the Royal Gunpowder Factory. This term refers to the gunpowder mills when they were still privately owned, before they were acquired by the Crown in 1787.

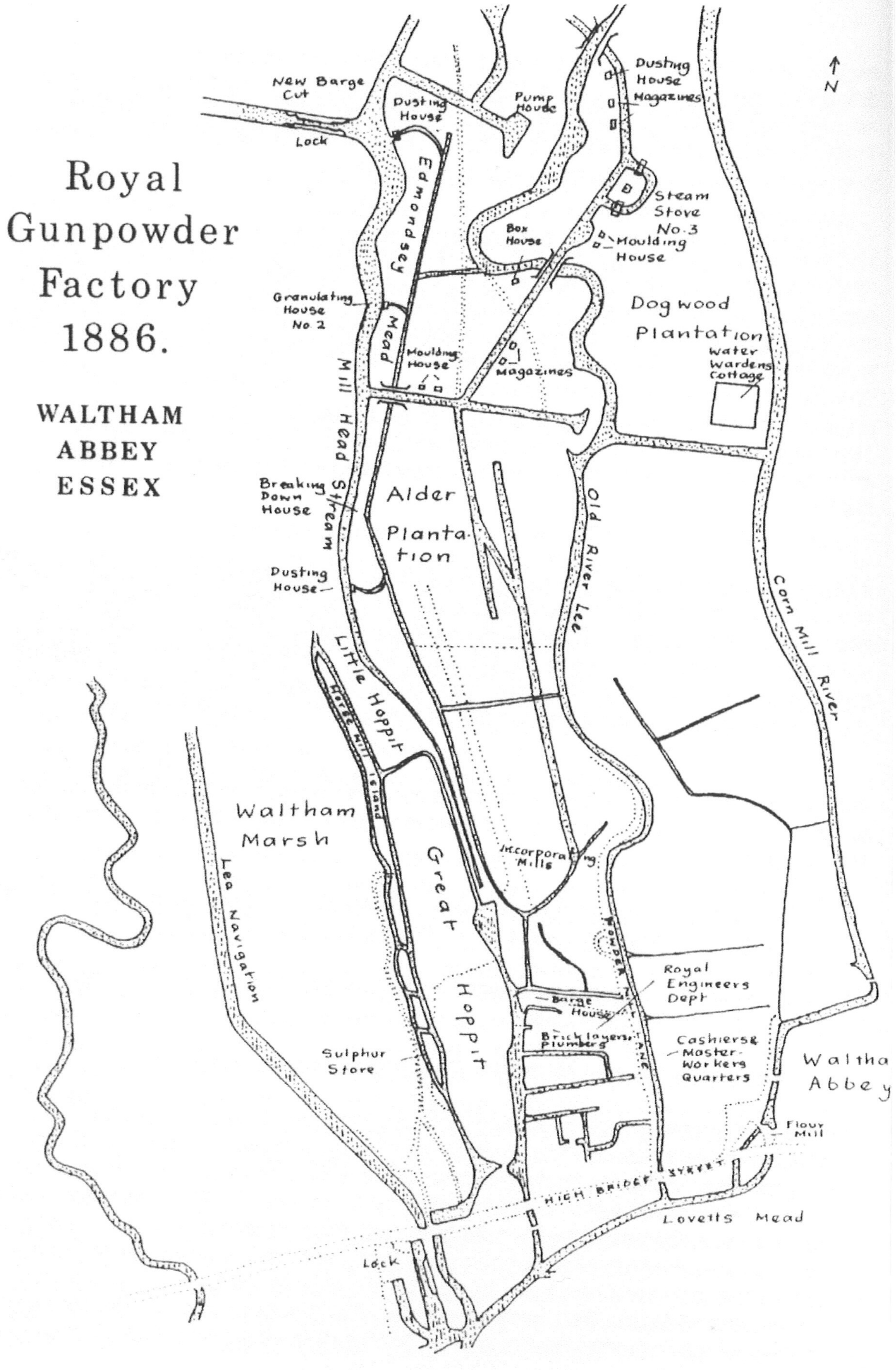
The foundations we see today are those of a mill dating from the second half of the 19th century. We believe they are top of the remains of the earlier stamp mills - giant, noisy, pestle and mortar mills that were used to mix the gunpowder ingredients.

In the 1760s the stamp mills were replaced by a pair of edge-runner mills known as the Head Mills. The two mills were in the middle of a long line of manufacturing buildings. These included horse-powered mills for preparing the gunpowder ingredients, and probably at least one mill by the famous engineer John Smeaton.

The Head Mills overlooked the Hoppit Pool. Opposite was the Loading House, where gunpowder was stored and then loaded omto barges to take it down to London, along the River Lea.

ROYAL GUNPOWDER FACTORY.

1896.



THE PRODUCTION Of GUNPOWDER.

GUNPOWDER.

Summary of the development of gunpowder technology in the most advanced works by the late seventeenth century.

PREPARATION OF INGREDIENTS.

Stack or 'pit' burnt charcoal, imported part refined sulphur and saltpetre, further refined by middlemen or within the works.

INITIAL CRUSHING.

Edgerunner mills _ probably animal powered. Charcoal and sulphur pulverised before incorporation.

MIXING.

Bolting mill and mingling trough. The ground and refined ingredients are first sieved, perhaps a bolting mill, and then loosely combined in the correct proportions in a mingling trough.

INCORPORATION.

Stamp or edge-runner mills- usually water powered. Intimate mixing and grinding of the ingredients.

PRESSING.

Hand operated presses. Powder is pressed to compact the grains together further and to increase its specific gravity.

CORNING.

Shaking Frames-water powered. Process whereby the pressed powder is reduced to corns or granules of approximately even size.

GLAZING.

Tumbling barrels-water powered.. In this process the corned powder is tumbled in a barrel to remove any sharp edges and to impart a glaze to the grains by friction.

DRYING.

Gloom stove. The powder is laid out on trays and dried by heat radiated from a cast-iron fireback or gloom.

FINISHING.

The powder may be sieved according to size and packed for dispatch.

BLACK POWDER.

The composition of the powder, which was first very variable, gradually being fixed at about 75% saltpetre.

In England and France respectively the standard mixtures are.

	England	FRANCE.
Saltpetre	75	75
Sulphur	10	12.5
Charcoal	15	12.5

In other countries the compositions are very similar.

RGPF WALTHAM ABBEY.

Gloom Stove constructed in the 1790s at the northern end of Horsemill Island; note the use of brick traverses and lightning conductor poles.
(from Illustrated London News 25, 11 November 1854.

Lt.GENERAL SIR WILLIAM CONGREVE.

When the mills were purchased the science of chemistry had barely started, control of the manufacturing process was loose and quality was a constant problemm. Of particular importance was the need to secure not only better performance but greater uniformity. Congreve was a visionary who saw that the way forward lay in scrupulous attention to purity of ingredients, precise measurements, close study of each stage of the process to introduce improvements where possible. These considerations might now seem self evident but in that time needed strong direction and control to be achieved.

William Congreve was succeeded in 1814 by his son, also William, as Comptroller of the Royal Laboratory, including supervision of the Royal Gunpowder Factories, and continued the emphasis on quality, measurement and machinery improvement. He was responsible for the patenting in 1815 of important mixing and granulating machine designs.

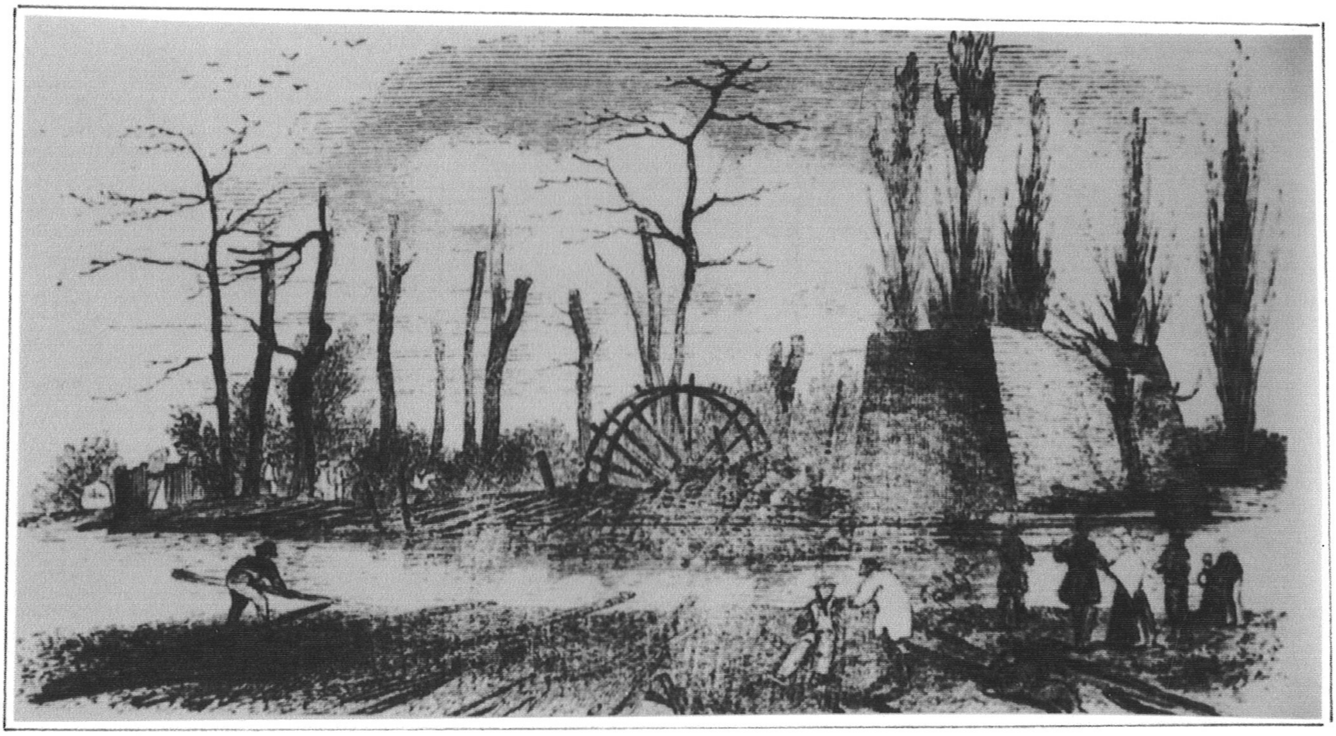
RGPF.
Lt.GENERAL SIR WILLIAM CONGREVE.
1st Baronet, died 1814.

WALTON HOUSE.
1787.

Management required premises to carry out their functions and house their staff and the building now termed Walton House was erected, probably on the site of an earlier structure. the original building was two-storeyed, of two bays by one bay, in red/brown brick of rectangular form in Flemish bond. The roof was hipped with pegged trusses (original carpenter's marks still visible). In the 19th century various extensions were added, In the early part of the century a third bay of two storeys was added on the north side then, from 1860 a two storeyed wing by two bays and another two storeyed wing. These additions resulted in the building ultimately having a U shaped plan. There was a progression of official titles - Storekeepers Office, by 1865, Superintendents Office and by 1917 the Mains Offices. In 1865 plans were drawn up for conversion to Master Worker's living quarters but it is not clear whether this ever took place. The shield on the frontage with animal head and winged angel appears to relate to previous owners rather than the Waltons. Perhaps, not surprisingly, in view of the large number of additions and the high water table, settlement has taken place. This is visible but on which side is not as straightforward as it might appear. Certainly the north side has a considerable lean as evidenced by the sloping internal floors.

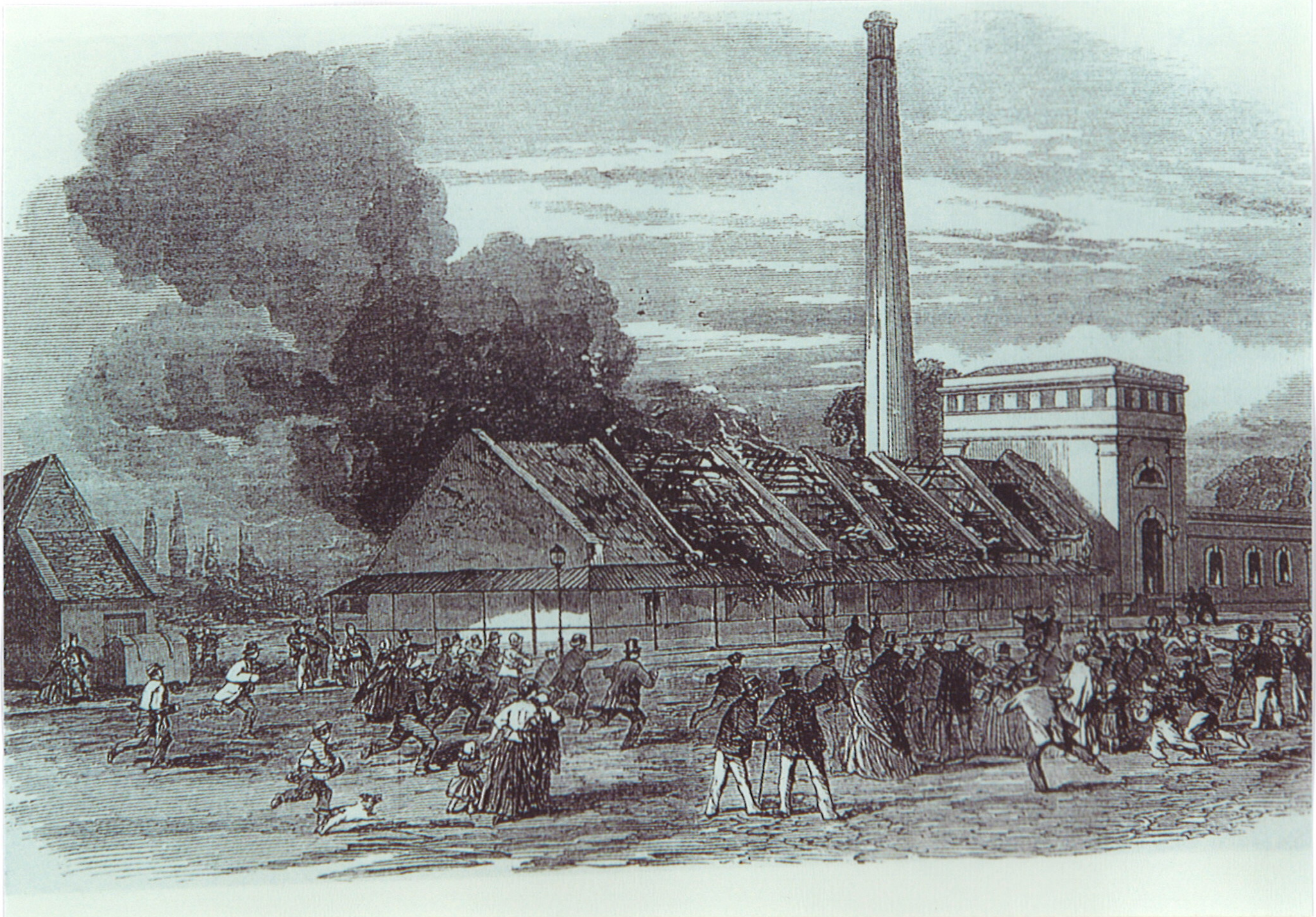
RGPF WALTHAM ABBEY.
EXPLOSION.

The explosion of 1843 claimed 7 lives. The blast wall on the right proved inadequte, Michael Faraday was brought into the resulant enquirey as a consult.



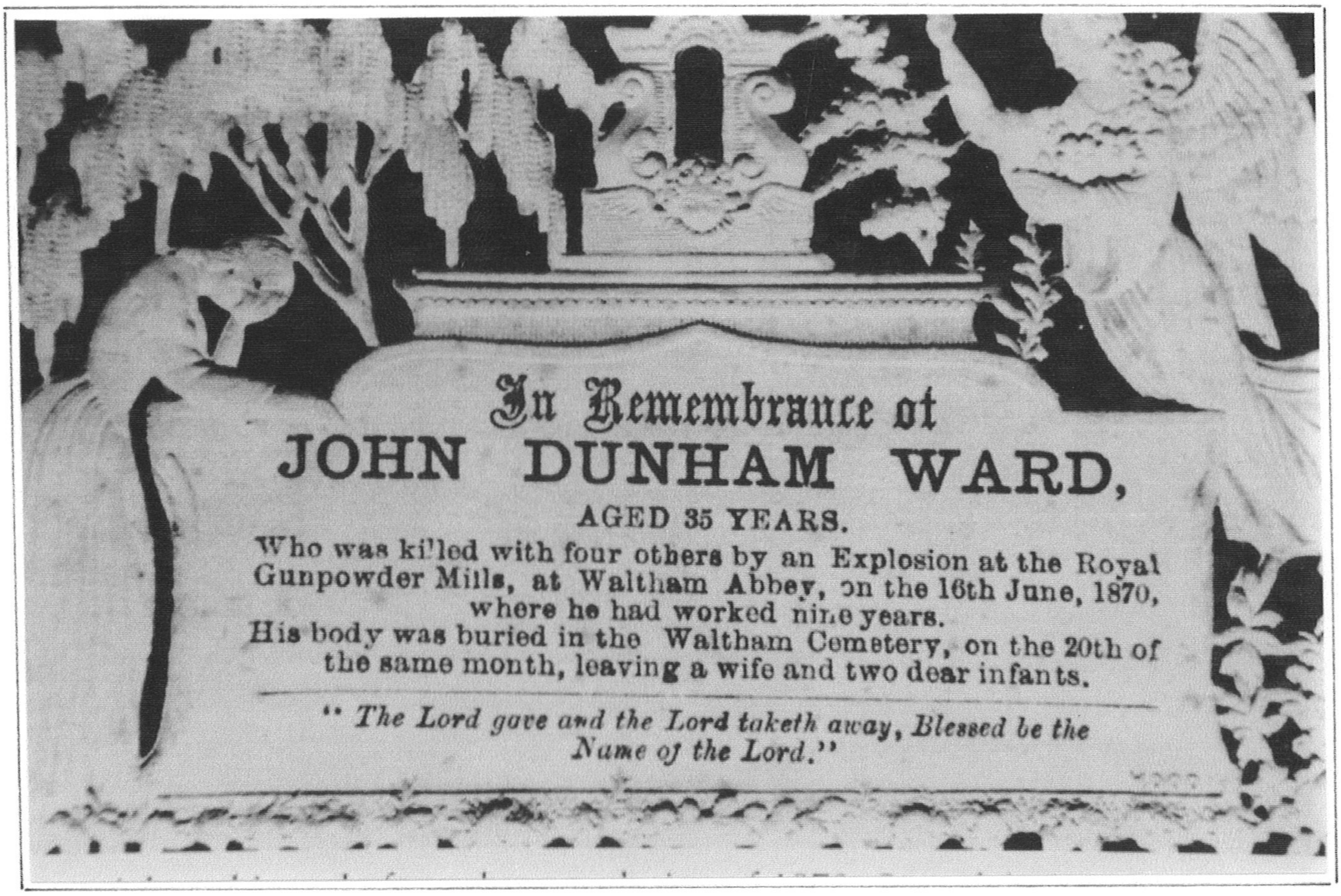
RGPF WALTHAM ABBEY.
Explosion at Group A Mills, 1861.
From Illustrated London News, 8 June 1861.

On the extreme left is an Expense Magazine and adjacent to it a hand-propelled powder bogie.



RGPF WALTHAM ABBEY.
EXPLOSION.

A memorial card issued after an explosion in 1870. One of the 'two infants' is Phoebe Ward.

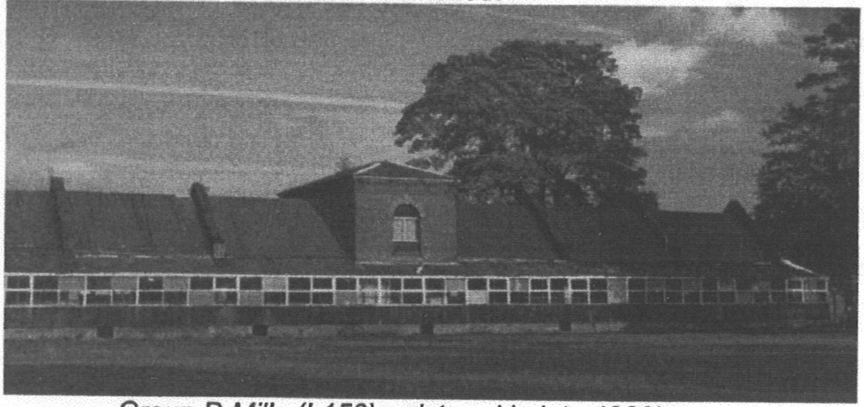


RGPF WALTHAM ABBEY.
INCORPORATING MILLS.

The edge runners in the new steam mills were of cast-iron, with a flat surface bevelled at the edge, turning on a cast-iron bed. Each was 6ft 6in in diameter, and weighed around 4 tons. The runners were set at slightly different distances from the central spindle so a greater area of the bed was covered, and mounted so that they were able to rise and fall within the crosshead depending on the thickness of the charge on the bed; the powder was spread evenly on the bedplate by a plough attached to the crosshead.

During incorporation, between two and eight pints of distilled water (the amount depending on the time of year) were added to ensure an intimate cohesion of the particles. The milling time for a charge of powder, set by the 1875 Act at 50lb for government powder, varied according to the power of the mills and the type of powder being milled. Cannon powder, for example, required 3 hours working under stone runners weighing 3 tons at 7 revolutions per minute, but only 2 hours under iron runners of 4 tons at 8 revolutions per minute. Powder for small arms required 5 hours in the former mills and 4 hours in the latter. It was calculated that a pair of water mills working night and day all year, excluding Sundays, could produce 660 barrels of cannon powder or 330 barrels of small arms powder; steam mills could produce 950 barrels of cannon powder or 473 barrels of small arms powder under the same conditions.

incorporating mills, termed Group A in 1857, followed by Group B in 1859. Group A and B mills have since been demolished.



Group D Mills (L153) - pictured in late 1980's

The succeeding Groups built - from C in 1861 to G in 1888 and the Group A engine and boiler houses comprise the listed steam incorporating mills - summarised below:

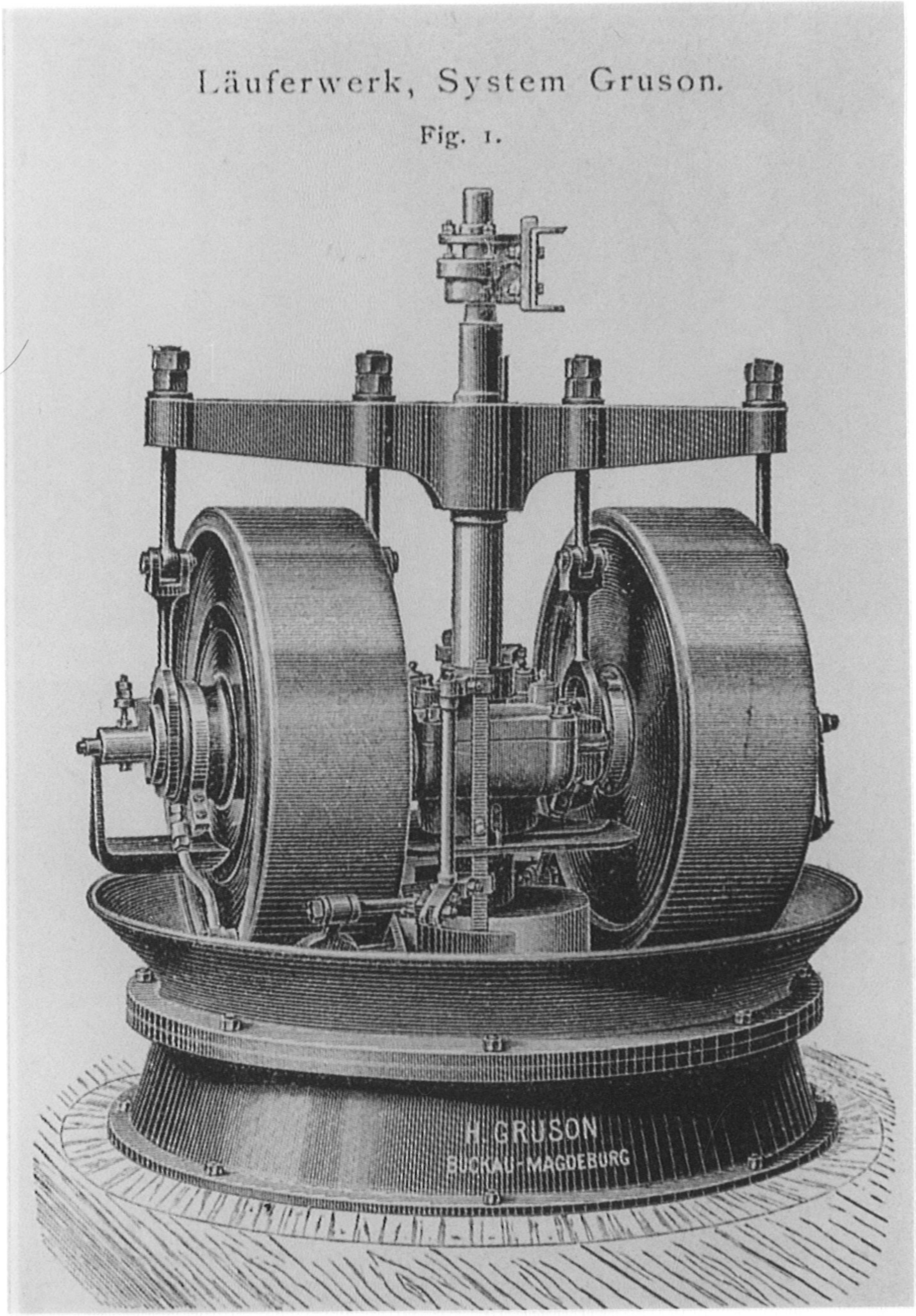
GROUP	A	B	C	D	E	F	G
Build Date	1857[1]	1859	1861	1867	1877[2]	1878	1888
Grade	2*	-	1	2*	2*	2	2*
Bldg No.	-	-	L157	L153	L149	L145	L148

([1] only Engine (L168) & Boiler (L176) houses remain)
([2] central part 1869 originally for pellet powder)

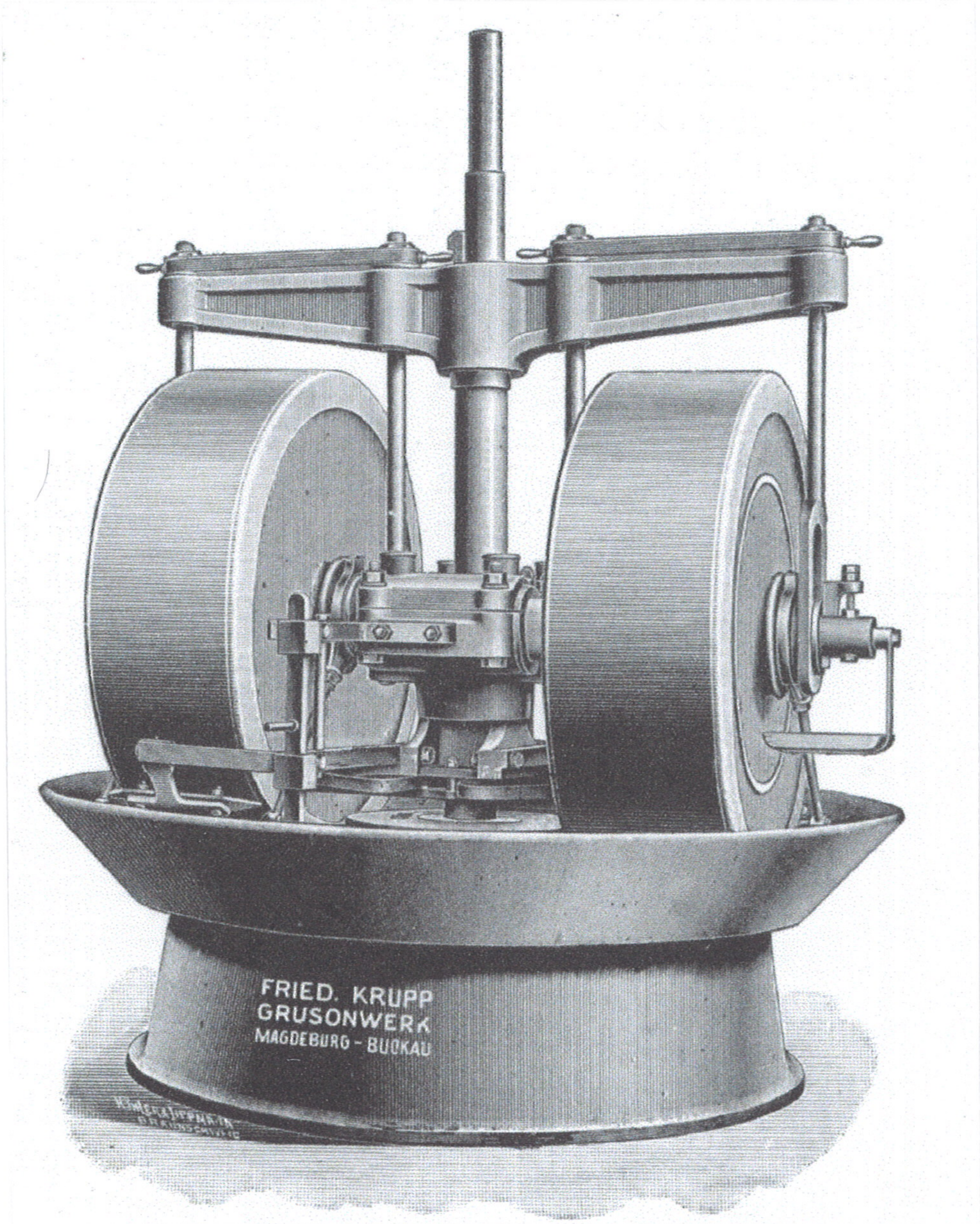
he steam mills represented a fundamental move away from the water powered Millhead:
1) In location - built on open land between the Millhead Stream and the Old River Lea.
2) In adoption of newer technology - replacement of water power by steam.
3) in scale - scale of buildings far beyond the timber structures of the Millhead.
4) In output - the steam mills represented a move to a fully industrialised basis.

INCORPORATOR.

Made at Grusonwerks Buckau-Madgeburg and installed by Chilworth Gunpowder Company in the late 1880s.



GUNPOWDER MILL.



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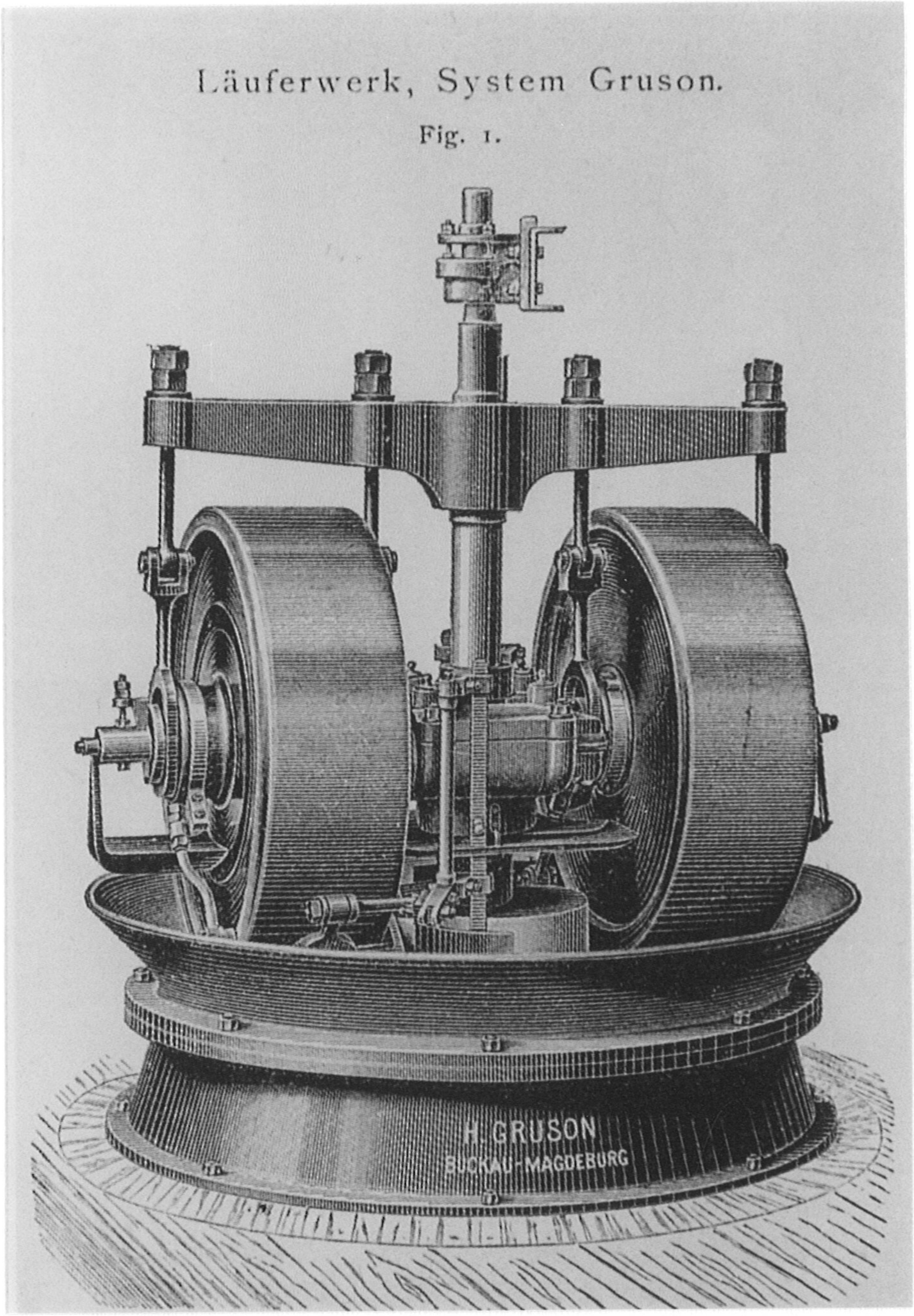

EDGE RUNNER MILL.

Before the introduction of smokeless powders the best sorts of gunpowder,either for military use or for charging sporting guns and rifles,were manufactured by a series of operations comprising the following stages.

(1) The three ingredients are ground separately in mills of various types,and sifted.

(2) They are weighed out in the right proportions and mixed roughly in a machine containing arms which rotate rapidly.

(3) They are incorporated together in an edge runner mill. This consists of a horizontal circular bed on which rotate two cylindrical runners weighing several tons each. The charge is 60 to 80 lbs. Of powder,which is kept moist during the milling operation,lasting 3 to 8 hours; the longer the incorporation the faster does the powder burn.

(4) When this operation is finished the "mill cake" is removed by means of wooden shovels and tools and taken to another house where the large lumps are broken down by hand with wooden mallets or by passing the material through gunmetal rolls.

(5) It is then pressed to increase the density and prevent the ingredients separating again from one another. For this purpose the broken down mill-cake is spread out in layers,each layer being separated from the next by a plate of gunmetal. The whole is then pressed by means of a powerful hydraulic press.

(6) The next operation is corning or granulating. This consists of passing the mill-cake through a series of rollers which break it down to grains of the required size. As it comes away from the rollers it is automatically sifted and the coarse material is returned through the rollers again. The material that is too fine is milled again for a short time and then passes through the same series of operations.

THE ROYAL GUNPOWDER FACTORY.
INCORPORATING MILL.

Incorporating Mills,which are built in groups of six,and are worked by independant machinery. Except for the division walls,these mills are constructed of the flimsiest material possible,the roof being of wood,and the fronts of canvas,buttoned on to a slight iron framework; this is in order that no resistance may be offered to a possible explosion. If the arms of the danger signals are raised,in order to show that the mills are working,no barrow or truck-load of powder,in any stage whatsoever,is allowed to pass by the mills.

In the mill is a big circular iron bed,round which revolve two enormous wheels,each weighing 4-tons. Into this bed is shot the contents of the half-charge sack brought from the mixing house. A wooden 'plough' is then fixed from the centre,so as to keep the powder continually under the rollers,and then all is ready for starting the machinery.

Even in this stage the mixture is highly inflammable,and there lies a flash board over the bed. In the event of an explosion,either through the wheels meeting with gritty particles in the mixture,or from other causes,this board would be violenty thrown up on hinges,and in its decent backwards would automatically overturn tanks of water,not merely on to its own bed,but also the beds of its working neighbours,who might also explode.

Owing to the risk,when starting the Incorporating Mill,the operator draws down the flaps of his cloth helmet,puts on his gauntlets,retires outside. The operator is clothed in a suit of 'lasting' a leathery material,that has no pockets,and the buttons are of bone; no powder adheres to this material. The men are even forbidden to cultivate long beards,less they contain particles of grit.

THE ROYAL GUNPOWDER FACTORY.
INCORPORATING MILL.
STARTING THE INCORPORATING MILL.

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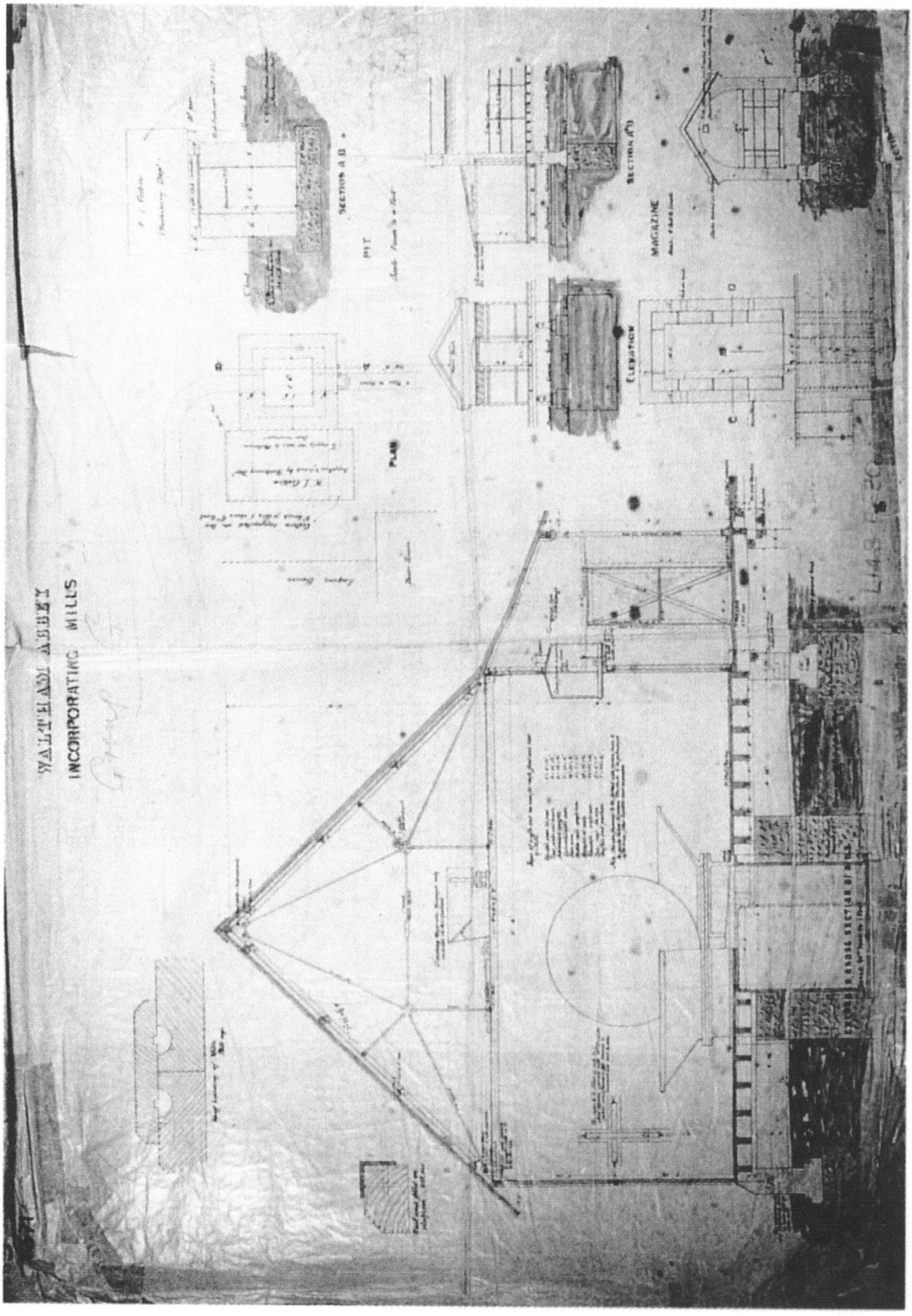
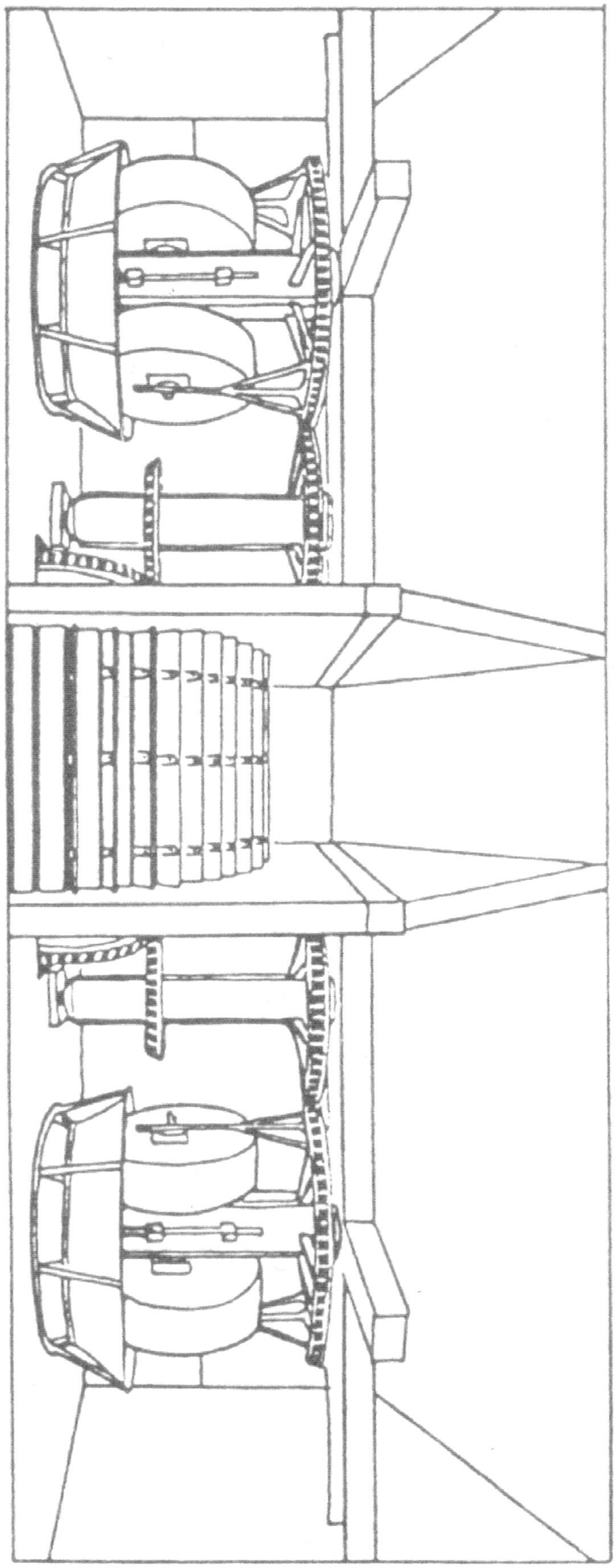
THE ROYAL GUNPOWDER FACTORY.
INCORPORATING MILL.
STARTING THE INCORPORATING MILL.

The groove in the brick wall for the starting wheel to be operated from behind cover can still be seen today.

RGPF WALTHAM ABBEY.
.GROUP G MILLS
1888-9.
Note the iron framing, drenching tub and lamp box.





RGPF WALTHAM ABBEY.

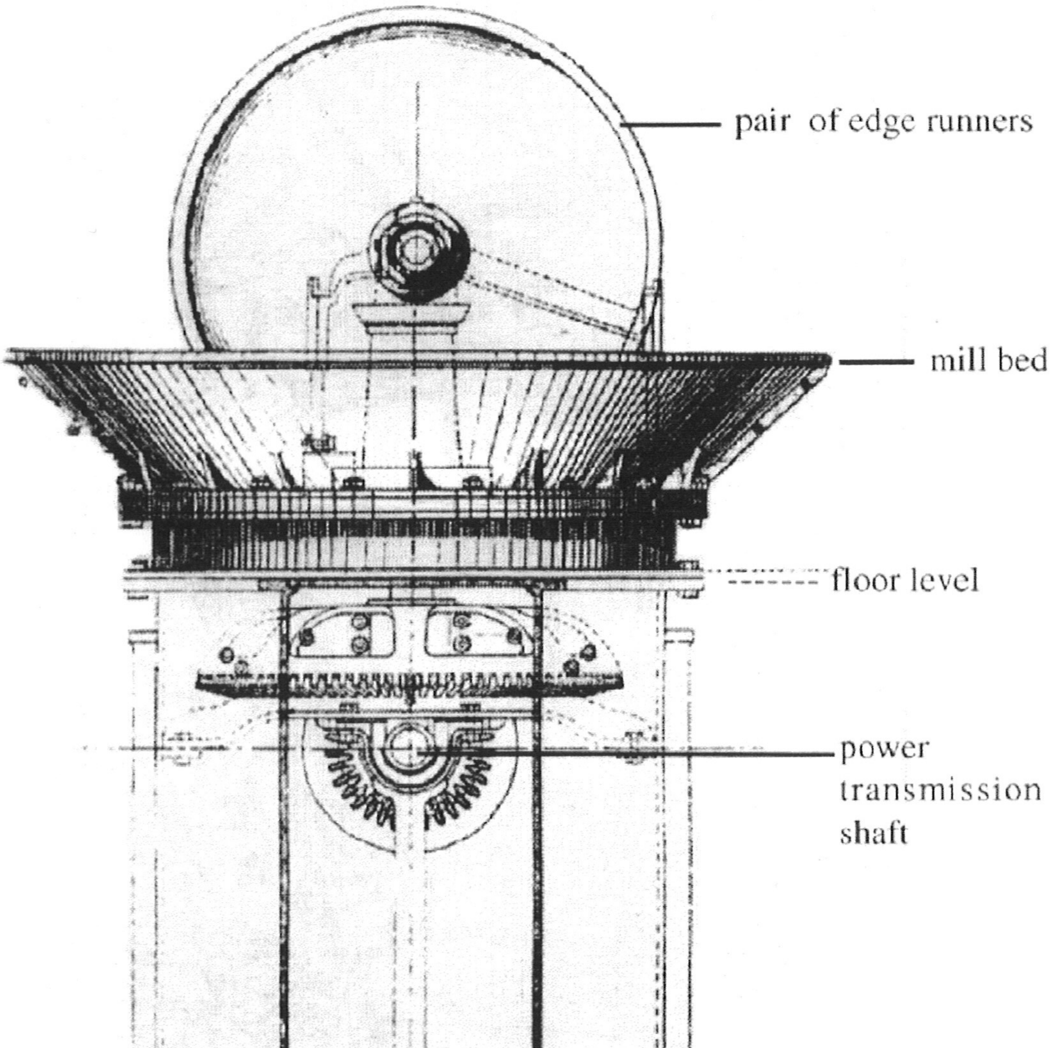
NORTH SITE.

Old stone runners once used in the gunpowder incorporating mills.
These were replaced by steel runners which were smaller and safer.

RGPF.

Group C Incorporating Mills 1859.

The drivewas taken from the engine via a connecting rod to a crank on the drive shaft, flanked by a pair of flywheels. Each mill has an horizontal bevel gear wheel with drive being transmitted via a pinion wheel. Motion from the drive shaft was transmitted via a friction clutch engaged by a remote control rod. From a bevel wheel a vertical shaft passed to an horizontal spindle on the edge runners.

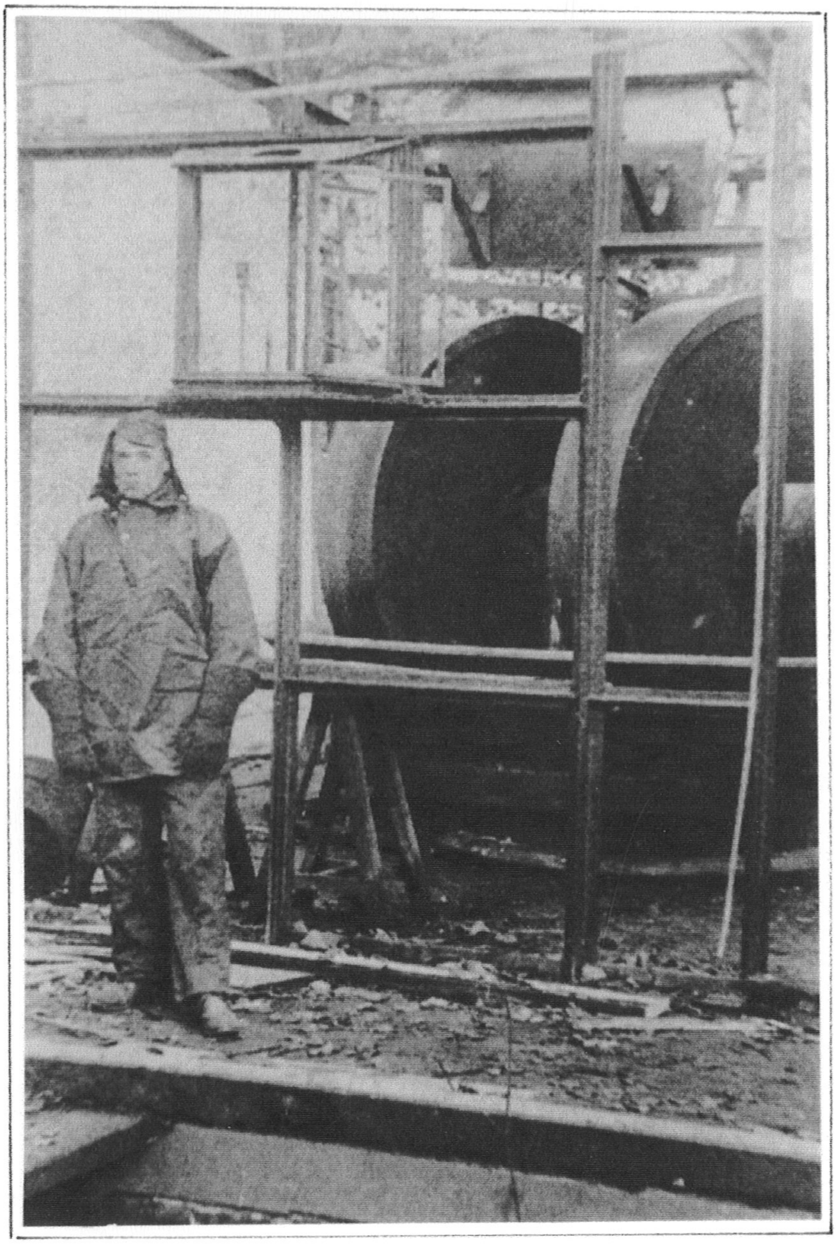


THE ROYAL GUNPOWDER FACTORY.
INCORPORATING MILL.

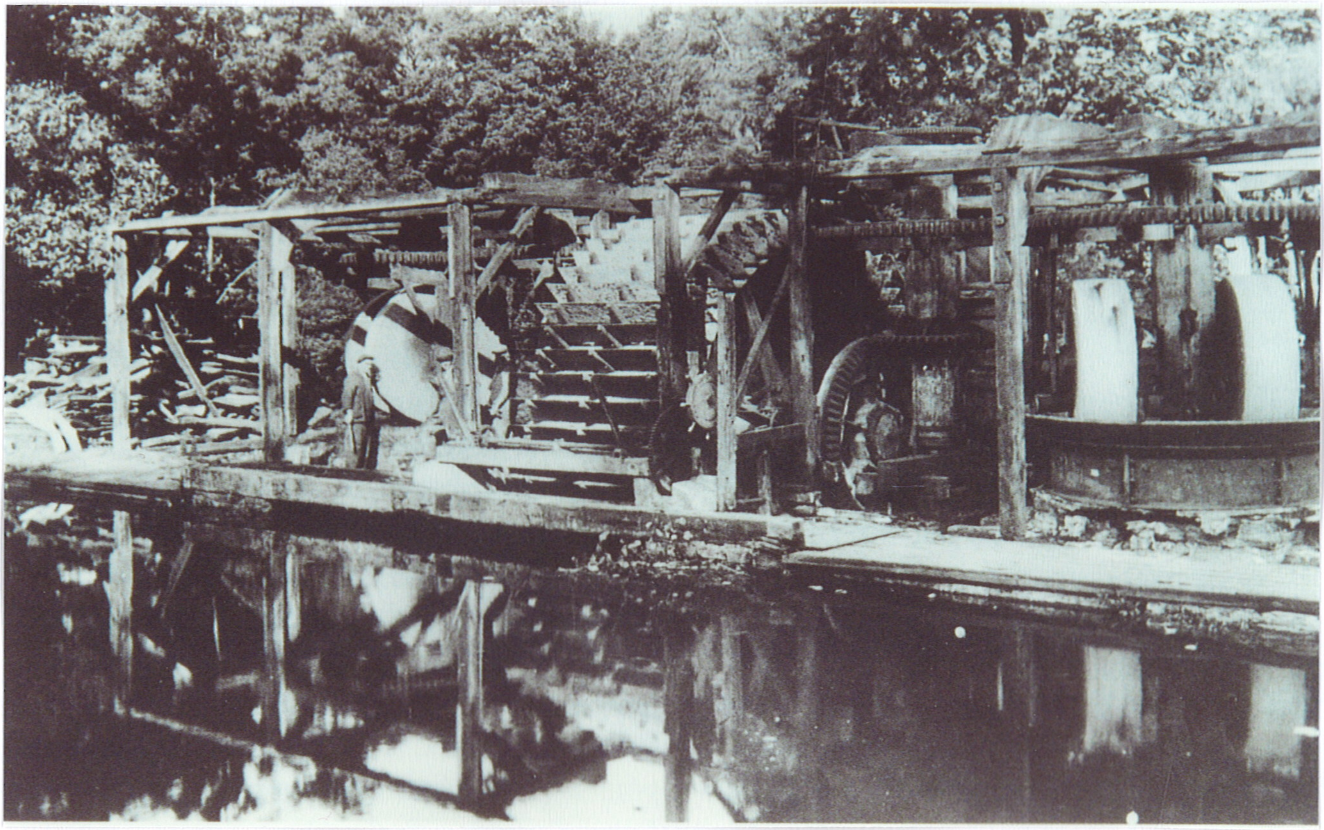
Exterior view of the Incorporating Mills. Note hand-pulled wagon on rail track.

RGPF WALTHAM ABBEY.
INCORPORATING MILL.

The aftermath of an explosion on 21st October 1890 in the Incorporating Mills.
This photograph shows iron runners or rollers and the overturned drenching pan above.
Iron runners superseded stone wheels, as they could be smaller and were safer.

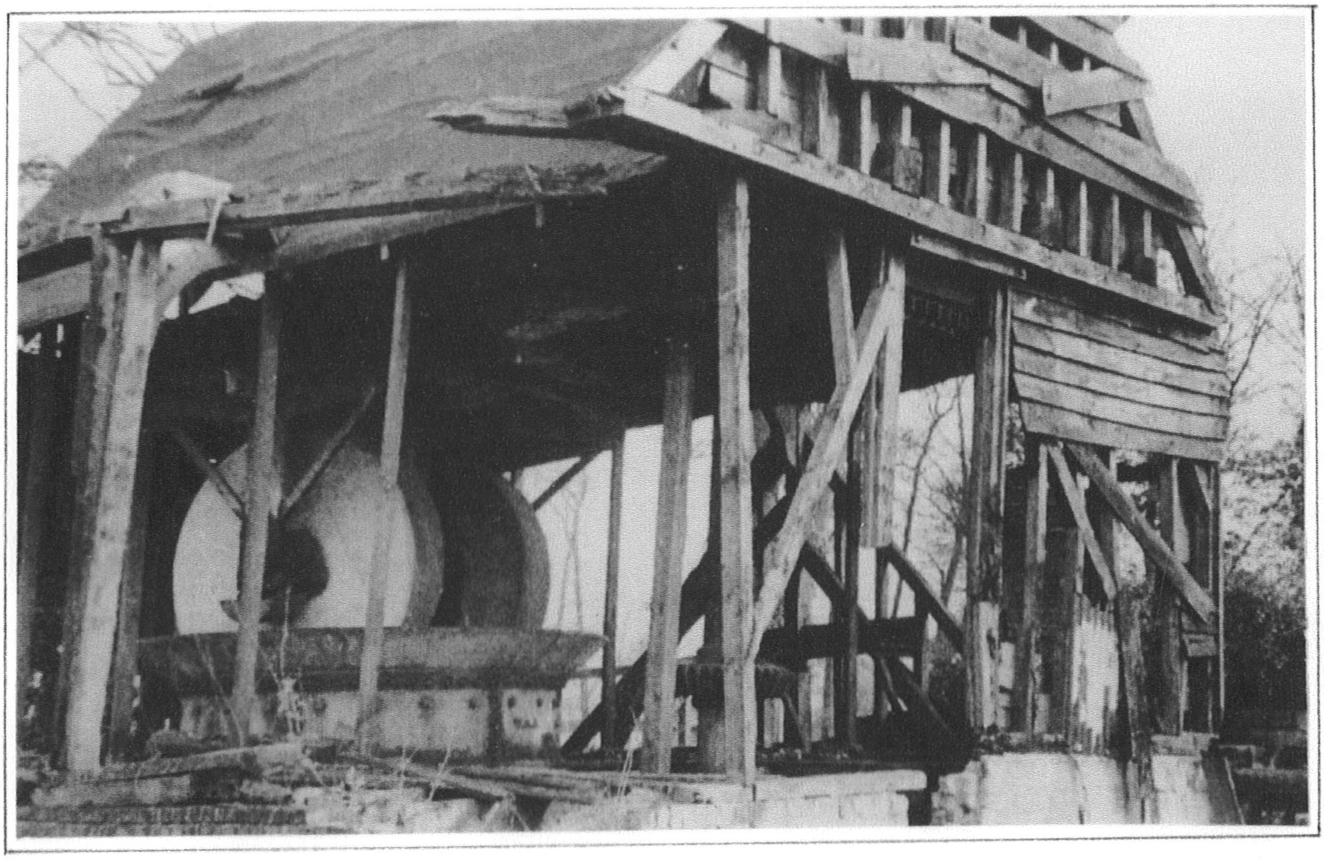


RGPF WALTHAM ABBEY.
DEMOLITION OF No.3 MILL ON MILLHEAD STREAM
SEPTEMBER 1936.



RGPF WALTHAM ABBEY.
INCORPORATING MILL.

The last of the gunpowder Incorporating Mills, the result of neglect not explosion.
Incorporation was a process of intimately mixing the looswly mixed 'green charge' by crushing and grinding; a mill-cake was the result.
The mill was destroyed in the late 1950s because of contamination.
The last functioning mill had been out of action by a bomb in 1941.



ROYAL GUNPOWDER FACTORY.
THE LAST GUNPOWDER MILLS.

When production at Waltham Abbey switched from gunpowder to cordite towards the end of the 19th century, the gunpowder mills around Queen Meads were all converted. With the outbreak of WW1 new cordite facilities were developed on the far side of Middle Stream.

But gunpowder production was not phased out altogether. Here, alongside Millhead Stream was the last group of water-powered gunpowder mills. Outdated facilities and seasonal water shortages would at times bring production to a complete standstill. Yet they produced gunpowder until the end of WW1. In 1941 they were damaged beyond repair by a German parachute mine, although they were slowly being dismantled prior to that date. The last gunpowder mill was demolished in 1956, an event recorded and photographed.

RGPF WALTHAM ABBEY.
GUNPOWDER PRESS.

Two types of press were adopted at Waltham Abbey to produce prismatic powders, hydraulic and cam presses.

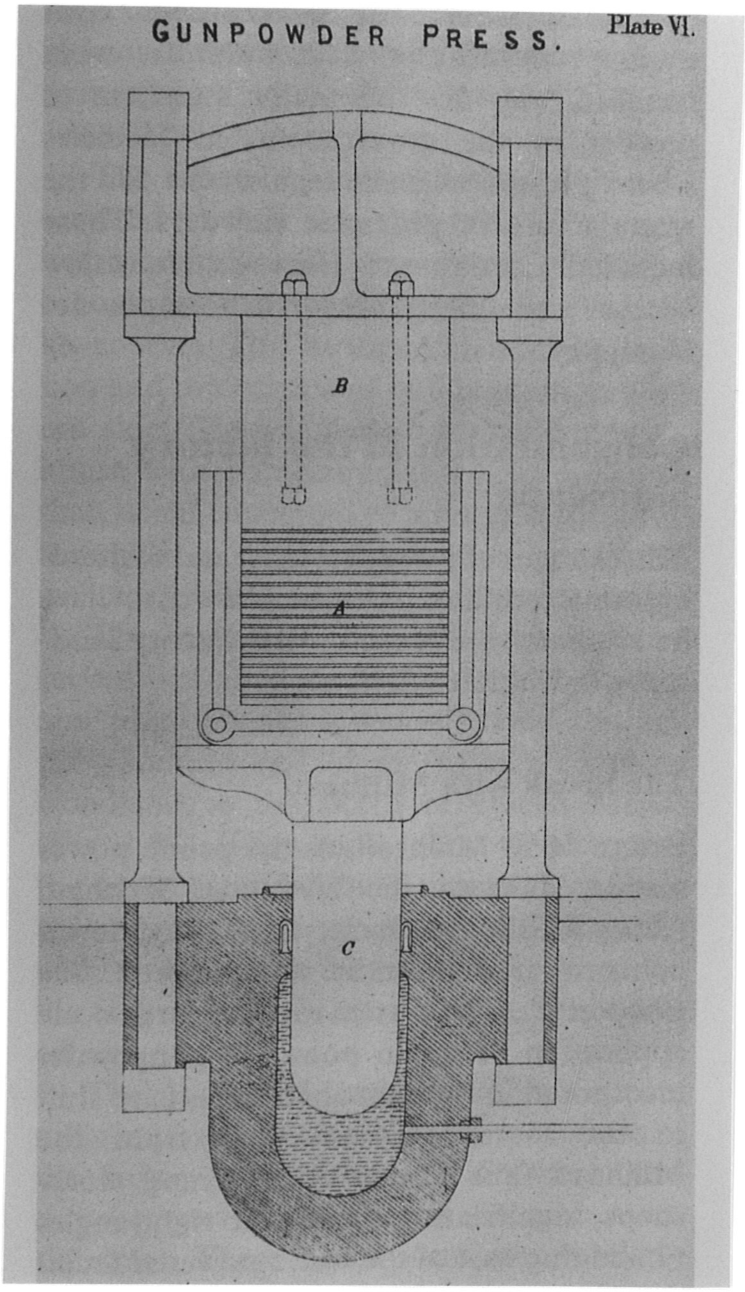
Those on the northern part of the RGPF were hydraulically operated and powered by the centralised hydraulic system. A variety of moulding machines were installed.

These machines moulded 64 prisms in one pressing, forming the perforations in the prism by phosphor bronze rods which passed through the lower plunger.

The cycle of charging, pressing, and unloading took about 2-minutes.

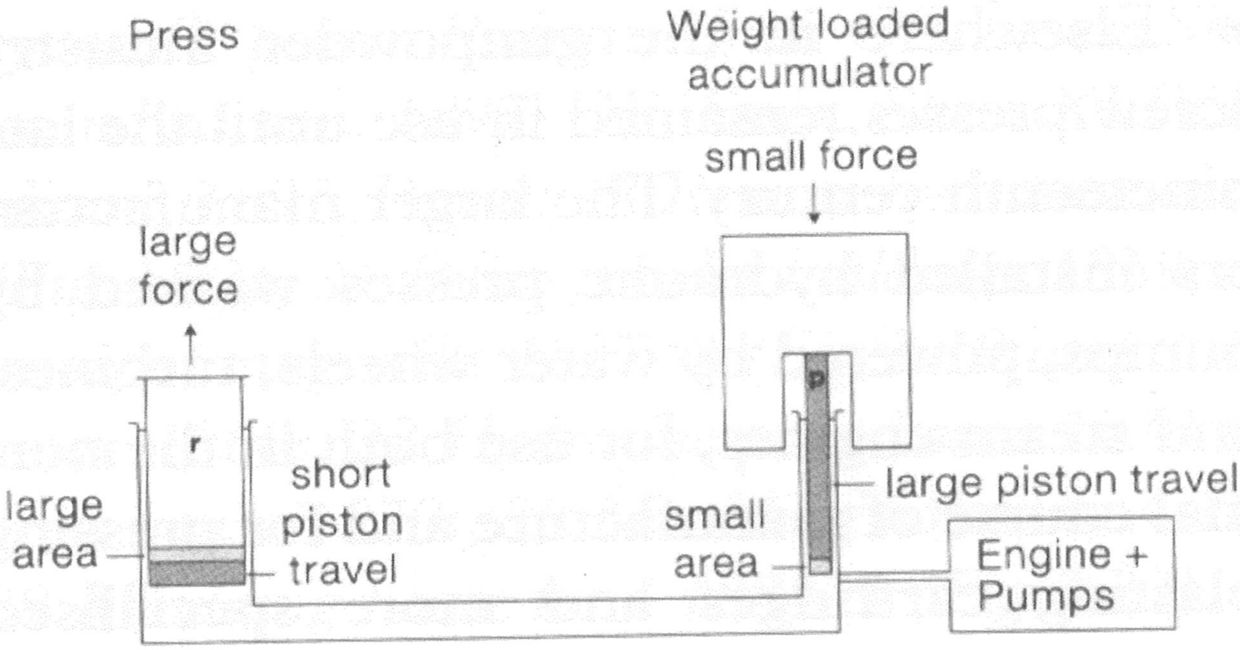
RGPF WALTHAM ABBEY.
GUNPOWDER PRESS.

Section through hydraulic gunpowder press 1888. The press has a fixed press block (B) which in earlier examples was moveable.



HYDRAULIC PRESS.

The principle of the hydraulic press:
A small force acting on a plunger (p) of small area over a long travel will create a large force on a ram (r) of large area over a short travel.



RGPF WALTHAM ABBEY.

SOUTH SITE.

GUNPOWDER PRESSES.

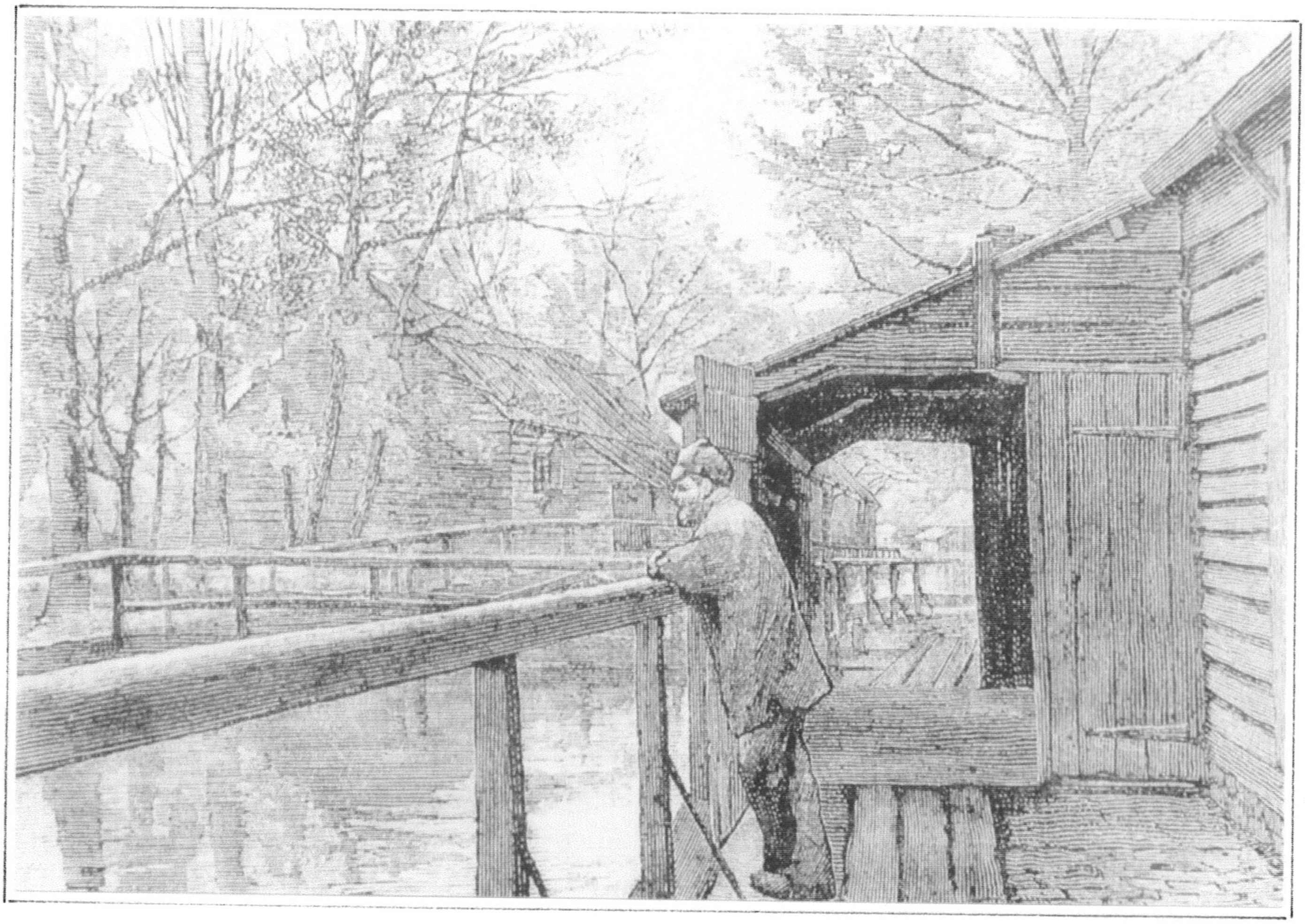
PELLET AND PEBBLE POWDER.

From the 1860's advances in metallurgy- new steels , alloys etc. anf in engineering techniques, enabled manufacturers to produce increasingly large guns which required larger charges. This however created a paradox in that the higher explosive force of pressed gunpowder in this quantity brought an increased risk of damage to the gun. A larger powder grain size was needed to enable better control and to slow the rate of burning. For this purpose, powders derived directly from presscake were developed - pellet and pebble powders up to 2-inches square for the largest guns. This led to the need for more powerful pressing facilities and the hydraulic story at Waltham Abbey entered a further phase of development. in the 1850's a Newcastle solicitor, William Armstrong, had demonstrated the effectiveness of his steam powered hydraulic system with weight loaded accumulated tower, comprising a vertical cylinder and ram eith a cylindrical weight case. In 1869 the system was adopted for the L 149 group E built to serve a press house producing pellet powders.

The accelerating pace of armaments development brought still increasing demand for press facilities and raised the problem of the safety hazard of separate steam engines being distributed around the site - not an economic use. Again, hydraulics provided the answer. Armstrong had further demonstrated the ability of the accumulator tower system to act as a centralised storage and distribution source powered by one steam engine with a supply of pressurised water by a system of pipes to wherever required. In addition, separate remote accumulator towers could be incorporated, linked to the central point to store, regulate and boost supply. In 1879 the L 149 steam facility was converted to gunpowder incorporation but the accumulator tower retained as the nucleus of a centralised hydraulic distribution system to serve new press houses producing pebble powders. At the same time L136 was built as a supporting remote accumulator tower.

Large charge technology progressed further with the introduction of prismatic powders, based on earlier American studies. These were pressed hexagonal shaped prisms about 1-inch high perforated with holes to facilitate gas transmission of burning. Further press houses, termed moulding houses, were built to produce these grades and the L149 and L136 hydraulic system was extended to power them. Moulded prismatic powders represented the peak of gunpower development and pressing or moulding was the fulcrum of their manufacture. in turn, therefore, hydraulic technology, as represented by this surviving accumulater tower occupies a key position in the progress of the technology of the Mills.

RGPF WALTHAM ABBEY.
ENGRAVING OF THE POWDER MILLS 1898.
by E.Watford.



THE ROYAL GUNPOWDER FACTORY.

CAM PRESSES.

THE ROYAL GUNPOWDER FACTORY.

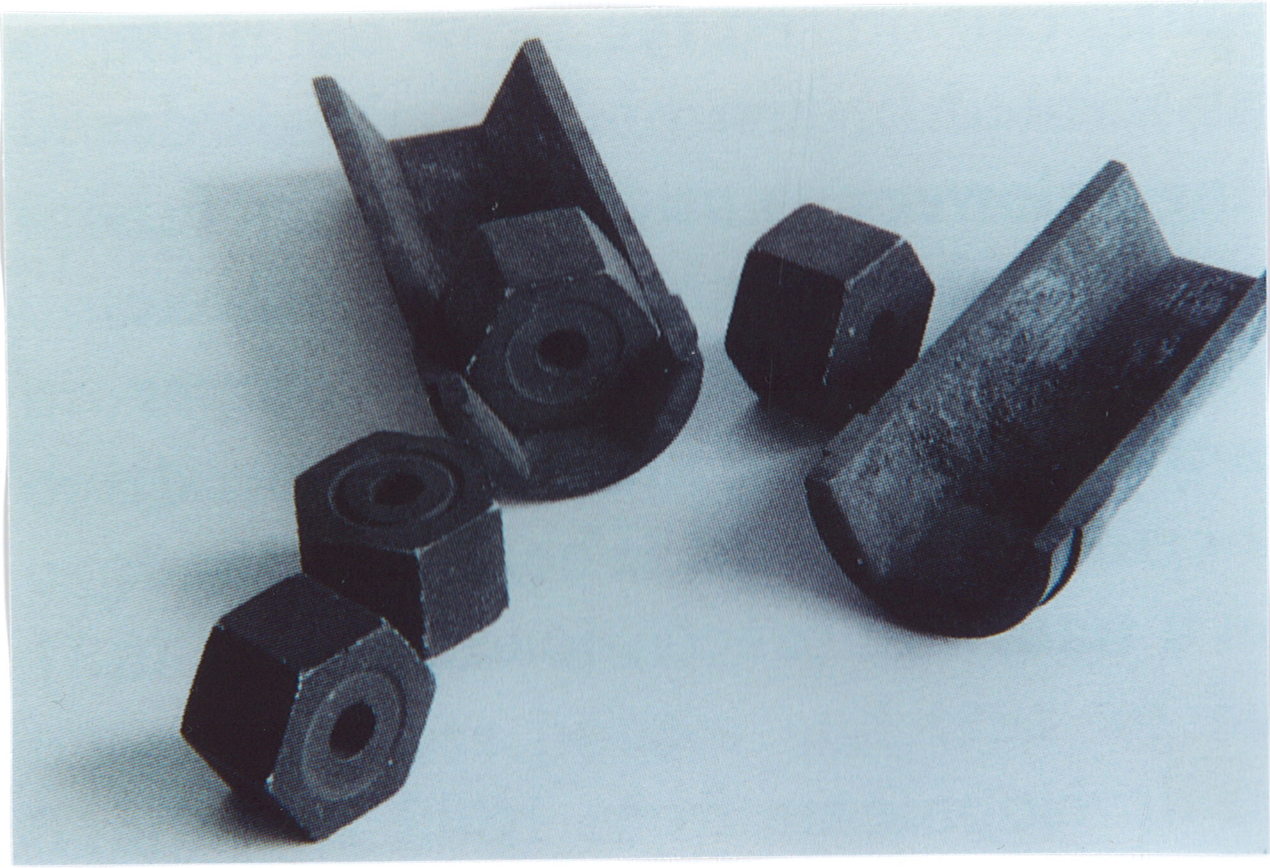
CAM PRESSES.

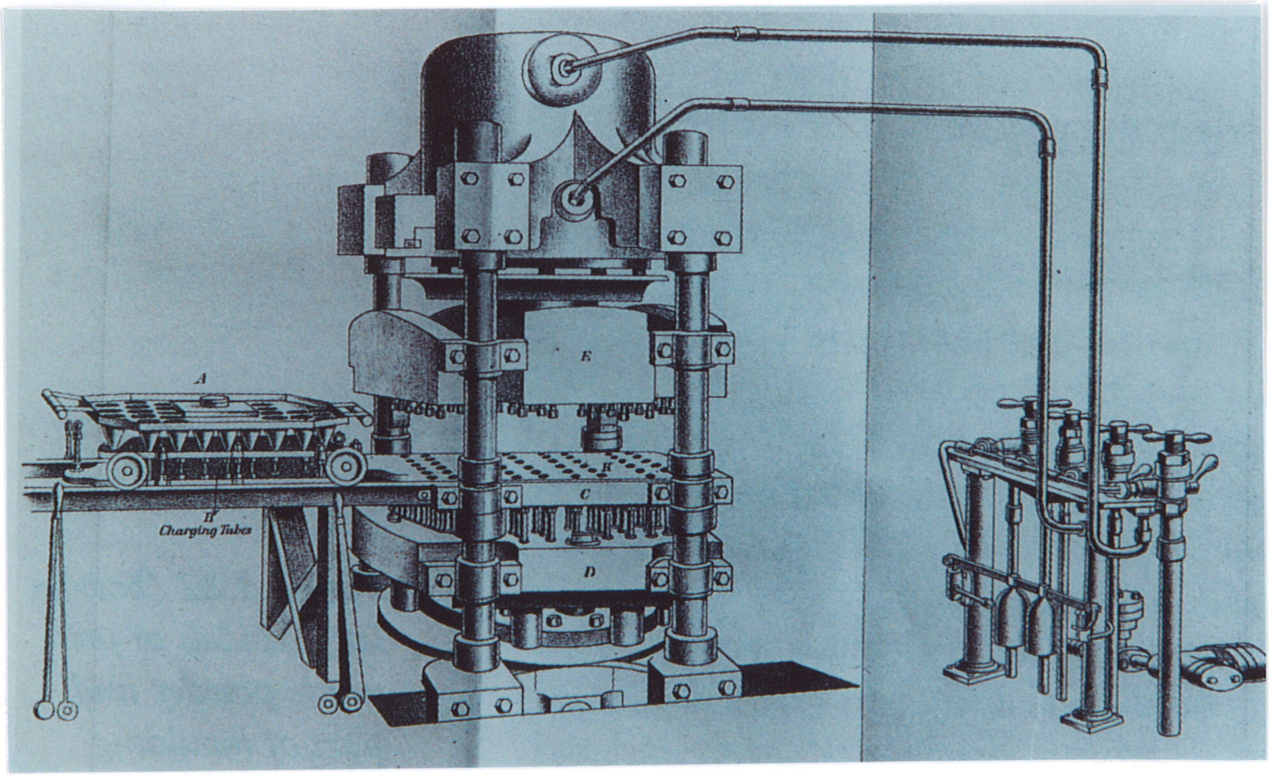
Cam presses for moulding prisms were first installed at Waltham Abbey RGPF in 1887. Compression in this type of machine was applied by means of a cam or eccentric on a shaft driven by water or steam power. This was similar to that devised by Professor Wischingratzi in Russia and had been widely used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

RGPF WALTHAM ABBEY.

PRISMATIC POWDER.

Models of prismatic powder and part of moulding machine. The annular ring on one prism distinguishes EXE prismatic and the circular hollow SBC prismatic.



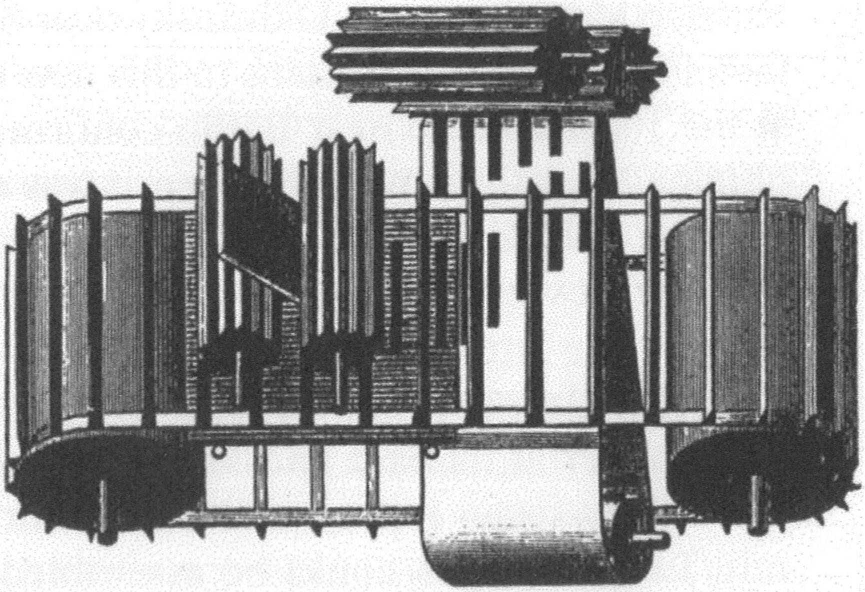


RGPF WALTHAM ABBEY.
MODELS OF PEBBLE POWDER.

PEBBLE POWDER.

Top.
Morgan's Pebble Powder Cutter 1872.

Bottom.
Models of Pebble Powder.

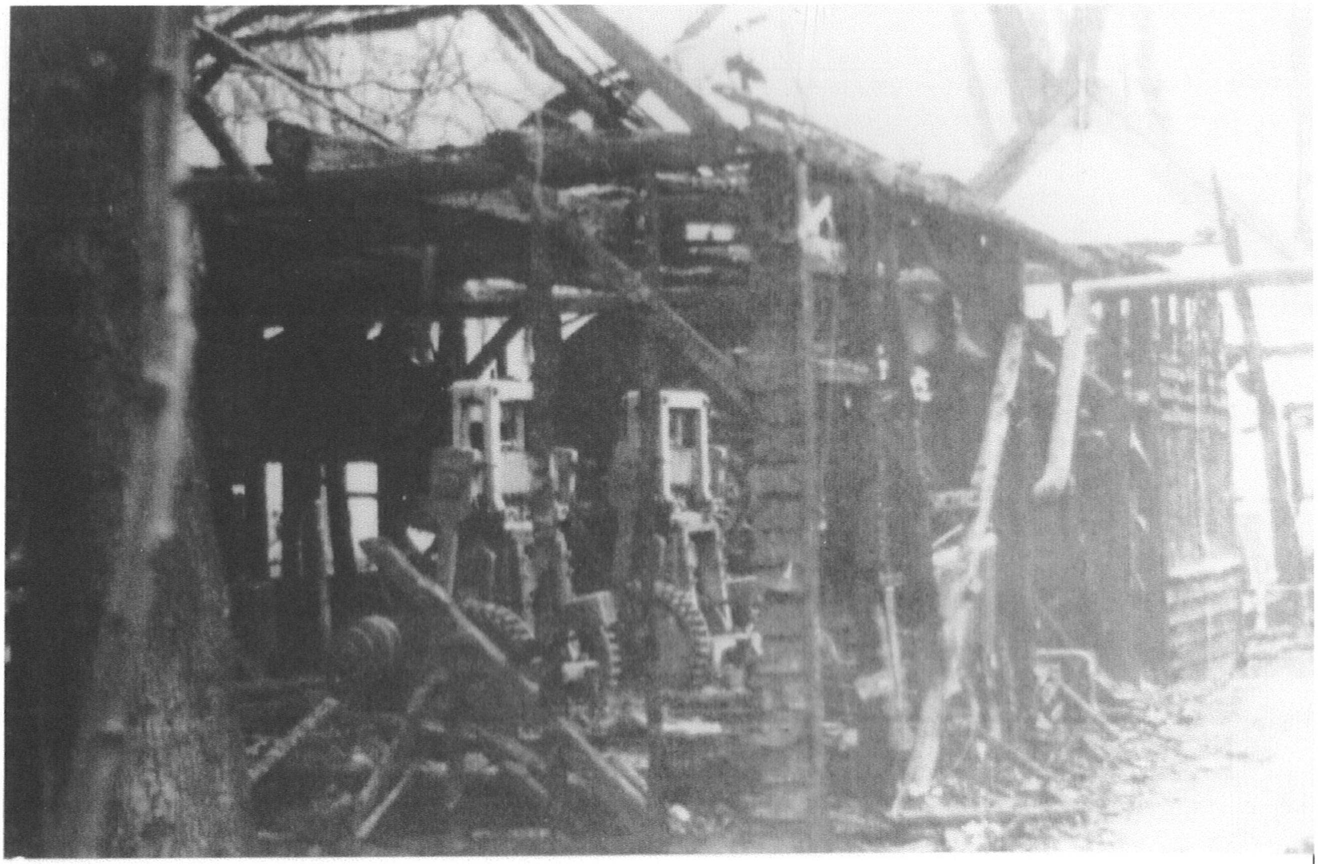


PRISMATIC POWDER.

Models of prismatic powder and part of moulding machine. The annular ring on one prism distinguishes EXE prismatic and the circular hollow SBC prismatic.

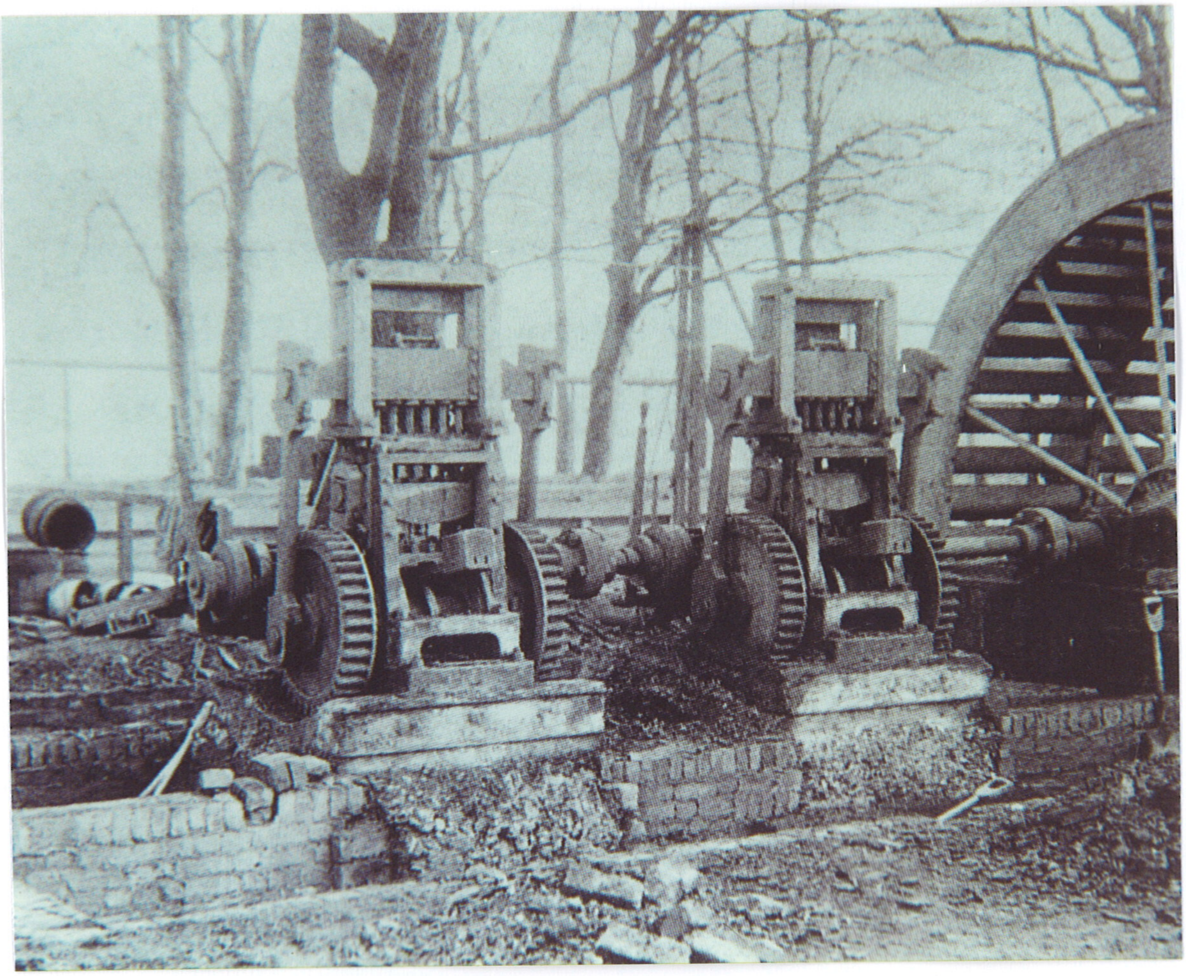
RGPF WALTHAM ABBEY.
CAM PRESSES.

Cam presses photographed after an explosion on 13 December 1893 in which 9 men lost their lives.



RGPF WALTHAM ABBEY.
EXPLOSION No.2 CAM HOUSE.

Damage caused by an explosion at 2.35-am, 13th October 1893, in No.2 Cam House. 9 men lost their lives in this distaster.



CAM PRESSES.

Cam Presses photographed after an explosion on 13 December 1893 in which nine men lost their lives.

Enquiries by the Explosives Inspectorate after an explosion in 1893 at Waltham Abbey RGPF revealed that only six manufacturers were using them, in three cases for pressing mining cartridges. John Hall and Son reported that they had been the first to use the principle about 20 years earlier at their oare Works at Faversham; the works at Chilworth had been using four since 1886. Curtis's and Harvey at Hounslow, after investing £2000-£3000 in 1890 on two cam presses, considered them too dangerous to operate and abandoned them shortly afterwards.

PRESS HOUSE.

These are the unique remains of a Victorian Hydraulic Press House. Pressing made gunpowder more effective and less likely to disintegrate during transport. In the Press House the crushed 'millcake' was loaded between copper plates in a wooden box and pressed for 15 minutes.

The press now stands in complete isolation on the left hand side. When working, it would have been housed in a light wooden building loke one shown on the left hand side of our main picture. This building was separated from the hydraulic pump house on the right by a traverse. Both of these features survive.

The Pump House was roofed with corrugated iron, an early use of this material. The water-driven hydraulic pump inside was powered by a low breast shot waterwheel made of cast-iron. This is believed to be the only surviving waterwheel driven hudraulic pump in England.

THE ROYAL GUNPOWDER FACTORY.

GUNPOWDER PRESS.

The Press Man.
The men who worked this 19th-century hydraulic press at Waltham Abbey loaded 800-lb. of crushed mill cake into a strong wooden box fitted with copper dividing plates.

Then they retreated to a control room behind the high protective barrier or 'traverse', and started up a waterwheel. this drove the hydraulic pump that created the pressure. The press exerted 70 tons to the square foot. (That's equivalent to 75 bags of sugar weighing down on one square centimetre!)

After some 15 minutes, the 'press cake' was about half the width of mill cake and looked like sheets of dark slate. it was left to dry. Within 24 hours it was so hard, it was difficult to break.

The press man's job was always one of the most dangerous on site. protection for the workers improved as the presses became more powerful.

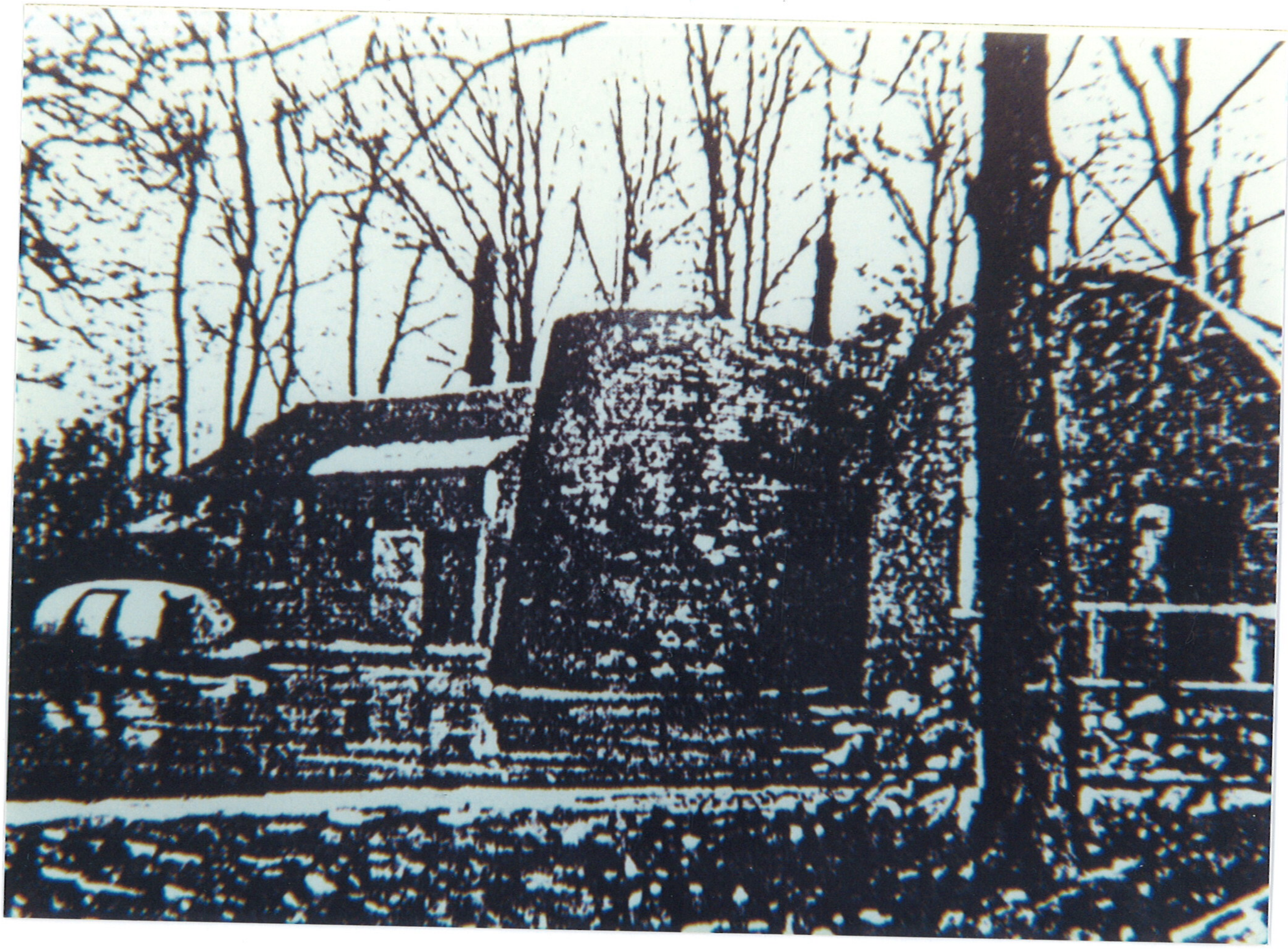
PRESS HOUSE.

EXTERIOR VIEW- OCTOBER 2002.

The site presents the full spectrum of the problems associated with preservation of an industrial monument:
Pump House roofless, exposing pump and machinery to the elements.
Water Wheel rusting, particularly paddles.
Press exposed to the elements, seriously rusting.
Traverse rendering breaking off and roots deeply embedded in traverse.
Brickwork spalling.
Area of dry mill basin in front of buildings heavily invaded by self seeding alder and sycamore which will ultimately cover the site.
In addition it lies within the area of a larger industrial monument and therefore decisions cannot be made independently.
The problems and possible solution fall into four broad categories.:
(1) Alleviation of rusting (2) Alder and Sycamore incursions.:
(3) Machinery restoration (4) Building restoration.

(1) and (2) are theoretically feasible but would require a concerted effort and a large number of volunteers. Realistically it is unlikely that the Friends could provide the number and they would have to be supplemented by other bodies such as Epping forest conservation volunteers, with the Friens concentrating more on the rust problem along the lines of the excellent work done on the 1939 cordite press.
(3) and (4) would have to be subject to funding and control by outside bodies such as English Heritage.
Action is required urgently. Failing that, this article will merely serve as an epitaph for yet another hast disappearing piece of Britain's technical heritage.

Article in the Newsletter 'Touchpaper' of the Royal Gunpowder Mills Waltham Abbey FRIENDS ASSOCIATION Dec. 2002.



PRESS HOUSE.
RENDERING BREAKING OFF.

MODEL OF A PRESS HOUSE.

THE ROYAL GUNPOWDER FACTORY.
HYDRAULIC GUNPOWDER PRESS HOUSE.
1879.

NOTE ON CORRUGATED IRON.

Part of the corrugated iron roof of the Pump House has been saved and is stored albeit in poor conditions, on one side of the site. this is a rare example of this material in 19th century wrought iron form. From the 1890's iron was replaced by corrugated mild steel, normally galvanised, i.e. dipped in molten zinc, but the habit remained of calling it iron. From the 1970's material has been developed with a coating including 55% aluminium/43% zinc and some silicon. Galvanised corrugated iron was massively sold in countries such as Australia and Argentina, particularly for roofing, and there is now anguished debate amongst conservationists on how best to repair/replace it, giving rise to learned articles with titles such as 'Corrugated Iron _ The profile of a National Culture and 'The Corrugated Iron Aesthetic'.

BRAMAH GUNPOWDER PRESS.

Section through the hydraulic gunpowder press. The press illustrated has a fixed press block (B) which in earlier examples was moveable.

The story of the Industrial revolution and beyond was partly one of an ongoing series of technological innovations being utilised to solve problems which had been blocking the way to increased production/improved quality, not necessarily in ways which had been envisaged by the originator, and the gunpowder industry was no exception. The Bramah press was a perfect simultaneous means of increasing presscake density and increasing safety - as the point of pressing was separated from the hand lever by the hydraulic pipe the system could be operated remotely. It is not surprising therefore that the Committee recommended its adopttion. By 1830 there were at least 14 Bramah presses in operation at Waltham Abbey.

The earlier part of the 19th century was a period of relative quiet at Waltham Abbey but external international events brought a gradually increasing demand, materially increased by the Crimean War 1854-1856. The Governmental response at the Mills was reflected in the commencement of a major incorporating mill building programme in 1857 together with the introduction of a new power source-steam. Incresed demand, both for output and quality, impacted down the whole of the manufacturing chain, including pressing.

The hydraulics of the Bramah press had represented a significant technical advance but it still relied on hand operation and it was reaching the limit of its development in terms of capacity and pressure / density of product.

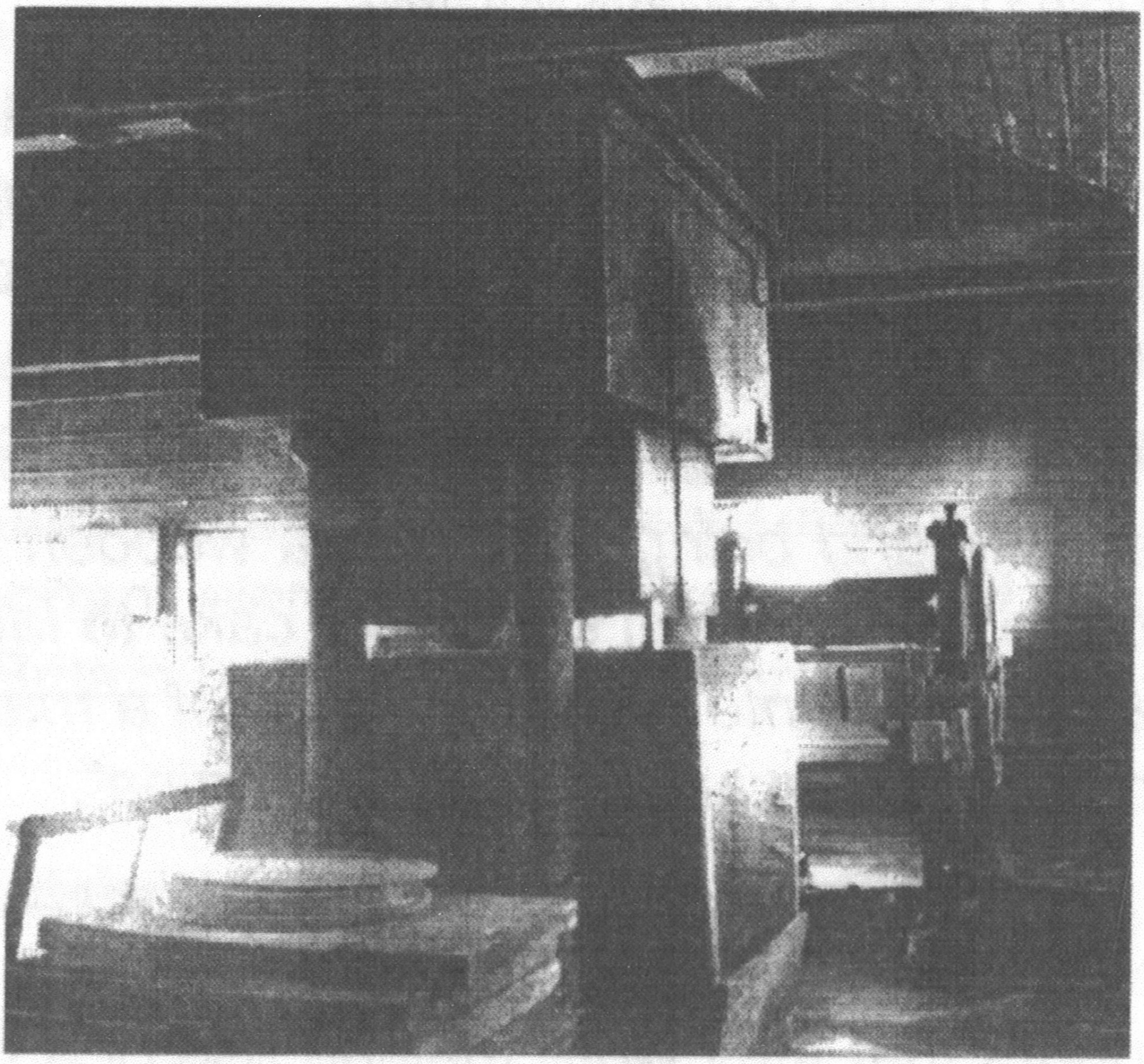
The response was to build around the time of the Crimean War two new press houses on the site of disused horse corning mills - Building 76 designated Press House No.1 and Building 103/4 designated Press House No.2. Building 76 was converted to a cordite mixing house in 1898 and later demolished. Building 103/104 has survived and was renumbered Press House No.1 For the first time pressing in the new buildings was mechanically powered. The power source was the long serving water wheel, powering hydraulic pumps.

Piston Pumps - have not survived. There were four, driven via two rocker arms, two pumps on each.
Pipework, with hydraulic flanges. With the exception of the pumps, all of above have survived, albeit in a parious state.

The Press now stands, open to the elements, an almost mesmeric symbol of the ruggedness and strength of Victorian engineering.

The elements of the Press were:
The Ram and over the Ram the press Table on which was placed the Press box of gun metal, lined inside and out with oak. An Oak Block was placed overhead.

SIDE VIEW OF PRESS (1940)



THE ROYAL GUNPOWDER FACTORY
WALTHAM ABBEY.

PRESSING AT WALTHAM ABBEY.

Post 1812-Hydraulic Development.

(1) Manually Powered- Bramah Press from 1812.

There was little technical development of the hand screw press and it had reached the limit of its productive capacity by the 18th century. For gunpowder production hand capstan operation was a serious inherent safety hazard.

In 1811 a serious explosion occurred in one of the hand presses at Waltham Abbey and a Committee of Engineers was appointed to investigate and make recommendations. It can be conjectured that in parallel with seeking to determine a means of reducing the risk of explosion the Committee would have taken the opportunity to look at ways of solving the problems of productivity of the hand system and of increasing the pressure and therefore density of the pressed material. it had become recognised that this increase in density brought an important range of quality gains - increased resistance to breakup in transport, increased moisture resistance, more powerful explosive performance per unit volume (e.g. although the information would not have been available to the Committee at the time, research by the Smithsonian Institute on the US Navy ship 'Philadelphia 'demonstrated that post pressing the necessary loading for the same gun between 1775 and 1812 war with Britain was reduced by 1/3).

At this point Joseph Bramah enters the scene. In 1795 Bramah, who reputedly acquired his enthusiasm for hudraulics from designing and installing the revolutionary new water closets for the aristocracy and gentry, had been granted a patent involving water, which is incompressible, as a medium for transmitting energy. The patent covered a number of applications, the most important of which was the use of water for applying pressure force - the hydraulic press, comprising a hand lever operating pump and reservoir connected to a hydraulic cylinder and ram. The burgeoning production of the Industrial Revolution had created a demand for improved means of handling and moving goods and after improvement, particularly by Matthew Murray, the Bramah press was widely adopted for arange of applications for 'the throwing of small articles into bulk', particularly in the all important textile industry.

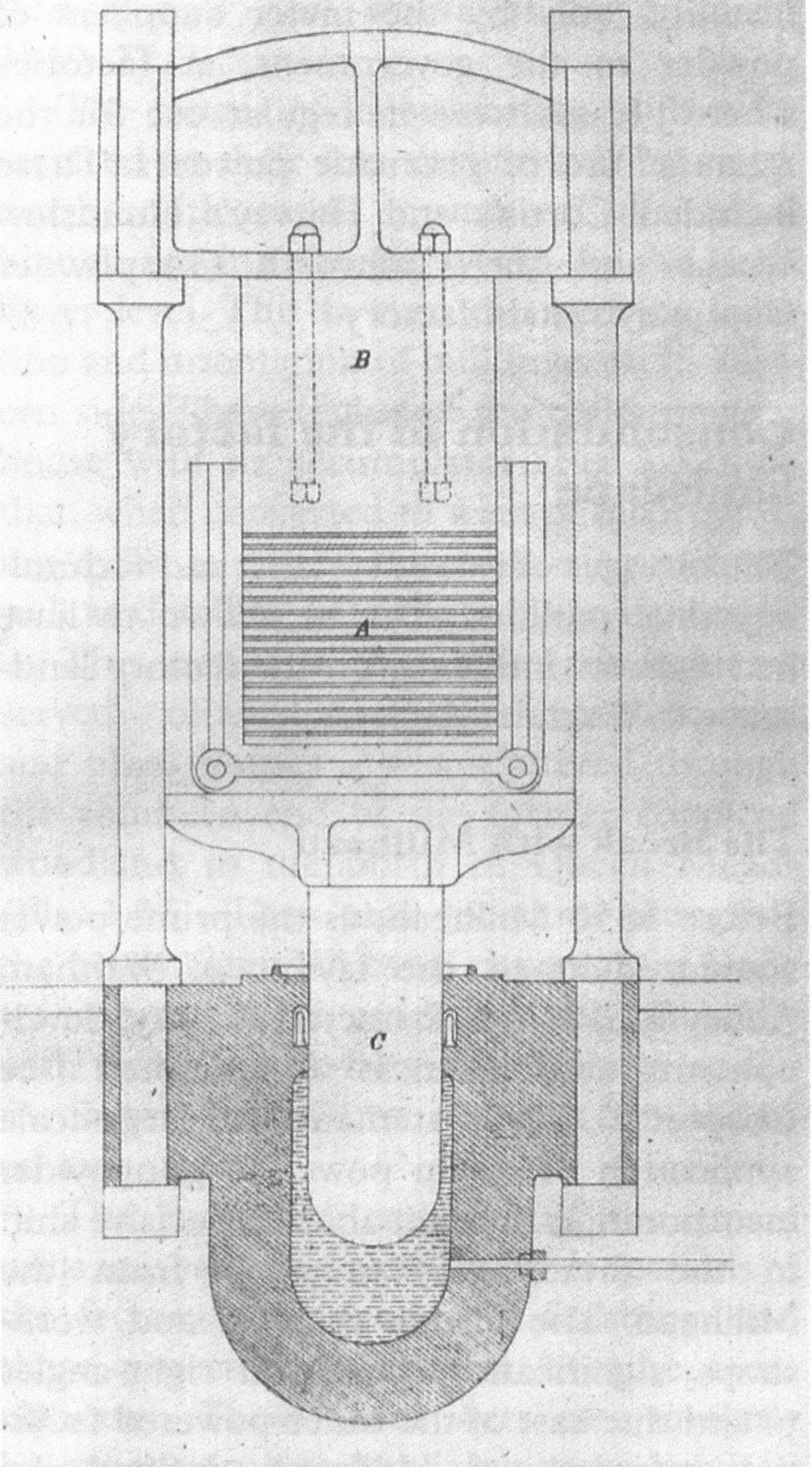
Bramah's patent was based on principles enunciated by the French physicist B.Pascal in the 17th century. The nub of Pascal's Law was that pressure is exerted at every point in the fluid. The practical effect which the genius of Bramah revealed was that in a combination of large and small cylinders with pistons connected by a pipe and filled with fluid a pressure in the fluid created by a small force acting on the piston in the small cylinder will result in a large force on the large piston- multiplication of forces (the size of the pipe is immaterial to the effect).

It can be seen from the illustration that where a force of 5 kgf is applied to a piston area of 2cm in a tank of 100cm a pressure of 2.5 kgf cm is produced at every point within the fluid acting with equal force per unit area on the walls of the system. This produces, in the larger tank of 1.5 m, an upwards force of 37500 kgf.

THE BRAMAH GUNPOWDER PRESS.

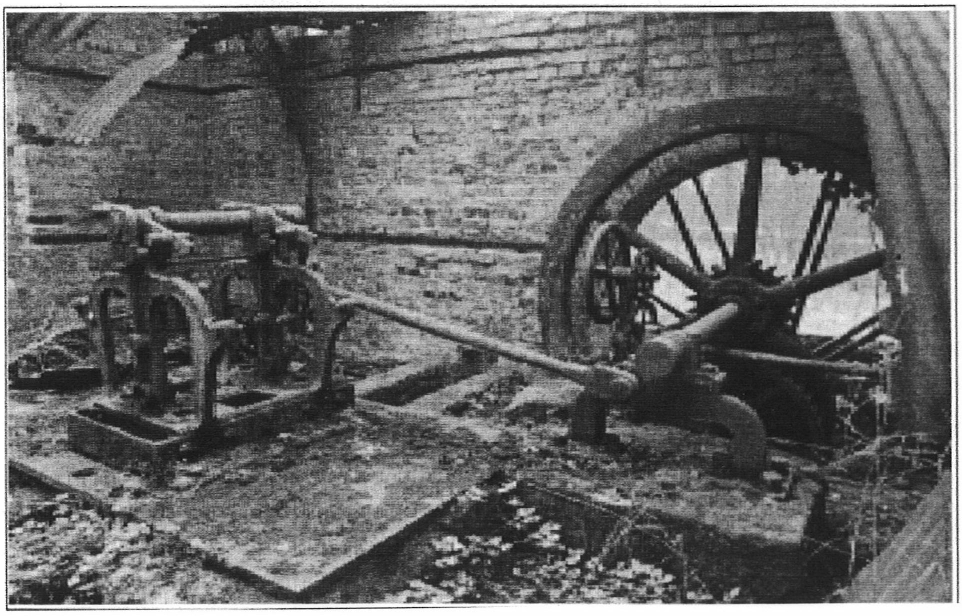
SECTION THROUGH THE PRESS.

C. Hydraulic ram.
B. Press block.
A. Copper plates.

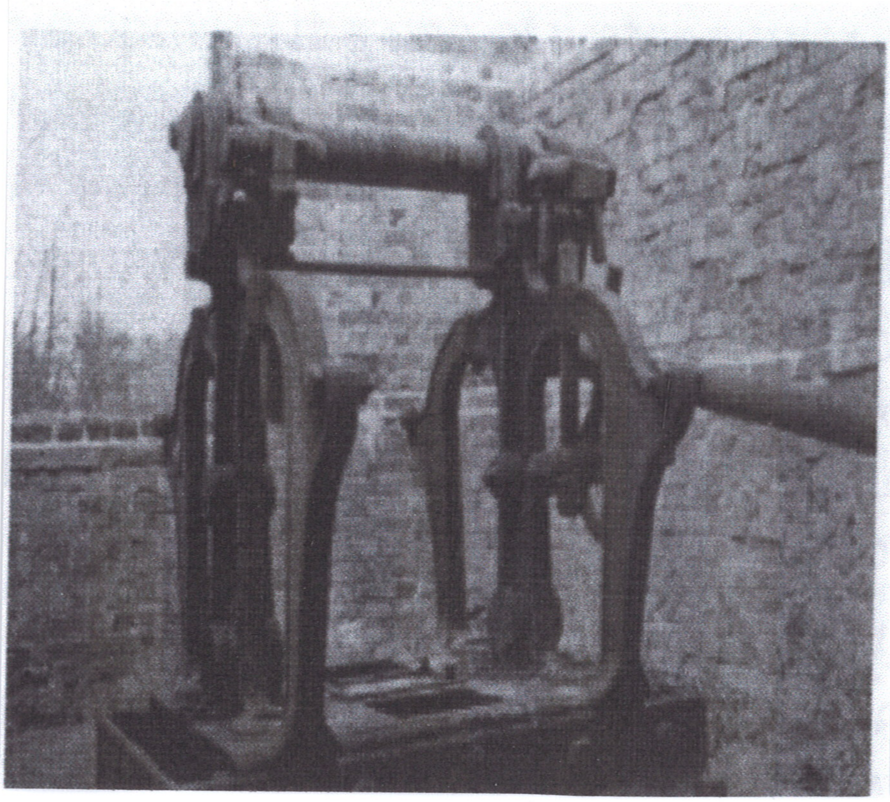


A. Press box, B. Press block, C. Hydraulic Ram.

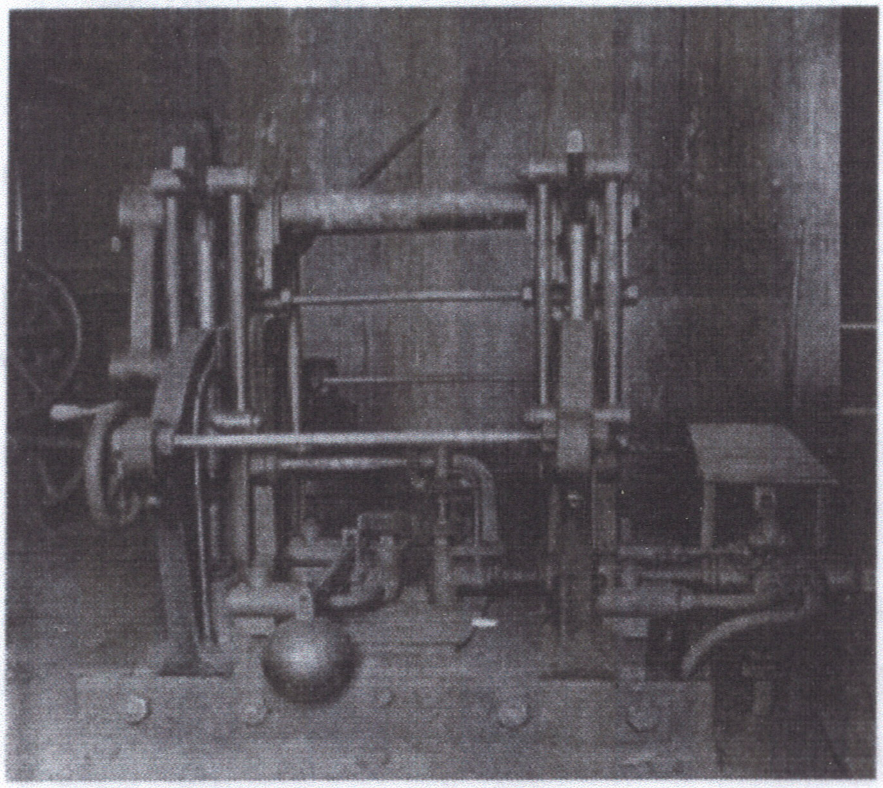
BRAMAH GUNPOWDER PRESS.
Remains of hydraulic pump attached to water wheel within the pump house.



PUMP FRAME (2002).



WORKING PUMP (1940).



BRAMAH GUNPOWDER PRESS.

Broken down millcake was pressed in layers and to achieve this it was loaded on to copper press plates, 30-40 to the box, half inch apart. To load or unload the box was swung out from the table. After loading the box was turned back on to the table and the overhead block was lowered to just over the top surface of the material in the box. The water wheel/ pumps were then actuated. Contary to modern practice, the pressure from the ram was therefore exerted upwards.

The foreman certainly earned his money. Whilst pressing was going on the workmen were safely in the Press House on the other side of the traverse but the foreman 'should go in (the Press House) from time to time to see that everything is working well'.

The normal loading of the press box was 500 lbs and the pressure exerted was 70 tons per sq,ft., sustained for 15-30 minutes. At the end of the pressing a relief valve was opened and the weight of the ram and the press table/box carried the table down for unloading.
Note: There has been some debate over whether this figure is correct as a figure of 800lb has been cited twice in military management accounts of operations at the Mills - 1857 and 1870. Nevertheless the press box was 2ft 6in square which with a pressure of 70 tons per sg.ft., gives a total pressure of 437 tons, not far off the 500 quoted and a report of 1830 describing operations specified a typical loading of 504lbs for a hand screw press at Waltham Abbey. The Act governing explosives manufacture at the time laid down a limit for pressing at any one time of 10cwt (1120 lbs) so even 800lbs would be within the limit.

The presscake adhered to the plates and had a slate-like consistency. The following descripiton in an 1870 management account of processing at waltham Abbey of seperation from the plates seems to show a rather startling complacency abot the risk associated:-

"Each plate, with a layer of hard slate-like cake adering to it, is separated from the one beneath it, and being lifted into a wooden bin, gets a few knocks with a wooden mallet which cause the cake to fall off in irregular fragments, which are broken into pieces the size of a man's hand, shovelled into tubs, and removed to an expense magazine".

After these words were written a disastrous explosion happened on the 16th June 1870 at the Lower Island Works. from the statement of one of the survivors it appears that they were making use of a copper chisel to separate the plates.

In terms of 19th century technical development the use of water power in preference to the power of the future, steam, could be viewed as some what regressive. However it is possible that safety considerations were a significant influence. The new buildings would have required individual steam engines and their dispersal could have been seen as a safety hazard. It is a moot point how far the decision to employ water power was a result of this consideration and how far technical conservatism and the existing availability of water from the Millhead in the canal leading to the site.

THE BRAMAH GUNPOWDER PRESS.

The press consisted of a cast iron (or by the end of the century cast steel) hydraulic ram with four round colums supporting the head stocks. Water under pressure was introduced through a narrow pipe at its base to raise the ram. Powder for pressing was brought from the breaking down house where the mill cake from incorporation had been crushed between rollers to form meal powder. It was loaded into a stout box measuring 2ft 6in square and 2ft 9in tall with opening sides, between 46 copper plates each 2ft 5in square. During packing with 800lb of gunpowder the box was turned on its side and the plates seperated by spacers. Once filled, the spacers were removed and the sides secured before it was righted and manoeuvred onto the table of the ram beneath the press block. the press was then operated remotely from a room on the opposite side of the traverse adjacent to the pump house, exerting 70 tons per square foot for a quarter of an hour. The most reliable method for ascertaining when the correct degree of compaction had been achieved was simply to measure how far the block had penetrated into the box. The box was opened and the powder removed,sometimes with the assistance of a wooden mallet and copper chisel, or spud. As in earlier processing the resulting press cake was then roughly broken by hand and allowed to harden further before granulation. Many private manufacturers dispensed with the press box, and simply formed a layer cake of plates and gunpowder. This had the disadvantage of allowing powder to spill out at the sides and producing a less densely pressed powder at the edges, which had to be cut away. Against this stood the hazards of chipping powder away from the box sides, and by the end of the century the box was no longer used. Also by this date copper plates had been superseded by ebonite in many private factories. Circumstantial evidence suggests that the machinery for this hydraulic press house was supplied by William Fairbairn and Sons of Manchester.

SIGNIFICANCE OF No.1 PRESS HOUSE.

Given that the building and machinery of the millhead were systematically destroyed it is a near miracle that the Press House did not meet a similar fate and that sufficient remains to present a coherent picture of a water driven hydraulic system.

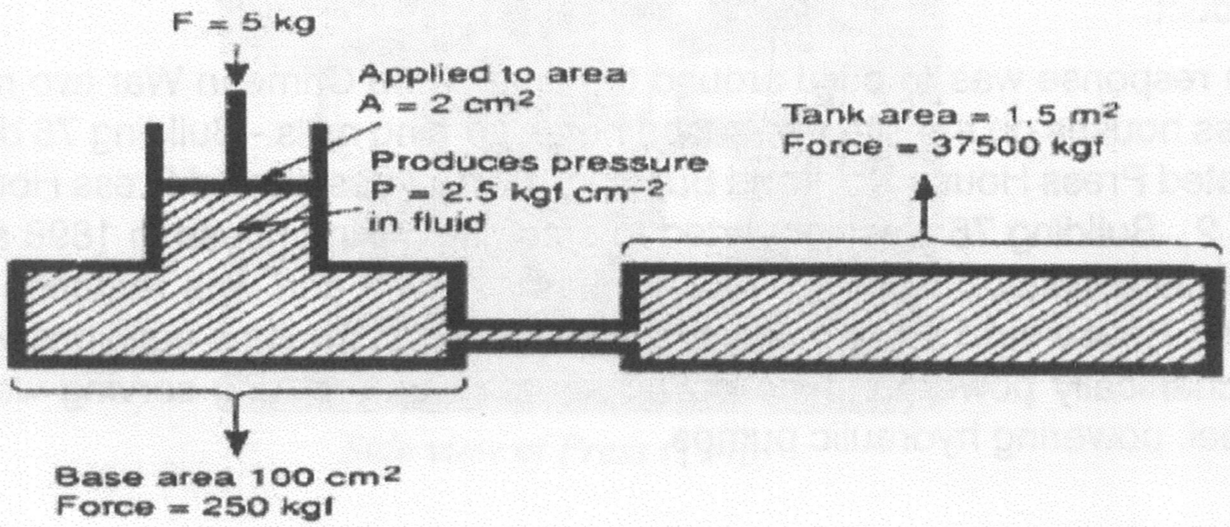
It is of major significance in the history of the gunpowder industry and to British if not international industrial archaeolgy in general.

* It is a very rare surviving instance of water produced hydraulic power, i.e. hydrokinetic energy from a water wheel producing hydrostatic energy from pumps.
* It is a unique example of the application of water powered hydraulics to gunpowder manufacture.
* It is an importance surviving example of the combined use of water for transport and hydraulic power in an internal industrial system.
* It is an important element in the catalogue of surviving hydraulic machines in Britain (a declining number).

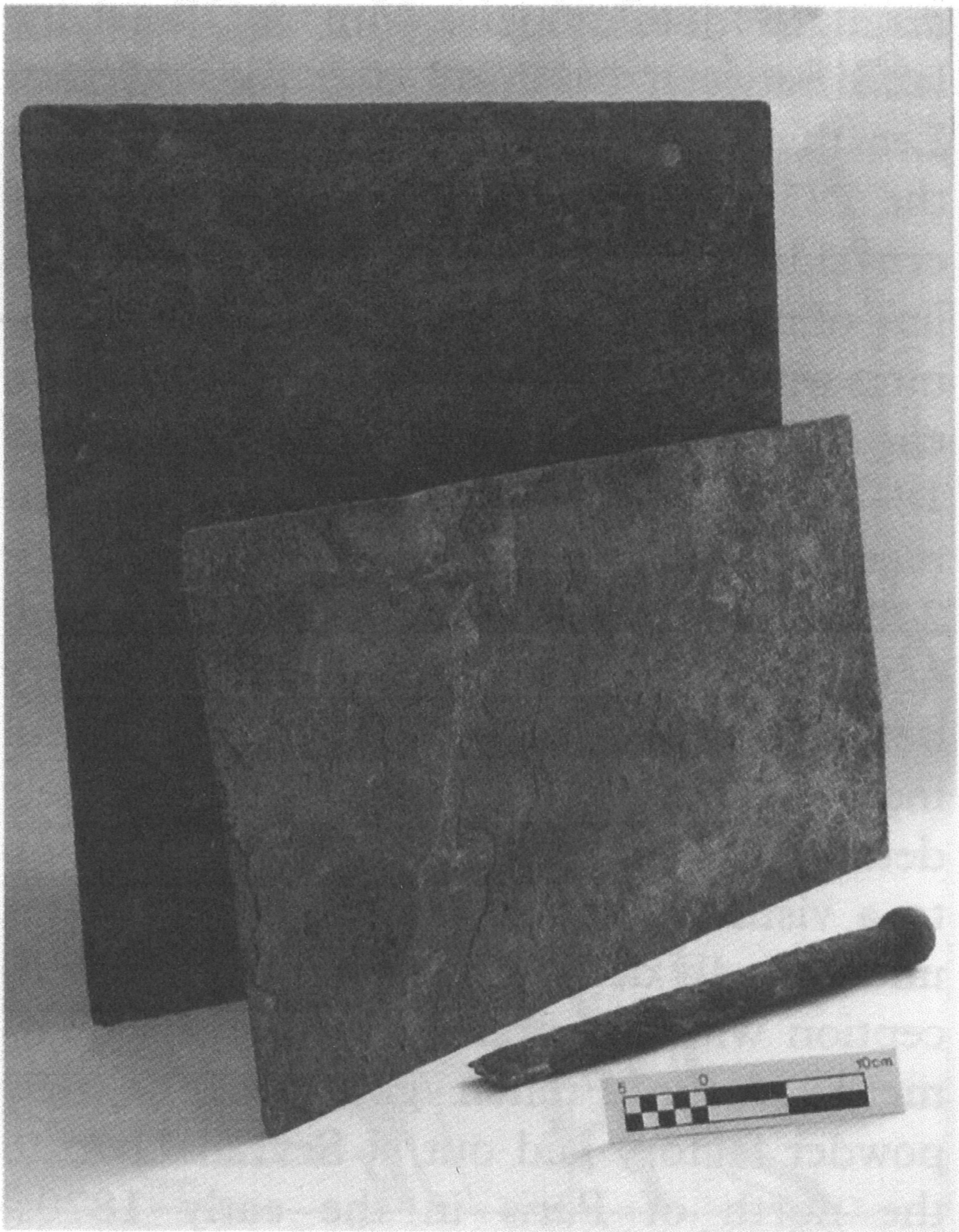
THE BRAMAH GUNPOWDER PRESS.

THE PRINCIPLE OF THE HYDRAULIC PRESS.

A small force acting on a plunger (p) of small area over a long travel will create large force on a ram (r) of large area over a short travel.



BRAMAH GUNPOWDER PRESS.
Copper press plates and copper chisel (or spud).



BRAMAH GUNPOWDER PRESS.
Press from Press House.

GUNPOWDER PRESS HOUSE. c 1850.

The remains of the hydraulic press to the left are separated from the water-driven pump house to the right by an oval, brick, earth-filled traverse.

THE ROYAL GUNPOWDER FACTORY.

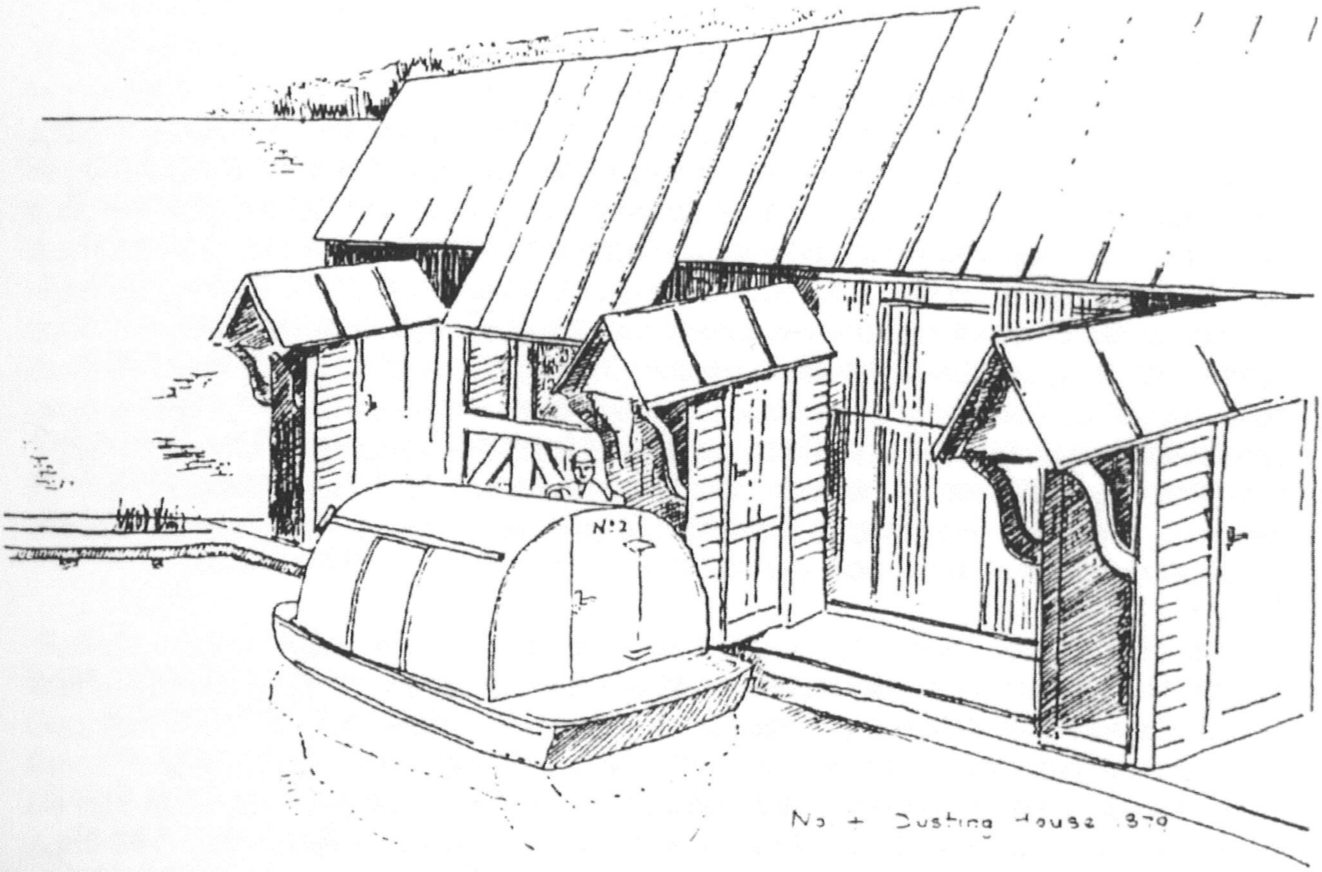
GUNPOWDER DUSTING MACHINE.

Dusted.
The corning machine created a great deal of dust, which clung to the pieces of gunpowder. Gunpowder dust caught fire easily, it also attracted moisture even more than the granules themselves. Damp gunpowder was at best inefficient, if not useless.

Polished.
The granules were turned in revolving barrels. The friction of one grain against another gave them a polished surface. The addition of graphite made it glossier still. this glossy surface made the grains much more resistant to damp, so the gunpowder had a far longer 'shelf life'.

And Ready For War.
The gunpowder was spread out on shelves in a heated drying room. Once dry, it was packed into oak barrels, marked according to the size of grain. They were loaded onto sailing barges, which were towed down the narrow River Lea before sailing on down the Thames to the Purfleet Gunpowder Magazines.

RGPF WALTHAM ABBEY.
DUSTING HOUSE, 1879.



No.4 Dusting House, 1879

THE 1875 EXPLOSIVE ACT.

SAFETY CLOTHING.

The 1875 Act went further than previous legislation in regulating working practices within licensed factories, and, to a certain extent, the construction of buildings. Although its primary purpose was not social reform of working conditions, it did have a benefical effect in making explosive factories safer places to work. foe example, it stipulated that suitable clothing should be provided for workers in the danger buildings. Characteristic clothing considered of a pocketless suit of wool, or other non-inflammable material, and a cap with pull-down ear flaps. Powder or magazine shoes were also provided for all those entering the danger areas. typically these were either entirely of leather, or if shod a non-ferrous metal usually copper, would be used. At Waltham Abbey RGPF, workers in the incorporating mills wore a suit of 'lasting' (a durable cloth) with bone buttons (to which powder did not adhere), gauntlets, and a cloth helmet, which gave some protection against fire. Concern for the workers was also manifest in deep wells outside each danger buildings that 'the authorities have thoughtfully provided...into which men who have been badly burnt may plunge'. Use of ferrous tools in the manufacting process or in repairing danger buildings was another hazard that was guarded against by restricting the materials from which tools and fittings could be made to safe materials, including leather, wood, copper, or brass. At Waltham Abbey this policy even extended to the use of copper barbed wire. More formalised distinctions appeared between 'clean' and 'dirty' areas. 'Clean' areas were parts of the factory where loose explosives might be encountered; a foot board, sometimes painted red often marked the boundry and acted as a physical reminder of the distinction. This may also have been visible as a change in flooring material. in larger factories changing or shifting rooms were built where the workers could change and was, as at Waltham Abbey RGPF, along with police posts or search rooms. Changing areas were also provided in the lobbies of danger buildings, where workers could leave outdoor clothing and change into magazine shoes. A shoe box was often provided for this purpose. Workers were searched to prevent the introduction of 'contraband' items into the danger areas and to enforce the wearing of regulation footwear and clothing. Employment of young people continued, although persons under 16 were only allowed to work in danger buildings and magazines under adult supervision.

RGPF WALTHAM ABBEY.

Worker in the gunpowder incorporator mills, late nineteenth century. He is wearing a 'lasting' suit, protective cap, gauntlets and magazine boots, and sits on a powder barrel.

THE ROYAL GUNPOWDER FACTORY.

THE CLEANING GANG.

Photographed at the turn of the century. Once the gunpowder ingredients have been mixed the powder or 'green charge' is explosive. The danger is minimized by sweeping up and cleaning with wet mops.

ROYAL GUNPOWDER FACTORY.

BARREL MAKERS.

The Tunnhan family, who were all coopers, employed in making the barrels which were to be filled with gunpowder.

ROYAL GUNPOWDER FACTORY.

GUNCOTTON WORKERS.

A group of guncotton workers 1890's, seen with a carboy of acid.

THE ROYAL GUNPOWDER FACTORY.

POWDER BOATS.

THE ROYAL GUNPOWDER FACTORY.

POWDER BOATS.

The site at Waltham Abbey was originally chosen for gunpowder manufacture because water from the River Lea could power the mills. The water from the Lea was later used to develop an extensive network of canals along which the powder boats carried gunpowder.
There were a number of brick built boathouses located around the network, which would accommodate boats to move between the waterway at different levels. There are also three aqueducts on the site carrying one waterway above another.

By 1907 the canal network extended for 5 miles. Two types of boat were used. the large boats like this one were up to 34-feet 5-inches in length and there were smaller flat-fronted boats of up to 28-feet 2-inches. The design appears to have remained the same from the mid mid-nineteenth century until the end of their use in the 20th century.

The boats were carvel-built, having planks which butted against each other. They were built with copper nails, bronze fittings, and internal leather-lined decks. The central section was covered by a wooded barrel-vaulted cabin with canvas flaps through which the powder was loaded.

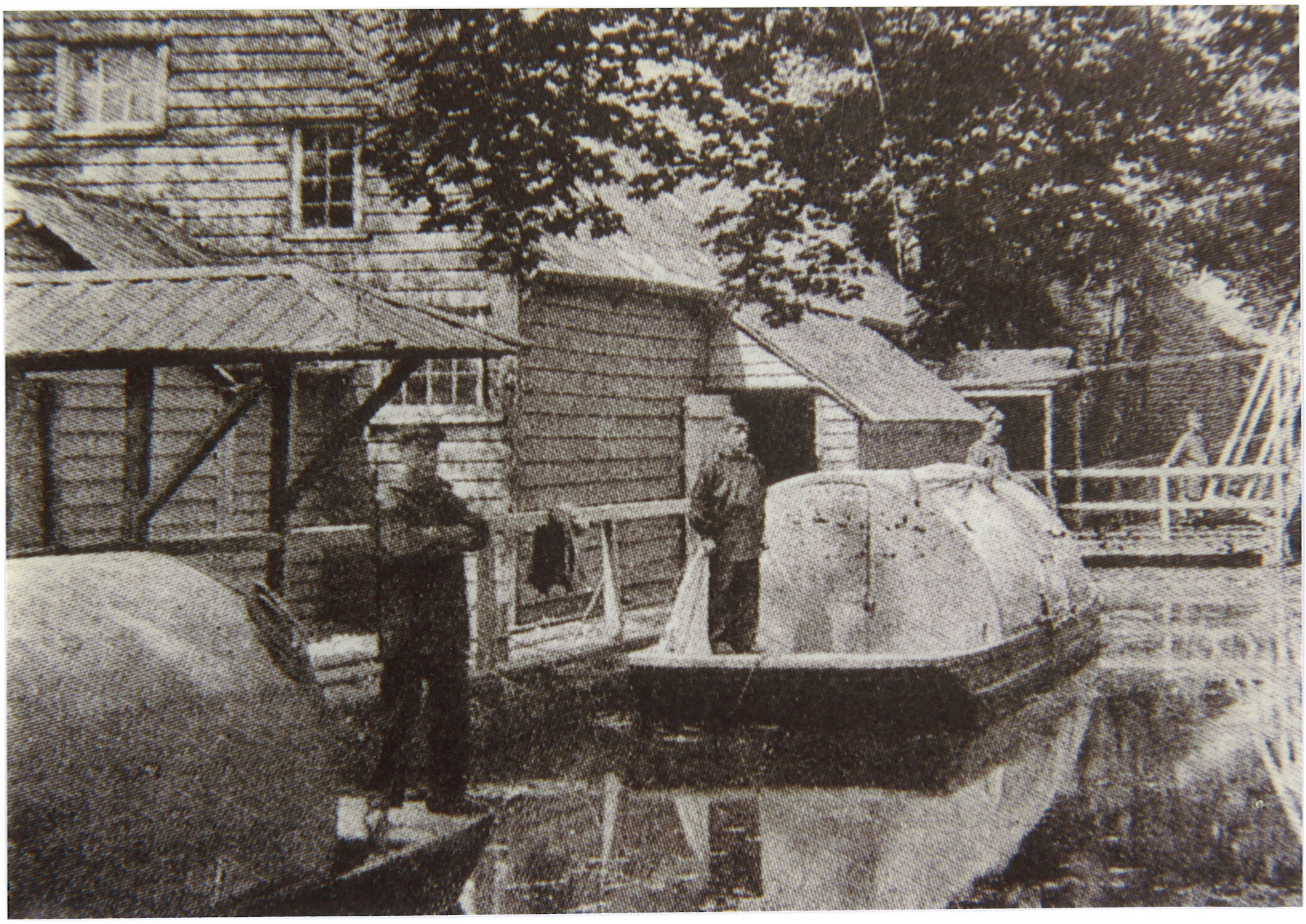
This boat is one of the last ones at Waltham Abbey.

Length: 1o.13-m.
Beam (max). 2.54-m.
Depth (keel to gunwhale midships) 0.67 m.
Frames and floors: Oak.
Canopy . Light wood canvas cover.
Fastenings: Bronze, copper nails.

ROYAL GUNPOWDER FACTORY.

COVERED POWDER BOAT.

There were 36 of these boats in 1895. No one was allowed to go over the bridge while one of them was passing beneath, less any dirt or grit should fall on the deck.



ROYAL GUNPOWDER FACTORY.

OSCAR GUTTMANN.

RGPF.

Lt.GENERAL SIR WILLIAM CONGREVE.

When the mills were purchased the science of chemistry had barely started, control of the manufacturing process was loose and quality was a constant problem. Of particular importance was the need to secure not only better performance but greater uniformity. Congreve was a visionary who saw that the way forward lay in scrupulous attention to purity of ingredients, precise measurements, close study each stage of the process to introduce improvements where possible. These considerations might now seem self evident but in that time needed strong direction and control to be achieved. William Congreve was succeeded in 1814 by his son, also William, as Comptroller of the Royal Laboratory, including supervision of the Royal Gunpowder Factories, and continued the emphasis on quality, measurement and machinery improvement. He was responsible for the patenting in 1815 of important mixing and granulating machine designs.

RGPF.

Group C Incorporating Mills 1859.

This mill building is of a T dhape with a central engine tower, originally housing a steam engine and a boiler house at the east end to the rear which contained two Lancashire boilers. To the north and south of the central tower are two sets of bays which held a total of 6 incorporating mills - 3 bays on each side. Each mill comprised a pair of vertically mounted cast iron edge runners, weighing about 4 tons, revolving on a circular iron bed.

(N.B. Earlier mills had stone runners, some of which can still be seen on the site).

Yellow brick laid in English bond was used to construct the engine house, boiler house and partition walls seperating the bays. The partition walls are 27-inches thick.

The front and rear walls of each bay were of a light felt on wood and the roofs were of composite timber/iron construction. To the west side an open timber veranda allowed loading of materials from the narrow gauge railway. After 1945 when the site became a research station the building were converted into laboratories and the veranda was closed in.

The boiler house roof reflected contemporary application of wrought iron tension rods with cast iron compression members.

The possibility of accident was inescaple. The design of the light construction front and rear walls and roof of the bays was to channel any explosion to the outside, avoiding transmission to adjoining mills. These walls were relatively easy and economic to repair whilst the strong partition walls provided protection and minimised damage to adjoining bays.

The power transmission from the engine reflected an approach similar to that employed in the textile mills of the time with an horizontal drive shaft in an under floor shaft alley, avoiding damage from the ever present risk of fire.. The alley in Group C was lined with cast iron plates bolted together with a top plate forming the mill floor above. The drive was taken from the engine via a connecting rod to a crank on the drive shaft, flanked by a pair of flywheels. Each mill has an horizontal bevel gear wheel with drive being transmitted via a pinion wheel. Motion from the drive shaft was transmitted via a friction clutch engaged by a remote control rod.

The use of underfloor transmission had two major advantages - it separated two 'alien' systems - metal drive gear and gearing, associated with heat and possible sparks, from the explosive powder dust laden atmosphere of the mill rooms and it lessened the risk of a machine part breaking or becoming detached and falling onto the mill bedplate. In addition, in the event of an accident, the drive machinery was protected and therefore reusable without expensive repair

Architecturally, full advantage was taken of the tall central engine tower and boiler house to design buildings beyond the strictly utilitarian. They were Italianate style with characteristic round arch openings. The engine and boiler houses had dentril cornices and chamfered brick plinths and the boiler house had brick dividing pilasters. Overall there is an impression of careful design and construction with the style of the central buildings offsetting the necessarily functional incorporating bays.