WASC 2239

Dissertation on Hydraulic Power at WARGM

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WALTHAM ABBEY
ROYAL GUNPOWDER MILLS

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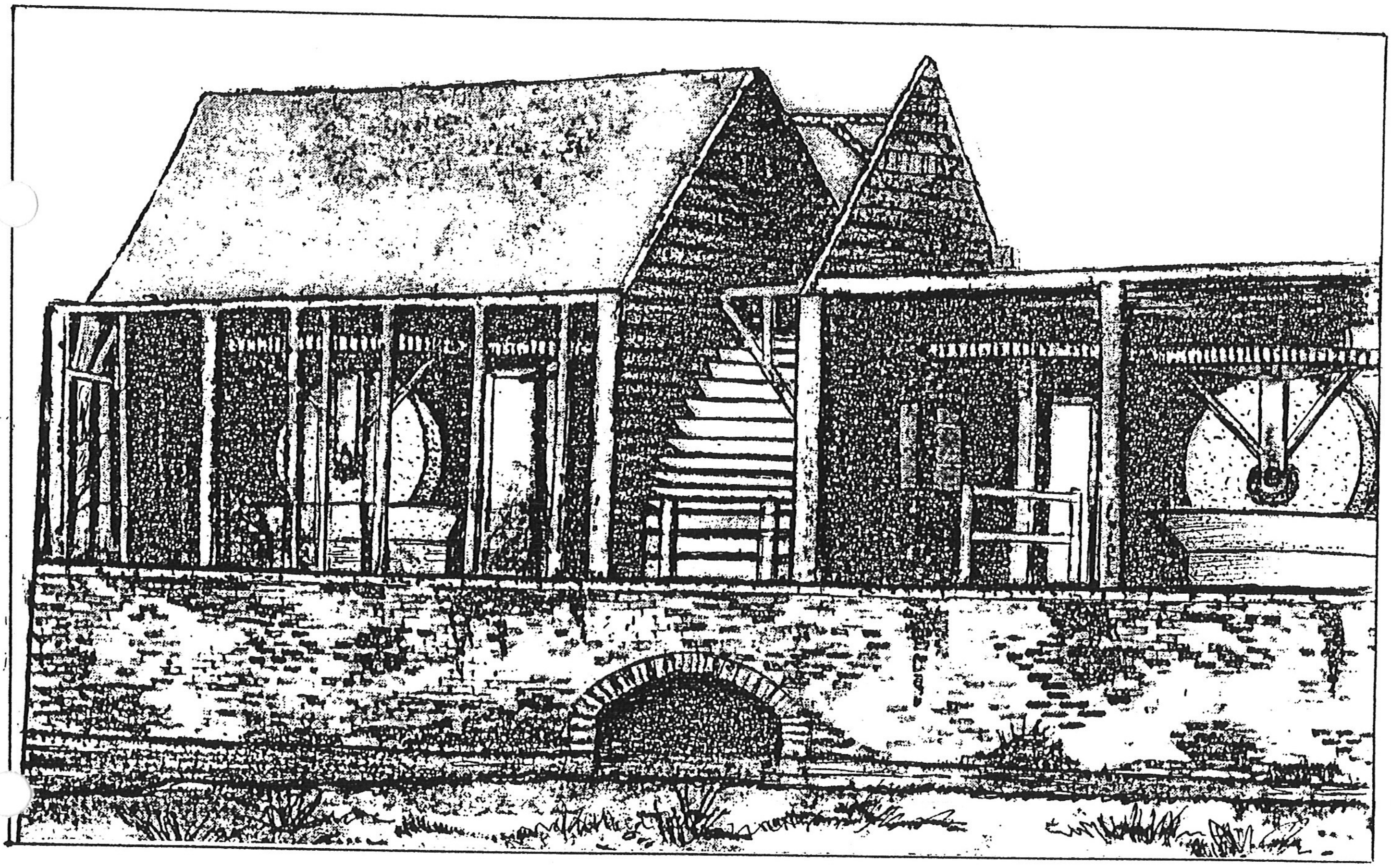

"The last pair of mills" - from a painting by E.A. Monro - 1956

ROYAL GUNPOWDER MILLS,WALTHAM ABBEY

HISTORY
HYDRAULIC POWER HISTORY AND ANALYSIS OF APPLICATION AT THE MILLS
RECOMMENDATIONS FOR ACTION

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Royal Gunpowder Mills Waltham Abbey - History History and Analysis of the Application of Hydraulic Power Recommendations

The three great elements of modern civilisation - gunpowder,printing and the Protestant religion Thomas Carlyle

1. Introduction/Scope

The Waltham Abbey Mills were over two hundred years of Crown ownership a key centre,nationally and internationally,for the production and research of gunpowder and later explosives and propellants.
Having passed through major phases of activity - the move to steam power with significantly increased production facilities,the fundamental change involved in the move from natural base gunpowder to chemical base material,and,after WWII,a Government Research Establishment, the Mills closed in 1991.
Ten years later after extensive refurbishment they opened to the public as a major interpretative centre.

This study :

1. Identifies the site
2. Establishes the historical and technical context of the Mills
3. Analyses the history,development and significance of a particular aspect of the engineering of the establishment - hydraulic power
4. Makes recommendations for action in the light of this analysis - on conservation,education,recording and publicity

2. Site Identification

The Town

Waltham Abbey is a small market town about 15 miles north east of London lying in the valley of the River Lea which runs from the north to meet the Thames below Blackwall in East London. It owes its origins to the foundation of a College by the Earl Harold in 1060 on the site of an earlier shrine in gratitude for being cured of paralysis. The College became a priory and in 1184 an abbey.

The Site TL 376 015 (Fig.1)

The Mills are situated immediately north of the centre of the town on the alluvial flood plain of the Lea,surrounded by marsh and water meadow occupying a linear site on a North-South axis. The distance North-South is around 2km. with an area of 75 hectares(185 acres).

The Mills originally extended to the town centre. With the introduction of guncotton in the 1880's expansion south of the centre to the Quinton Hill area took place. The original area was designated the North Site and Quinton Hill the South Site. All trace of activity on the South Site has been removed and the area covered by the new interpretative centre is therefore effectively the North Site.

Boundaries are defined by two early constructed water courses,both tapped from the Lea which split into four courses just north of the Mills. To the west a leat on embankments,the Millhead Stream,adjacent to the Horsemill Stream, and on the east the Cornmill Stream, utilising a gravel terrace on clay which rises to Epping Forest,and to the south of that the Old River Lea.

Both were designed to produce a head of water for power - the Millhead for a fulling mill and the Cornmill for the Abbey cornmill and later a pin factory and also to supply the Abbey fish ponds. Until the mid 19th century the Millhead was the core power source for gunpowder development.

The head of water produced was 6ft. and this can still be observed on the site.

Broadly the North Site can be split into a southern section,containing the gunpowder processing buildings,most later converted to later chemically based production, and a northern section devoted to new chemical development from the end of the 19^{th} century. Most of the site is a Scheduled Ancient Monument.

For safety reasons explosives production is in separated buildings. There are around 270 buildings,ranging from an impressive terrace of steam mills to the smallest stores. 21 have been listed by English Heritage - 1 Grade 1, 8 Grade 2* and 12 Grade 2.

Technical Commentary

A technical commentary on gunpowder and the chemical base explosives is attached (Appendix 1).

3. History of the Royal Gunpowder Mills

Early History - to 1787

Gunpowder was first used by English forces at the Battle of Crecy 1346.

Production in England was on a small scale workshop basis,dispersed over the country but with greater concentration in London.

By the reign of Elizabeth I there was increasing Government concern over security and volume of supply and the building of larger mills was encouraged.

Surrey and Kent - Early 17^{th} century Initially these were established in Surrey and Kent - Long Ditton and Chilworth in Surrey and Faversham in Kent were early centres, reflecting availability of timber for charcoal,water for power and for transport - raw material inward and finished product out to London / the Thames.

The Lea Valley - Mid 17^{th} century The Civil War in the 1640's stimulated demand for fresh supplies and the Parliamentarians encouraged building beyond Surrey and Kent. The Lea Valley had similar facilities and by the 1650's had become a major producing centre,although at the time not specifically in Waltham Abbey.

Waltham Abbey Previous Mills

By 1590 the Millhead Stream was powering a fulling mill. In the 17^{th} century this was converted to an oil mill.

Gunpowder at Waltham Abbey

Private Ownership

The Hudsons 1662-1701

Around 1662 Samuel Hudson converted the oil mill to two gunpowder mills. Gunpowder had arrived at Waltham Abbey.

The Hudsons,later Ralph then Peter, obtained Board of Ordnance contracts,but there was a quality dispute and Peter ultimately withdrew from the business.

The Waltons 1702-1787

By 1702 William Walton,a London trader in gunpowder,had taken over the mills and obtained his first contract with the Board,coinciding with the start of the War of Spanish Succession 1701-1714.

The Waltons could be termed a gunpowder dynasty. After William's death in 1711 the mills passed firstly to his wife Phillipa then various descendants and finally John Walton.

The Waltons pursued a policy of continuing improvement and investment,establishing the Millhead as,in the context of its day,a factory on an industrialised basis.

By 1770 inefficient and dangerous horse powered stamp mills had been replaced by water powered incorporating mills.

In the early 1770's John Smeaton,pre- eminent in mill design,was commissioned to design for the factory. Following this several mills were built.

By the 1780's there were 7 incorporating mills on the Millhead together with a mixing house,a composition mill,a corning house,a dusting house, two gloom(drying) stoves and a saltpetre refinery

The Government had always sought to control and influence gunpowder production. This had led to 'nationalisation',in 1759,of part of the mills at Faversham. However by 1783 Pitt,largely for cost reasons, was proposing 'privatisation'. In response Major,later Lt. General Sir,William Congreve at that time Deputy Comptroller of the Royal Laboratory at Woolwich demonstrated that Government production could be profitable,i.e. a saving could be made against purchase from outside, and that saving could be devoted to improvements and Faversham was retained.

Further, Congreve put forward a strong case for purchase of John Walton's mills at Waltham Abbey. In 1787 Walton agreed a sale - for £10,000,although not finally formalised until 1795.

Government Ownership

Royal Gunpowder Mills 1787-1945

The Mills became the Royal Gunpowder Mills and over 150 years of Government production of gunpowder at Waltham Abbey had commenced.

Early Days and the French Revolutionary and Napoleonic Wars 1789-1815

In spite of the Walton's policies the mills were not up to the standard required by Congreve and a programme of rebuilding and repair was instituted together with improvement of water supply. Senior personnel from the Govt. works at Faversham were employed.

A new mixing house and saltpetre refinery were decided on along with machinery improvements - a new press in the corning house and a new glazing and dusting reel. All this meant that over a year passed before production commenced - in mid 1789.

The Mills now had 10 incorporating mills and manufacturing capacity had been increased from 15000 to 20000 barrels p.a.

£35,000 had been spent - 3 ½ times the purchase price.

The French Revolution and the Napoleonic Wars brought a surge in demand and a flurry of fresh building activity. Over 1801-1806 9 incorporating mills and later a further 5 were built together with new saltpetre and sulphur refineries and the Grand Magazine for storage prior to shipment out via the Powdermill Cut and the Lea to the Government magazines on the Thames at Purfleet.

Congreve's influence on Waltham Abbey was profound :

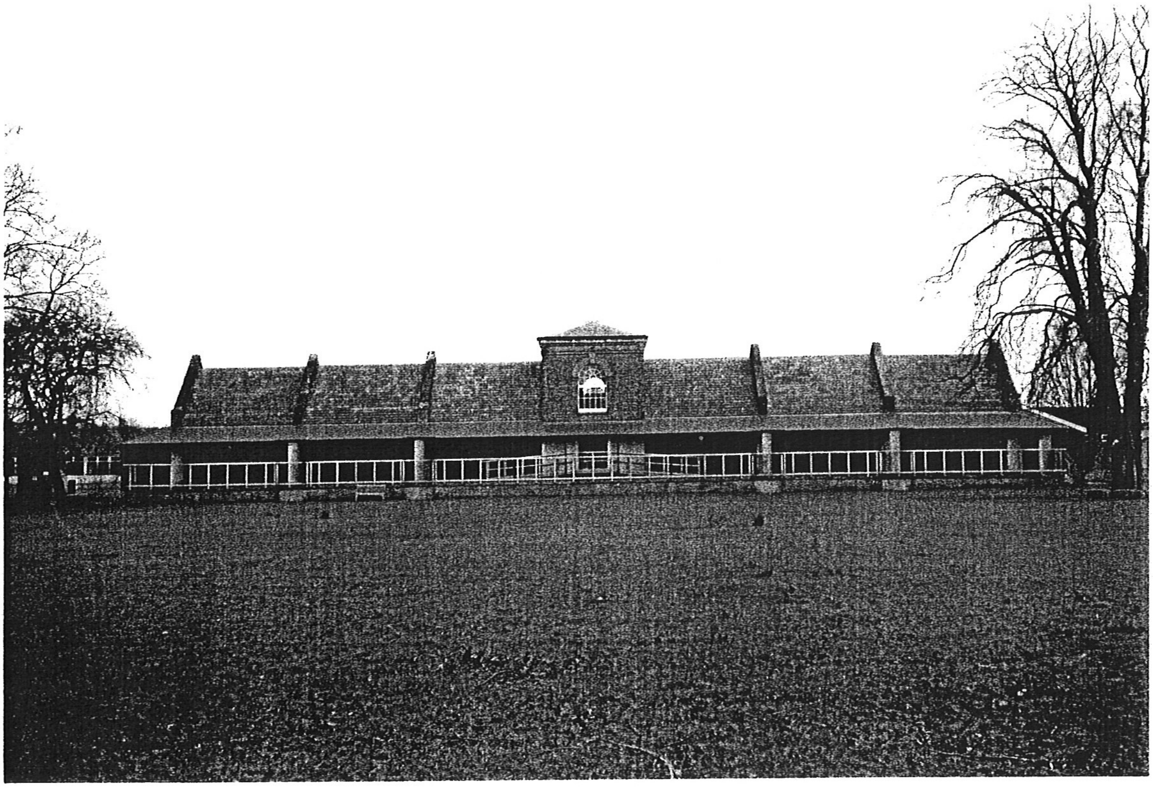
At a time when gunpowder production had not long left the alchemy stage he was responsible for - Clear and quantified processing instructions,rigorous quality testing,effective and cost saving reworking of deteriorated powder,improved saltpetre

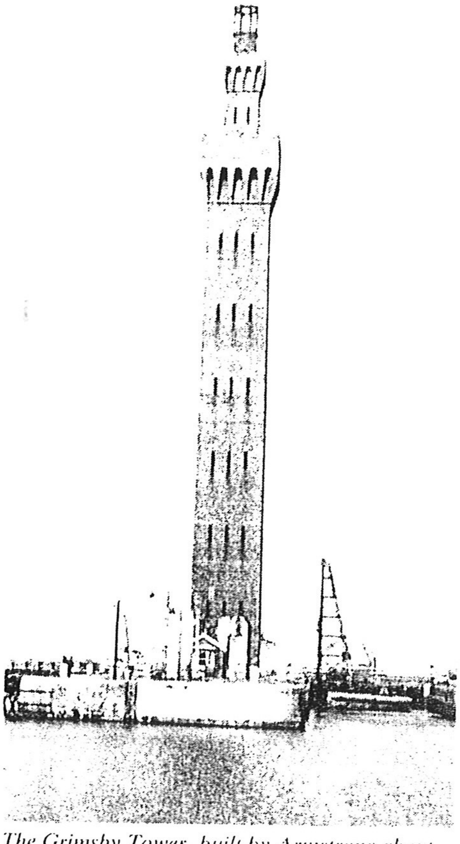
recovery,enhanced production lessening need to purchase from outside sources,reduced production costs and improved quality acting as spur on outside suppliers to improve efficiency and price,general introduction of scientific method.
In 1811 an analysis concluded that Congreve's policies at Waltham Abbey had produced savings which,after the initial costs of £45,000 were covered had created a further £50,000 of savings against the outside purchase which would have been necessary if the extra production from improvements had not been available.
In 1814 Congreve's son,also William and also later Sir William followed in his father's footsteps as Comptroller of the Woolwich Laboratory,including control of Waltham Abbey. (In 1805 he had invented the gunpowder propelled rocket,one of the forerunners of modern rocketry and the rocket which figures in the reference to the 'rocket's red glare' in the American national anthem).
He continued his father's policies,with emphasis on close examination of processes to obtain continuing production and quality improvement. Particularly noteworthy were a new mixing machine,a patented granulating machine,the introduction of cylinder charcoal and steam drying. Again scientific method was emphasised.
The nature of gunpowder production with the product moving from one building to another required a mode of transport which was smooth running to avoid the risk of explosion and with ease of access to loading facilities. Water was the evident solution and at this time canals were dug linking process buildings to the Millhead. These were the nucleus of what became the unique Mills internal water transport system extending for about 5 miles with a fleet of 35 boats and punts and 4 sailing barges for bringing in saltpetre,sulphur and coal from London Docks and taking product to Woolwich and Purfleet.

1816-1856 - Consolidation

Although not marked by any significant building,over this period improvement in processing continued and Waltham Abbey became increasingly recognised as a leader in technology,quality and efficiency.
Private contractors supplied part of Governmental requirements and improvements in manufacturing techniques etc.at Waltham Abbey were diffused not only in the

Plate 1
Group C Mills L157
built 1861
2002





The Grimsby Tower, built by Armstrong about 1849. It stands 300 feet (91.2 m) high and supports a tank of 33,000 gallons (149,820 litres) capacity at a height of 200 feet (60.8 m). It was soon rendered obsolete by the adoption of weight-loaded accumulators, but continued in use until the 1880s.

Plate 2
The Grimsby
Gravity Accumulator
Tower
built 1849

military sphere but also throughout the private sector,benefiting their entire operation,civil and military.

Further,gunpowder had assumed an increasingly significant non military function as an essential earth and rock mover in the massive expansions of the 19th century - railways,quarries,mines,harbours,ports,construction etc.(to cite an example at random - the contractor for the Box Tunnel on Brunel's GWR got through 1 ton of gunpowder a week).

The Steam Age 1857 -1889

The Crimean War 1854-1856 had revealed glaring inadequacies in British military supply and strategy (some of the senior British staff officers had fought at Waterloo 40 years earlier and caused acute embarrassment by being unable to adjust their mindset to the their opponent being the Russians and not 'the French'). This plus the shock of the Indian Mutiny and fears of French incursion led to a fundamental review of the nation's preparedness and not surprisingly gunpowder production figured largely.

A massive building programme at Waltham Abbey involving also the introduction of a totally new power technology was authorised - steam was to be the motive force for yet another industry.

Over 1857 to 1889 a series of grouped steam powered incorporating mills was built.

They were given alphabetical references A - G. (Figs 2,3 , Plate 1).

Apart from A each group comprised 6 mills grouped in 3 bays of 2 either side of an engine house served by two Lancashire boilers.

Groups C,D,E,F,G are ranged along a canal,forming a fine architectural composition (Plate 1), and are the core of the listed buildings.

The scale and form of the steam mills represented a quantum leap in investment and capacity. By 1870 Waltham Abbey mustered 32 pairs of incorporating mills,water or steam. In 1853 it could produce 10000 bbl p.a.,in 1870 27500 bbl p.a.

Although the water of the Millhead was no longer the dominant power source its mills continued in production.

1870's

Gunpowder development at its peak

Hydraulic Power

Increased incorporating capacity and production brought with it a requirement for increased capacity down the processing line. Around 1856 two new press houses were built utilising a new form of power - hydraulic power,generated by water wheel. In the 30 years after the Crimean War progressive advances in metallurgy and engineering techniques made possible the development of larger guns utilising larger charges. In response new grades of powder were introduced - pellet and later pebble and prismatic. Again hydraulic power was used for the pressing and moulding involved - now by steam driven pumps from 1869 with accumulator towers incorporated in the system. These new grades represented the peak of gunpowder development and again Waltham Abbey became the recognised centre of expertise.

The rise of applied Chemistry - 1862 - 1945 Smokeless Powders

By the 1880's therefore in its role as the key service propellant gunpowder had become a volume production industrial product,refined into a variety of types and qualities according to application. However in the world of chemistry developments were taking place which would lead to the demise of gunpowder,over a very short time scale.

In 1846 nitric acid based nitrocellulose (guncotton) had been evolved. After considerable further work,particularly by Frederick Abel,resulting in the patenting of his pulping process in 1865,Waltham Abbey commenced volume production in 1872. Growth in demand was such that land for new production facilities was purchased on what was to become the Quinton Hill South Site and production there commenced in 1890.

Guncotton however was suitable only for use as an explosive - in mines,torpedoes and for military and civil blasting ; it was too sensitive to be used in shells and too violent in force to be used as a propellant. Much research took place into the development of a chemically based propellant. This resulted in the patenting in1889 by the

Government Explosives Committee,headed by Abel, of cordite - a blend of guncotton,nitroglycerine and mineral jelly(vaseline).

The adoption of the new propellant was rapid,replacing gunpowder as the main British service propellant literally within a few years. The term 'smokeless powders' was applied to the new chemical base explosives and propellants.

The implications for Waltham Abbey were profound. As well as the South Site development practically all gunpowder facilities on the North Site had to be converted to cordite and to the north of the site extensive acid and nitroglycerine factories were built,in addition groups of guncotton drying stoves.

By 1910 gunpowder had all but disappeared as a military propellant. It was still required however for specialised fuse purposes and the old Millhead mills continued production,albeit in reduced fashion.

Having managed a major change in power technology in mid 19th century the Mills had therefore over a very short space of time at the end of the century managed a total change in the technology and nature of its product,from a basis of the natural - saltpetre,sulphur and charcoal to the chemical - nitrocellulose,nitroglycerine,with all the implications this carried - new unfamiliar plant,conversion of old plant,new manufacturing,materials handling,safety procedures,recruitment and training of staff,new laboratory and quality testing procedures etc.

In WWI there was a massive expansion of output at Waltham Abbey,by this time termed the Royal Gunpowder Factory,obtained by round the clock working.The number of employees increased from 1200 to 5000. Cordite production rose from 26 tons per week to 140 tons.

At this time locomotive haulage was introduced on the tramway system operating on the North Site and extending to the South Site.

The 20's and early 30's were a period of relative quiet,but in the late 30's as well as continuing production Waltham Abbey fulfilled an important role as the site for pilot plants for factories for newly researched explosives which were to be built in the safer West of the country. Not all had been built by 1939 and for the first two years of WWII Waltham Abbey was the sole producer of certain of these vital new materials.
Although most of the mills on the Millhead had been progressively dismantled some gunpowder production for fuses remained - until 15th November 1940 when a parachute mine put the last mill out of action,thus putting an end to over 150 years of Government production of gunpowder at Waltham Abbey.
The Millhead Stream has been partly absorbed into the adjacent Horsemill Stream,part was buried by decontamination work and part survives in open earthwork Some mill sites can be identified by surviving concrete traverses(blast walls).
There is significant scope for below ground archaeology.
The Royal Gunpowder Factory ceased production in October 1943 and closed on 28th July 1945.
Closure was brief however. On 30th July 1945 the site assumed a new identity as a research establishment up to the pilot plant stage. The range covered was wide,including propellants,rocket fuels,effect of climatic conditions on explosives,explosives handling,materials and polymer research. The Establishment had various titles,the last the Royal Armament Research and Development Establishment.

The Establishment closed on 30th June 1991. Its activities were transferred to Fort Halstead.

English Heritage had described the site as the 'most important site to the history of explosives in Europe'. In 1997 after spending several million pounds on decontamination the Ministry of Defence handed it over together with an income generating endowment fund to a Charitable Trust which had been formed to manage the site. A Heritage Lottery Fund grant was also secured and in April 2001 the Mills opened to the Public as an interpretative centre.

4. Hydraulic Power - History

The primary object of this study is to establish the importance of hydraulic power to the Mills and to understand the interlinking between developments at Waltham Abbey and development of hydraulic power in the wider world it is necessary to examine the history and chronology of this technology.

Hydraulic power has been defined as 'A system for transmitting energy through the medium of water or other incompressible fluid' (1) The power transmission is either by the force of a fluid in motion e.g..a waterwheel turning a cornmill - hydrokinetic energy or by the pressure of the medium - hydrostatic energy.

The basis of hydraulic machines operating by pressure was the concept of the 'equilibrium of liquids'propounded by the French physicist B.Pascal in 1647 explaining the apparent paradox of the multiplication of forces. In practical terms the effect was that in a combination of a large and a small cylinder connected by a pipe and filled with a fluid a pressure created in the fluid by a small force acting on the piston in the small cylinder will result in a large force on the large piston.

1795 - Joseph Bramah - Hand Lever pumped hydraulic Press

Pascal's work remained a laboratory exercise until the end of the 18th century when Joseph Bramah was granted a patent in 1795 involving water as a medium for transmitting energy. The patent involved a number of applications,the most important of which was the hydraulic press,based on Pascal's principles. Utilising the concept of the multiplication of forces Bramah patented the idea of a hydraulic press,based on a hand lever operated pump and reservoir connected to a hydraulic cylinder and ram. The operation was direct acting screw based. The idea had a large potential. The process of pressing,in such applications as seed oil,had existed since early times. and little development had occurred,with a pressure of about 25 tons the limit. Bramah's machine could exert much greater pressure and made seed and vegetable oil pressing more efficient. Its potential beyond this was quickly recognised and it became utilised for a wide range of applications involving in a contemporary phrase 'the throwing of light articles into small bulk' - e.g. hay,textiles etc.

Textile production was becoming one of the key drivers of the economy,creating a multiplicity of requirements for increasing efficiency and economy. Among these was the need to efficiently put wool and cotton into bales. Matthew Murray made an important advance on Bramah's pioneering work with the patenting in 1814 of an effective baling machine for the textile industry.

Early 19^{th} century - Steam powered Pumps

It was not long before it was realised that there was a massive potential to be released by the application of steam to hydraulic pumping. A striking early example was the Glasgow Bandana Factory. This factory employed a process known as 'discharging' in which a pattern was printed on to a coloured cloth by partial bleaching under mechanical pressure. In 1818 the factory installed 16 presses of 320 tons capacity,with steam pumps delivering the astounding pressure of 6.36 tpsi - a remarkable demonstration of the advance of hydraulic power.

In an era of constant development and experiment with new materials,e.g. cast and wrought iron,materials testing became of increasing significance and an important development in the second decade of the 19^{th} century was the application of steam pumped hydraulic pressure to testing machines. Bramah's sons were prominent and they and Matthew Murray developed machines of massive force, e.g. one exerting a pressure of 1000 tons for proof testing ships' anchor cables was purchased by the Navy Board in 1826.

By the middle of the century therefore in a situation analogous to Trevithick's significant widening of the scope of the steam engine by utilising high pressure in place of Watt's atmospheric pressure,similarly the new high pressure hydraulic machines were utilised in a wide range of applications.

1846 on - William Armstrong - Weight loaded Accumulators and Hydraulic Distribution

Hydraulic technology was now poised for a further leap. In 1846 a train of events was set in motion by a Newcastle solicitor William Armstrong which would establish hydraulic technology as one of the key technologies of the Victorian era. Having noted the dock cranes in Newcastle being worked 'slowly and expensively by hand' he conceived the idea of using hydraulic power as a prime mover. In 1845 he read a paper to the Newcastle Council - 'On the employment of a column of water as motive power for propelling machinery' and proposed its application to a dock crane. Its performance exceeded all expectations and following patenting of the hydraulic crane in 1846 by 1852 142 had been sold to various authorities.
Armstrong had been fortunate in the uncommonly high 200ft. head of the Newcastle water supply,and where this head was not available he pumped water to a high level reservoir,the most imposing being the one built for Grimsby Docks in 1849 (Plate 2).
However the pure gravity system had disadvantages,pricipally that it was expensive and restricted working pressure to that which could be achieved from the head established. In addition even when pumping to a reservoir was not required the use of mains pressure presented problems - pressure fluctuated and was fairly low for machinery operation.
Confronted by the problems of raising and lowering the platform between the railway station and a floating ferry landing stage at New Holland on the Humber Estuary Armstrong developed an idea of fundamental importance - the weight loaded accumulator (Fig. 4). This device created pressure by load instead of elevation,i.e. an artificial head of water under pressure was created,giving controlled hydraulic power.
The mechanism consists of a sealed vertical cylinder B with a ram A standing in it. Water is pumped into the cylinder by a steam pumping engine. The top of the ram has a crosshead or yoke D which moves up and down the accumulator tower between guides bolted to timbers on the walls. The timbers are joined at the top by a cross piece which acted as a buffer. From the yoke is suspended a cylindrical weight bin

normally made of riveted boiler plate filled with ballast. This acts on the ram creating an artificial head of water/water pressure. As power is used the ram falls and via a connection by chain or other means to the steam pumping engine throttle valve the engine is automatically restarted to maintain the head of water.

The advantages of the weight loaded accumulator were manifold :

Facilities were less expensive to construct than high gravity towers

It utilised steam pumping in a controlled manner

Steam pumping avoided the cyclical variations of water pumping

It could store power for use when required

It delivered power at a steady pressure,avoiding the difficulties of fluctuating mains supply

Above all,it enabled the use of higher pressures

This meant that for a given amount of power transmitted less bulky more economic pipes,valves,cylinders and other fittings could be used and frictional losses reduced.. Also as less water was used payment for water was reduced.

Armstrong used a pressure of 700lb/sq.in.; to achieve this by the gravity method would have required a tower 1615ft high - the Grimsby tower was 300ft.

In an address to the Institution of Mechanical Engineers - ‘On the application of water pressure to driving machinery and working shop tools’ in 1895 RalphTweddell, pioneer of the hydraulic riveter,said;

‘The accumulator is the whole secret of the success of hydraulic machinery. The power is stored up and can be used at any moment economically and expeditiously; it is just like a big balance at the bank,on which a cheque can be drawn when wanted’.

In 1851 an accumulator system was adopted for the Port of Birkenhead - the Grimsby gravity system was already obsolete.

The most important of Armstrong’s other innovations was the multiplying sheave or jigger (Fig.4). The hydraulic ram could produce great forces over a short travel but this was of little use in machinery with a long travel,such as cranes,lifts etc. The jigger solved the problem,using the principle of multiplication of force, working like a block and tackle in reverse with the ram and cylinder between the two pulley blocks.

When water pressure was applied the ram forced the blocks apart,and thus the free end of the chain moved through a distance equal to the travel of the ram multiplied by the number of runs in motion.

Mid 19thcentury on - Hydraulic Distribution - Remote Accumulators

In his patent of 1812 Bramah had postulated the idea of hydraulic power distributed from a central source. The idea was ahead of its time but realisation came with Armstrong's introduction of the remote accumulator - i.e. satellite towers in the system. These balanced fluctuations between supply and demand,'took the strain' and smoothed out pump fluctuations. They were the final link in making available a reliable hydraulic power supply which could be distributed over distances from a central production source.

From the middle of the 19th century there was significant expansion of distributed hydraulic use. It was particularly suited to use in ports,harbours and transportation - not only for cranage,but handling,hauling,lock and sluice gates,capstans,turntables, swing bridges,etc.,and it arrived at a time of great expansion of these facilities.

Many new ports were being developed by the railways and they mirrored these applications over their whole operation,port and inland. Brunel was an enthusiastic advocate and the example set by the GWR at Paddington was quickly followed.

Industry in general found a multiplicity of prime mover applications - presses,jacks,handling systems,lifting,metal shearing and forming,riveting,ship steering systems,materials testing,baling etc.

Such was the demand that the in the last quarter of the century the concept of a publicly distributed supply was developed - firstly Hull then London,Liverpool, Birmingham,Manchester,Glasgow,largely advised and supplied by E.B.Ellington,director of the Hydraulic Engineering Co. of Chester. As well as general industry the Ellington systems supplied the expanding world of commerce and entertainment - office lifts,safety curtains etc.,whilst the Armstrong company concentrated on the dock,railway and larger industrial systems.

20th century - relative decline

For a variety of reasons the 20th century brought a decline in large scale hydraulic use.- The competition from electricity became increasingly difficult to match as ever increasing size of generating stations brought increasing economies of scale and more competitive prices,industry moved away from traditional city areas where distribution networks were sited,WWII substantially damaged the systems'infrastructure,containerisation with new ports closer to the sea tended to lessen the need for hydraulics in dock operation.

However as a prime mover as opposed to distributed power hydraulics still exist in some important dock and other heavy industrial functions such as metal extrusion presses. Major examples are:- the Tower Bridge (now employing oil as the pressure medium rather than water),the Thames Barrier,the Barton Swing Aqueduct .

5. Explosives Processing History and the Application of Hydraulic Power at Waltham Abbey

A summary and diagrammatic scheme of the development of the Mills hydraulic power system is appended (Appendix 2).

Hydraulic power at Waltham Abbey was intimately linked to one particular aspect of the processing chain - pressing.

The successive stages of gunpowder manufacture were introduced as the result of empirical observation,response to the demands of service use,improved armaments,scientific research. Pressing was the last main process to be evolved,not coming into use until around the 1760's. It had been in use before then,but only as a very crude method of reclaiming surplus gunpowder dust. From the 1760's it was developed as a full scale separate process,reflecting the perceived technical advantage of the increased density which it produced. Initially this was concerned with the perennial problem of moisture resistance,but later it was realised that a whole range of advantages were conferred and pressing became recognised as a vital part of the manufacturing chain.

These advantages were summarised by Major F.Baddeley in 1857 (2) as:

> 'The density of the powder is increased,which prevents it falling to dust in transport,or by rough usage
>
> Its keeping qualities are improved,for it withstands the action of the atmosphere, and absorbs less moisture than a porous light Powder
>
> It produces more grain in the manufacture than millcake;and a less proportion, consequently,is lost in dust
>
> A closer connection of the ingredients is obtained
>
> A greater volume of inflammable gas is produced from a certain bulk,than from a corresponding bulk of lighter Powder'

It can be seen that pressing was a significant development. An example of its effect is the research performed by the Smithsonian Institute on the US Navy ship 'Philadelphia',where in the period between 1775 and the 1812 War,over which pressing was introduced,the recommended loading for the same gun was reduced by 1/3. (3).

Pressing at Waltham Abbey

Pre 1812 - Non Hydraulic Manual

Prior to the beginning of the 19th century the manually operated screw press,which had remained largely unchanged in concept for centuries,as used in vegetable and oil pressing,paper making etc.,represented the means available to the Mills for gunpowder pressing. The Mills process was most similar to the method employed in paper making, - vertically loaded with layers of millcake separated by copper sheets compressed by a screw turned manually by capstan arms up to 14' long.

1812 - 1850's - Commencement of the Hydraulic connection
Hydraulic Manual - Bramah hand lever Hydraulic Press

Not surprisingly the hand screw process involved high risk and in 1811 a serious explosion occurred in a screw press,prompting an investigation by a committee of Engineers. In 1812 they recommended that a Bramah hydraulic press should replace the screw press - the hydraulic connection at Waltham Abbey had begun.
Bramah had patented the hand lever operated hydraulic press in 1795 (See P.11) and by 1812 it would have been evident that it was eminently suited to gunpowder pressing. Apart from the ability to exert greater pressure than possible with the screw press,giving greater density and therefore quality,it was particularly pertinent to gunpowder operation with its associated risks in that the hydraulic pump could be operated remotely with a traverse between the operator and the press with the hydraulic pipe from the pump to the press passing beneath the traverse.
A report written in 1830 (4) suggests that by then there were at least 14 Bramah presses in operation at Waltham Abbey.
Physical evidence:-
No building which would have contained a Bramah press survives.

1856 - Water powered hydraulic Presses - the full circle

The Crimean War 1854-1856 revealed serious deficiencies in British military capacity and supply systems. To increase production capability more pressing capacity was required. It can be conjectured that it was considered that the hand operated Bramah system did not have the potential for the expansion required.

In an elegant engineering solution water was employed as the power source for two new press houses which were built on the sites of disused horse corning mills - Buildings 76 and 103/4 Press Houses Nos. 1 and 2 (later re numbered No.1). (Plates 3-20,) (Fig.5).

Water from the high level canal system was utilised to drive water wheels powering a hydraulic pump which powered the presses operating at a pressure of 70 tons/sq ft taking about 800lb of powder at one time. The pump was separated from the press house by the original traverse of the corning house with the hydraulic pipe passing under the traverse, and safe working was therefore achieved.

There was an attractive symmetry in the solution - the hydrokinetic energy of the water wheel was used to produce the hydrostatic pressure energy of the pump - water power had come the full circle.

Physical evidence

The original Press House No.1 Building 76 was demolished and a canal cut through part of its foundations.

All the elements of Press House No.2,later No.1,Buildings 103,104,survive (Plates 4-12) :-

Foundations of Press House Press Traverse Pump Room

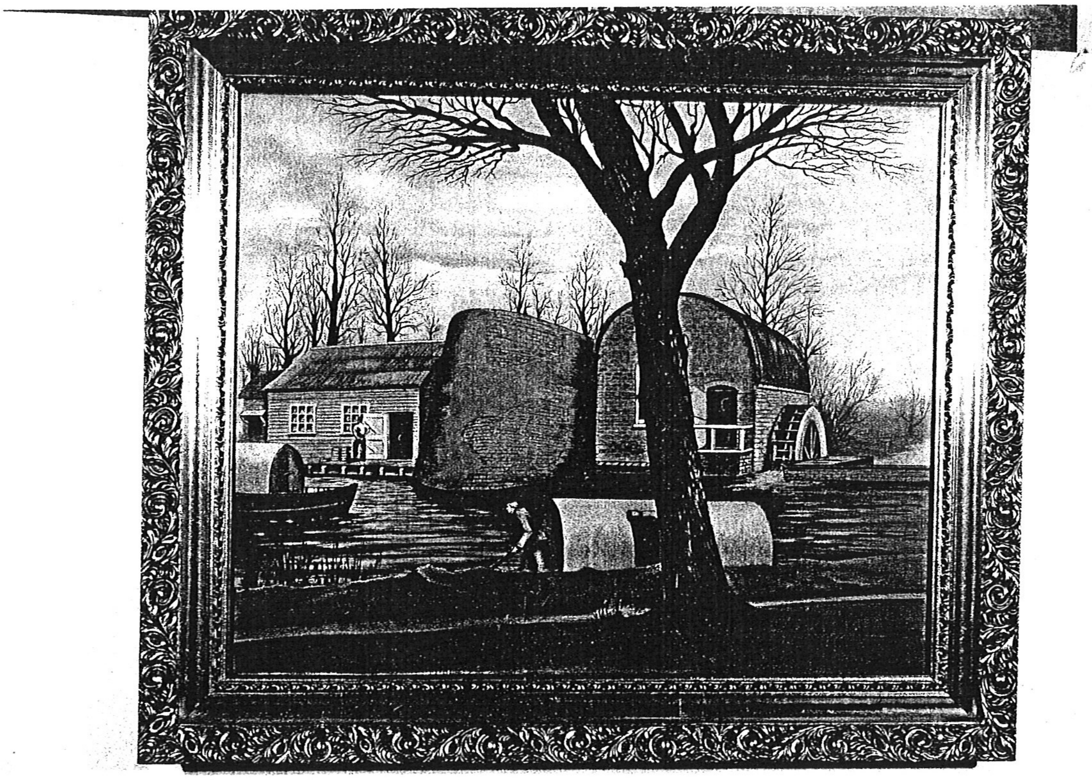
Pump Piping Water Wheel controls Gearing Low Breast Shot Water Wheel

The fabric gives great cause for concern however - see 7. Recommendations P.25.

Press House No.1
built c1856

Plate 3
Exterior
Press House
to left of Traverse
Pump House
to right
Powder Barges
Tail Leat to Old
River Lea in background
1880's

19



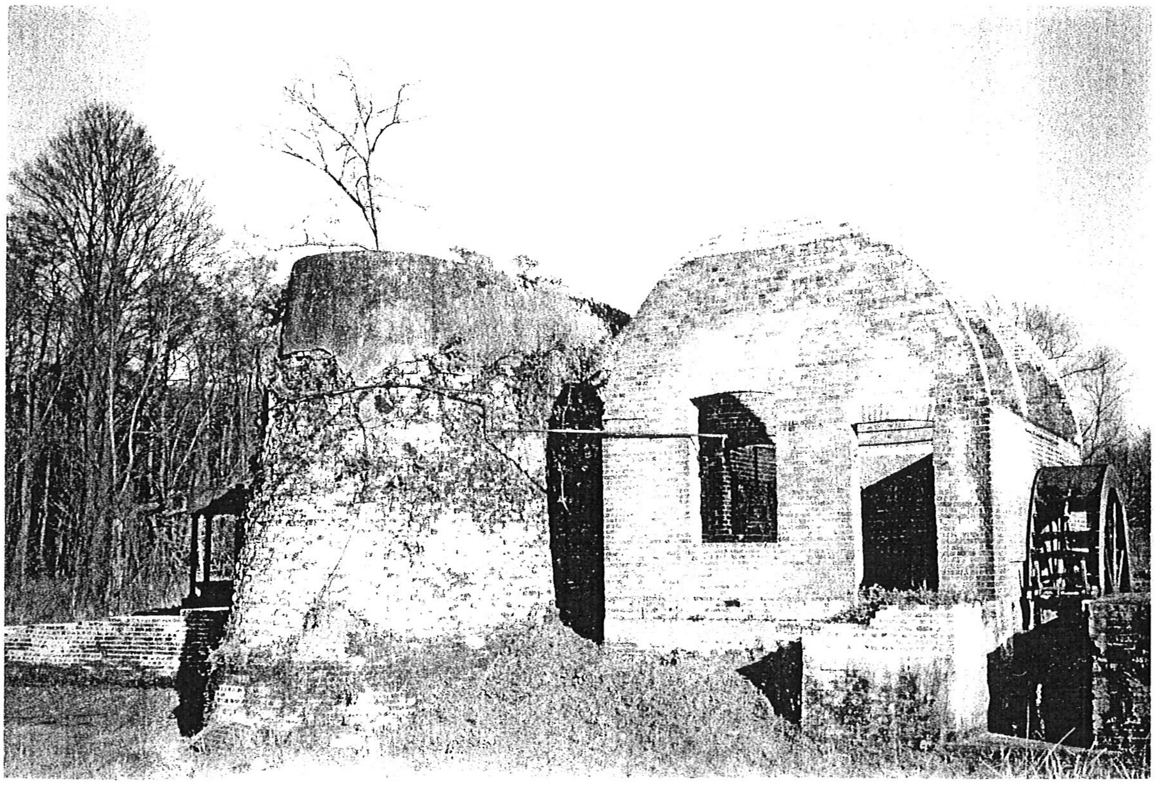
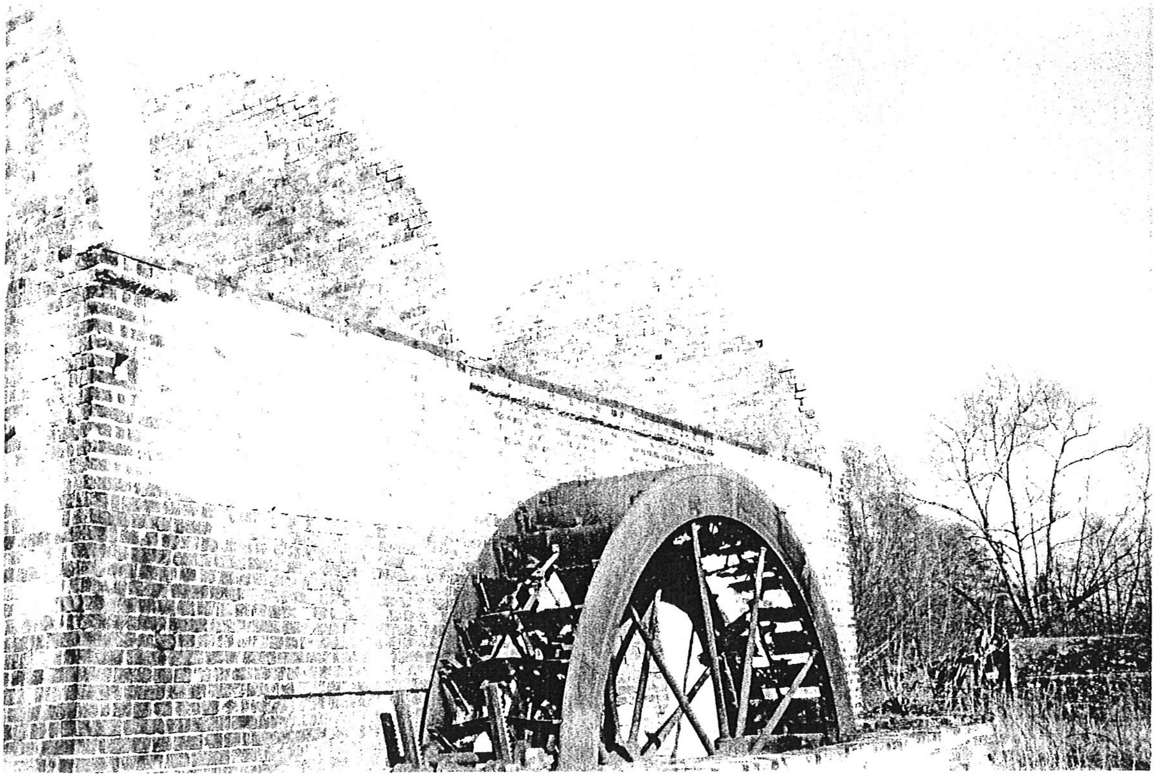


Plate 4
Exterior
2002

Press house No.1
built c1856

Plate 5
Roofless Pump House
2002



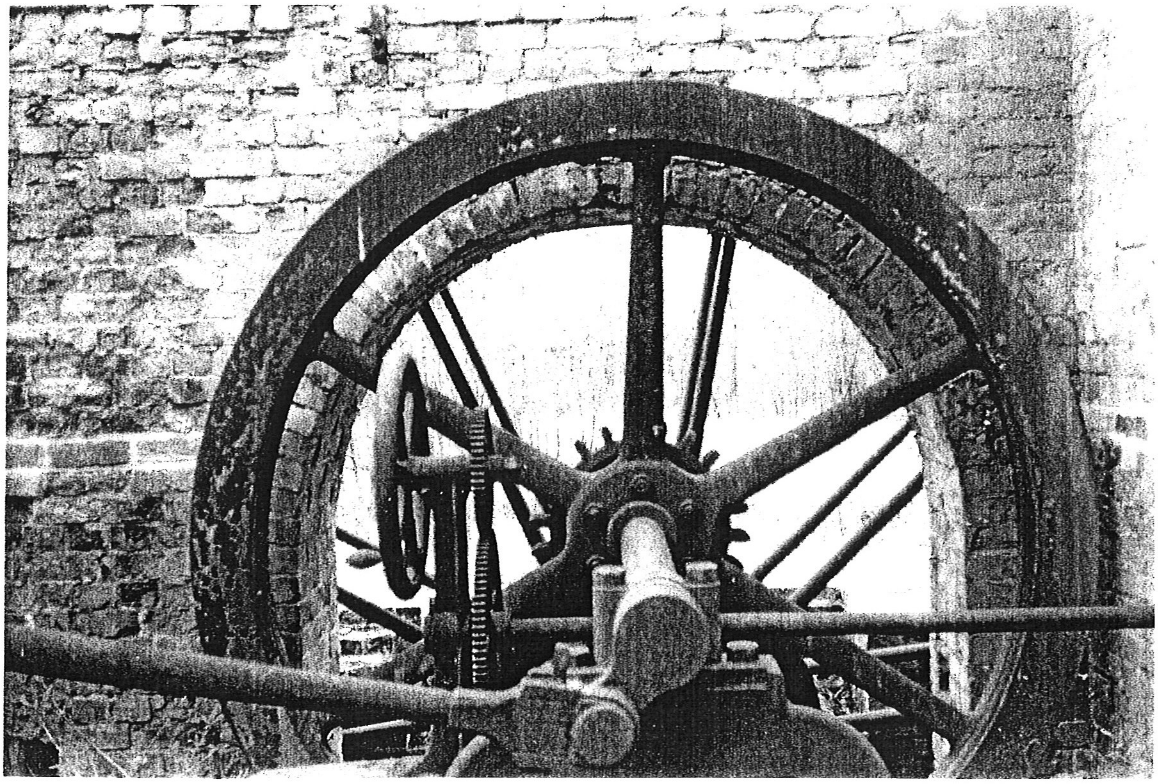
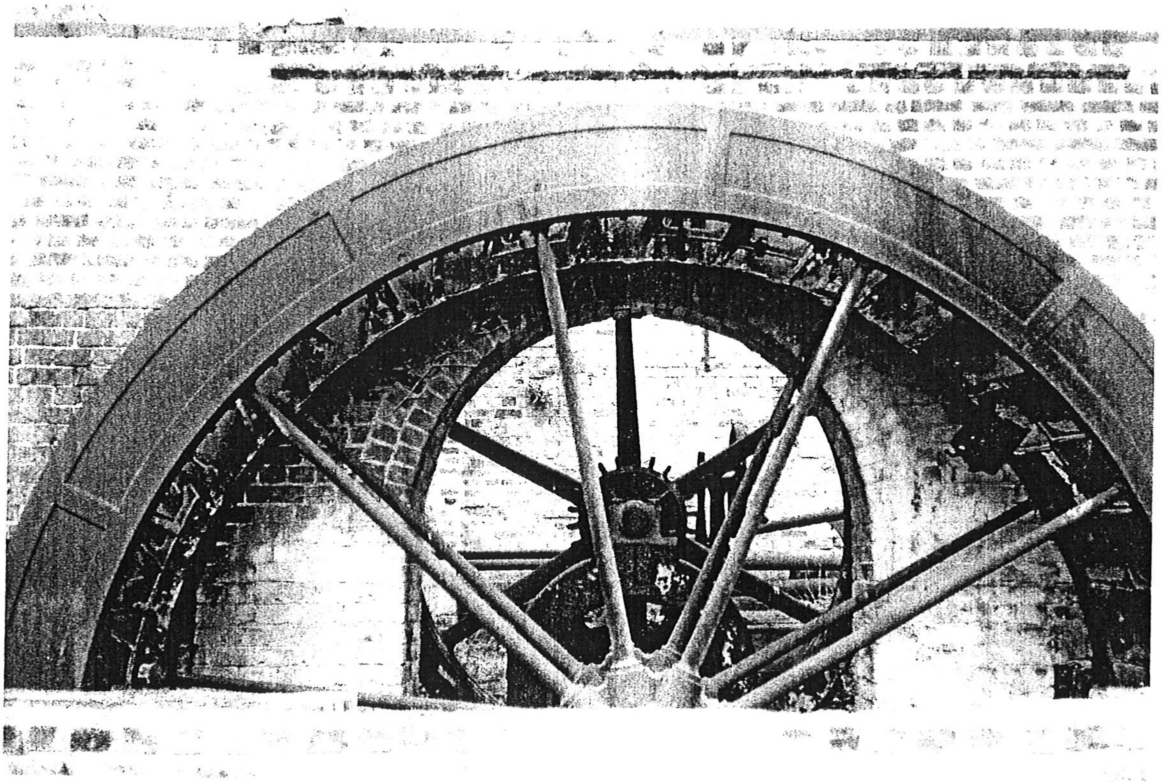


Plate 6
Interior
Flywheel, Gearing
to Sluice Gate
and Pump
2002

Press House No.1
built c1856

Plate 7
Exterior
Water Wheel
2002



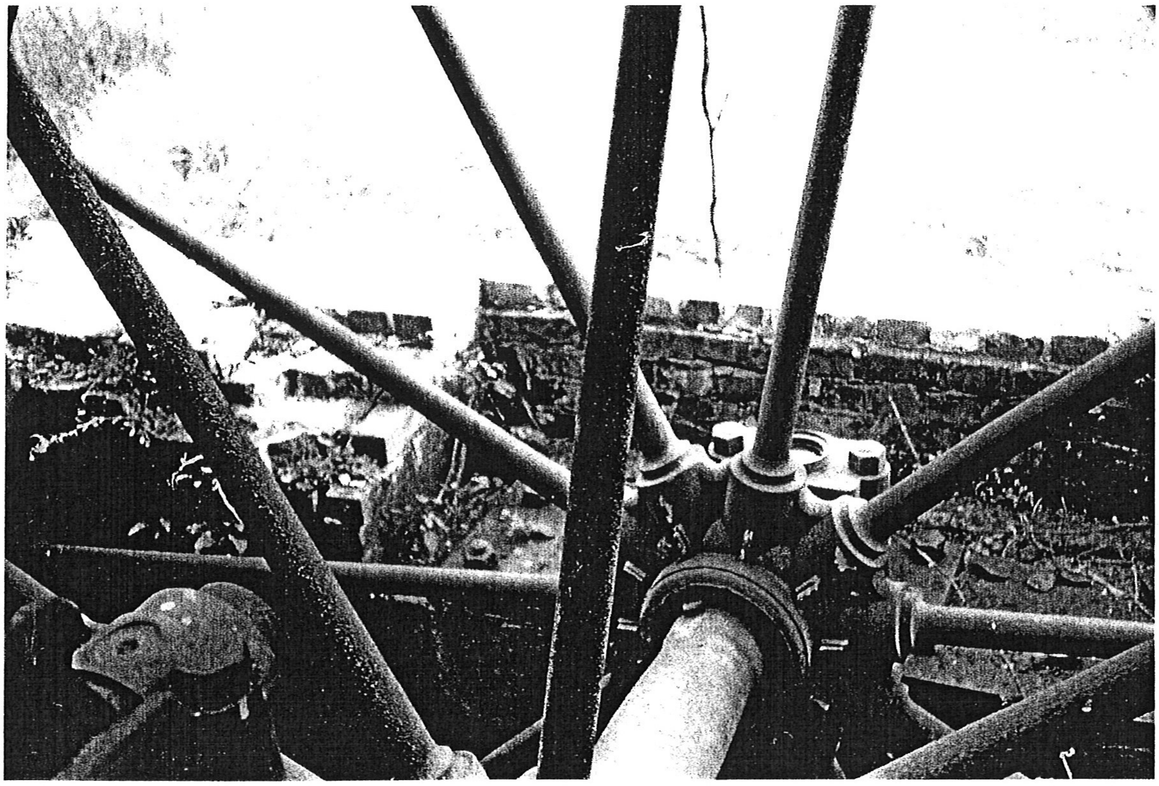
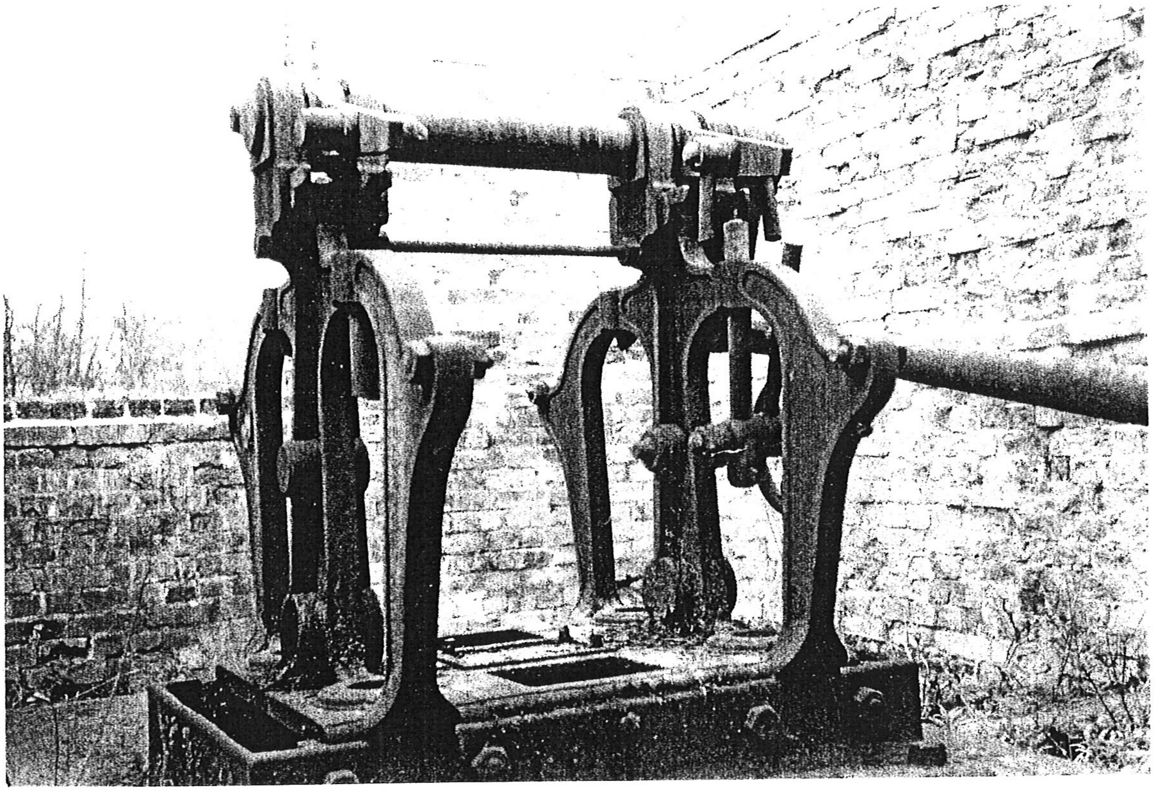


Plate 8
Exterior
Water Wheel
2002

Plate 9
Pump
2002



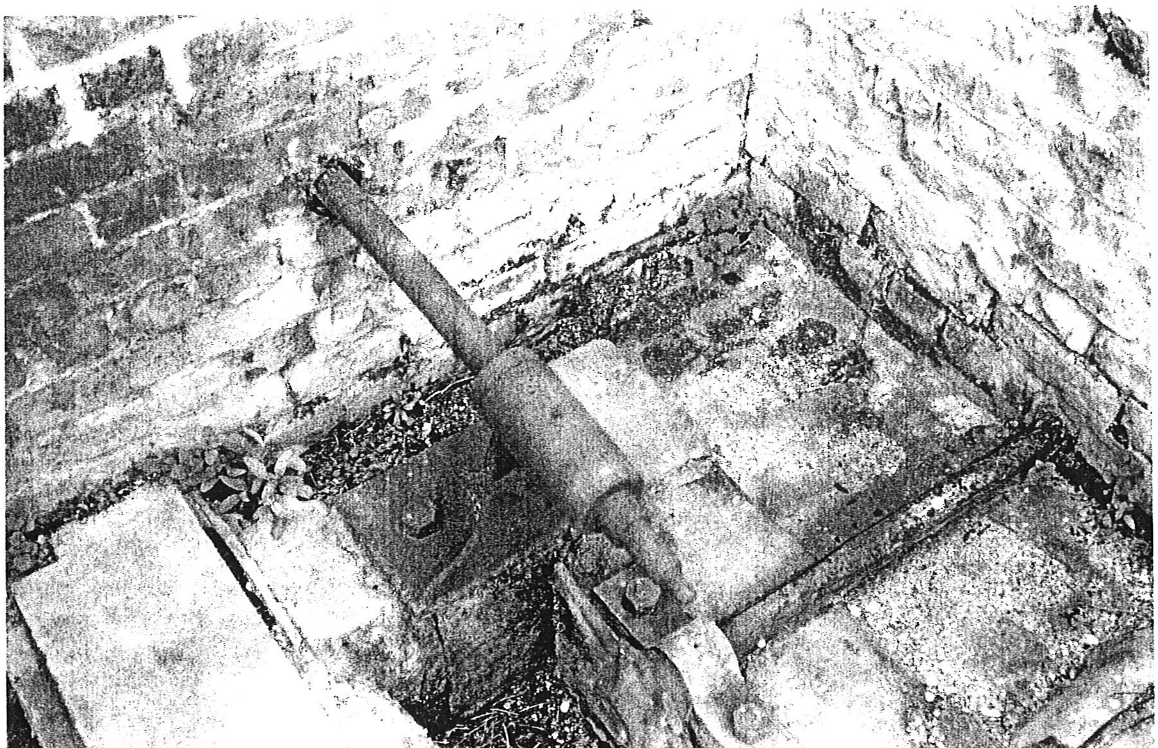
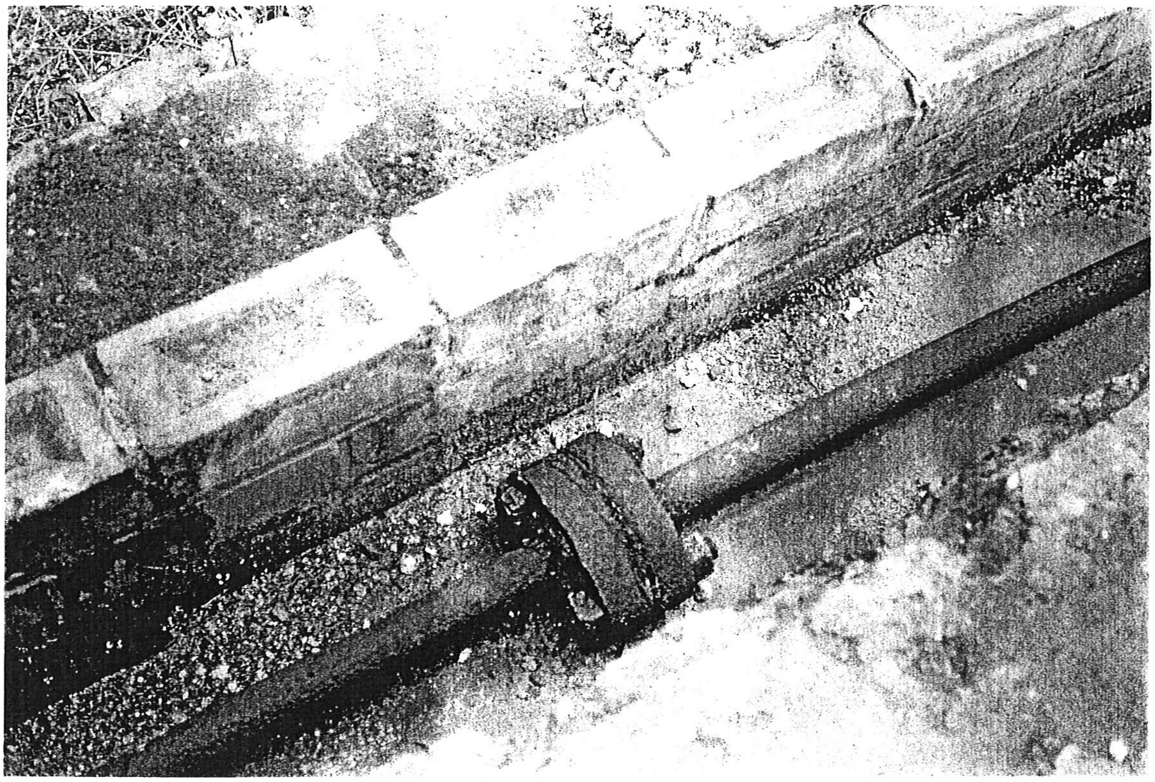


Plate 10
Link
to Sluice Gate
2002

Press House No.1
built c1856

Plate 11
Hydraulic
Flange Connection
2002



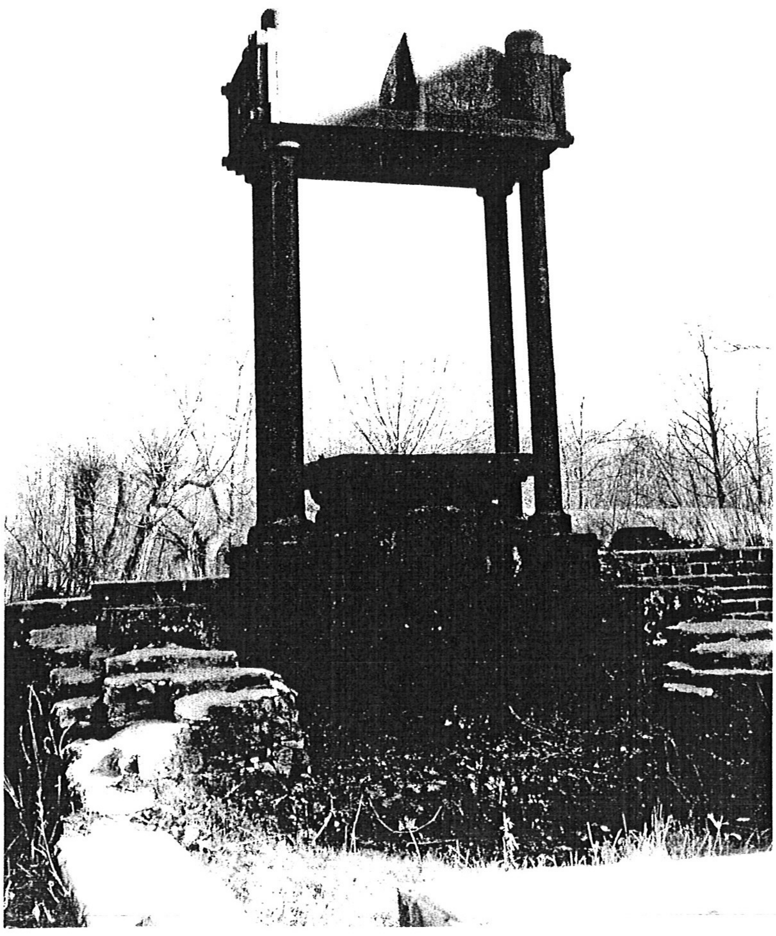


Plate 12
The Press
2002

Press House No.1
built c1856
as it was in 1940

Plate 13
Exterior
showing
High level Canal
1940
(cf. Plate 4)

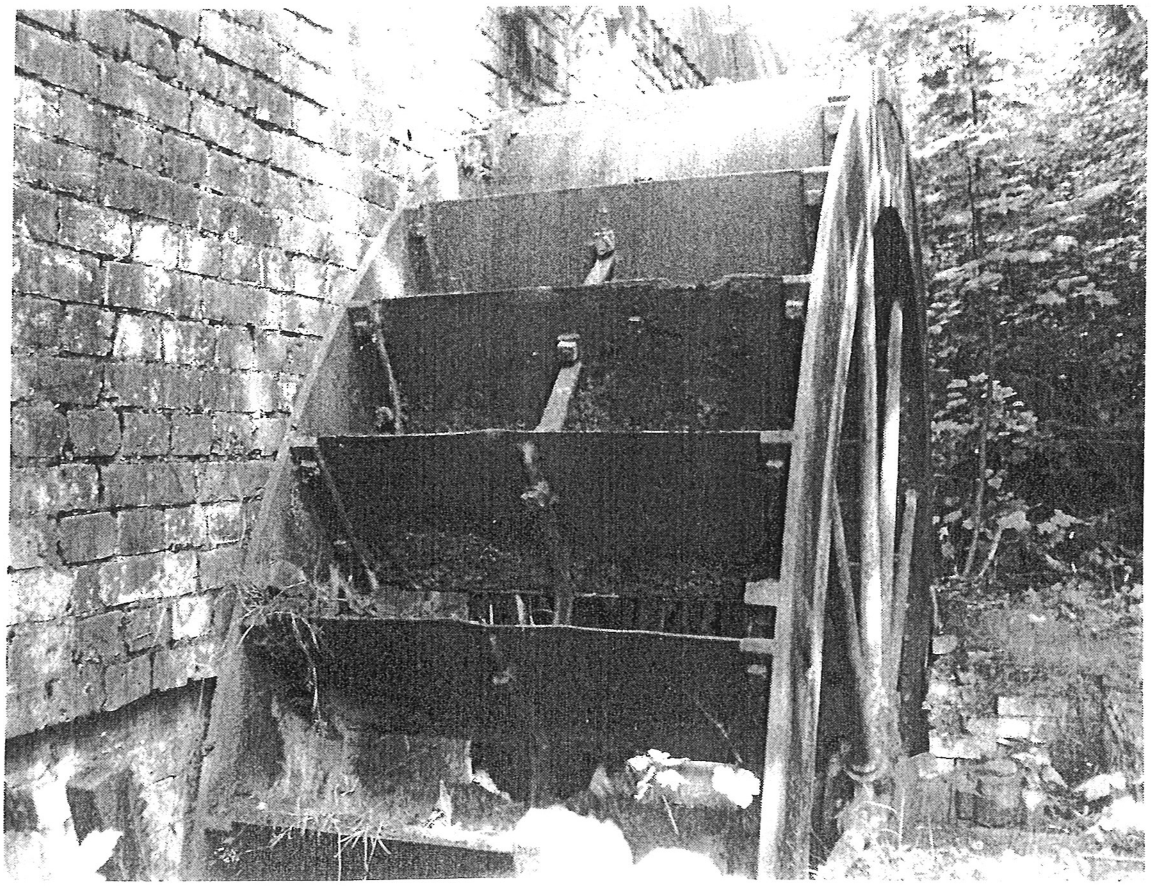
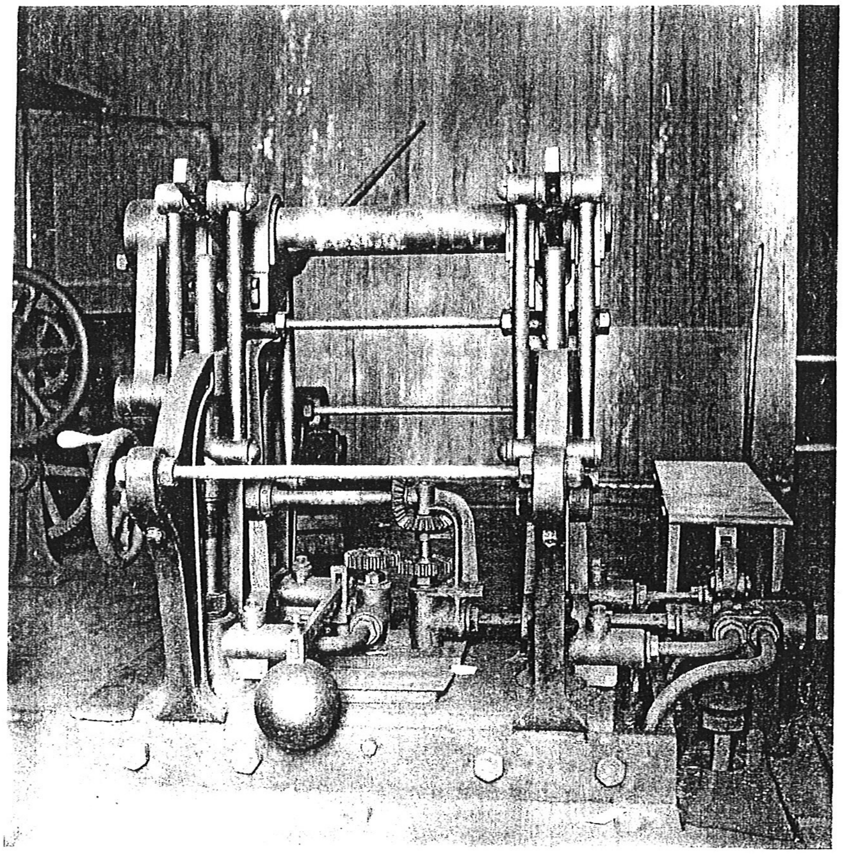


Plate 14
Water Wheel
1940

Plate 15
Pump
1940
(cf. Plate 9)



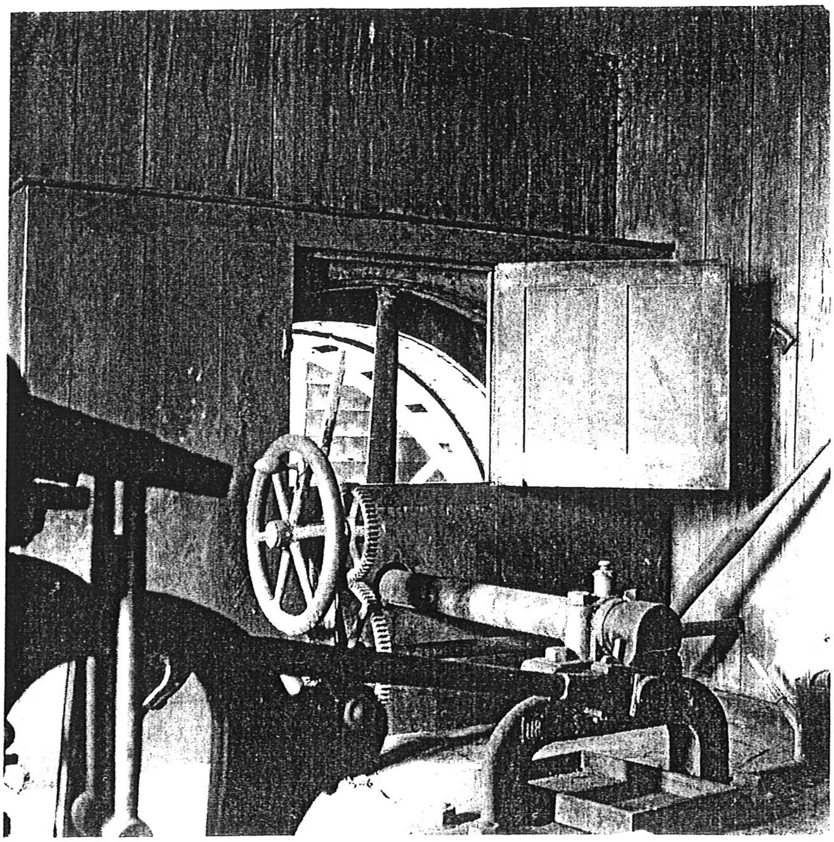
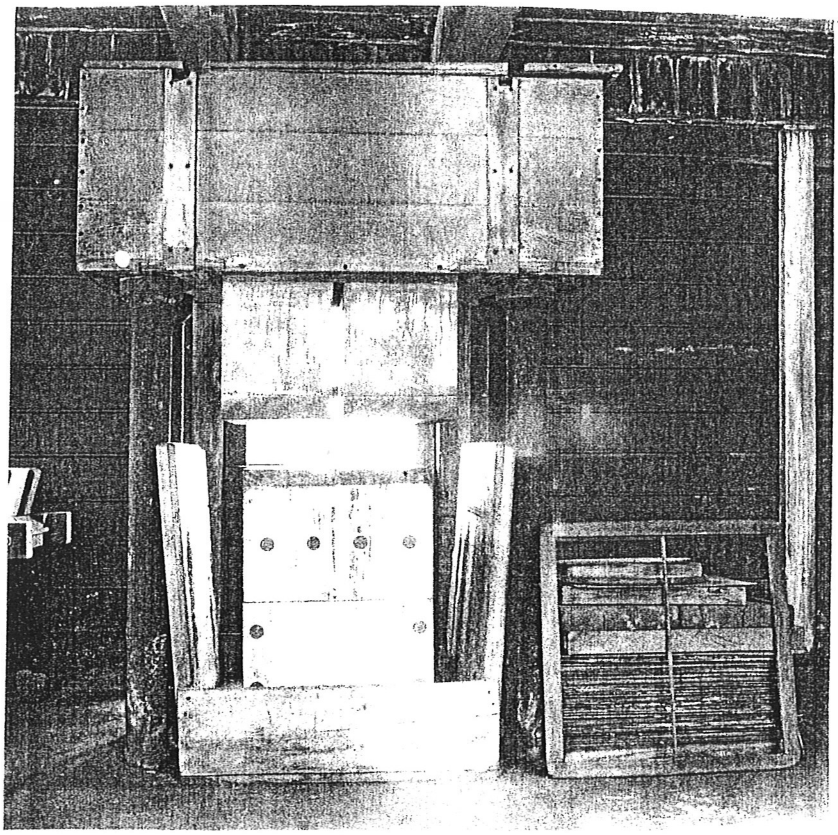
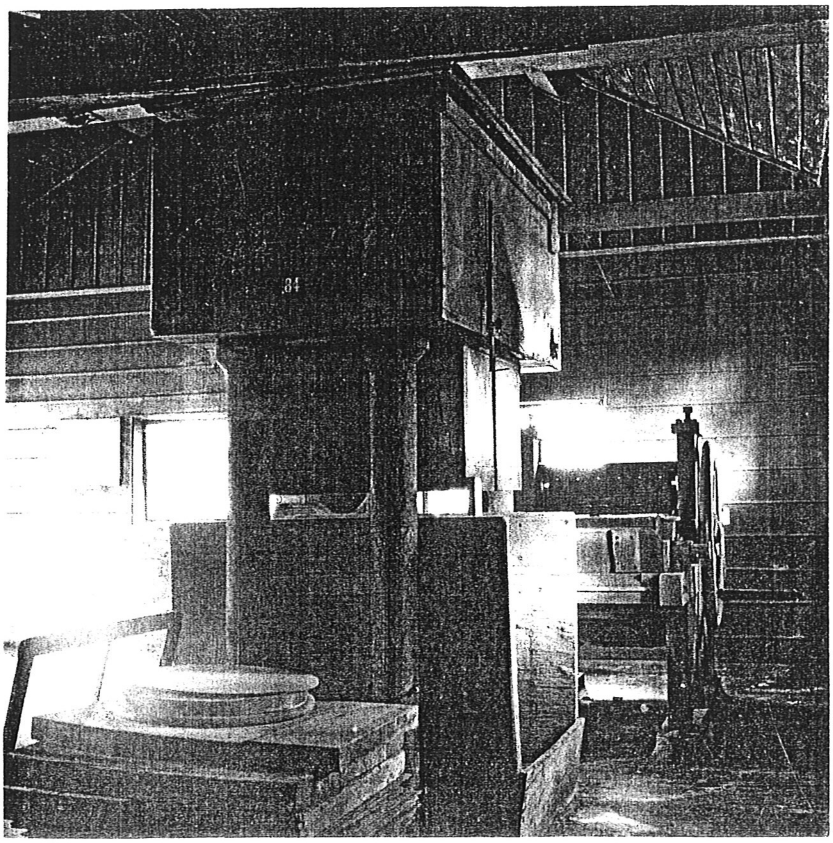


Plate 16
Sluice Gate and Pump
Gearing and Links
1940
(cf. Plate 6)

Press front view
with press plates
to right
1940

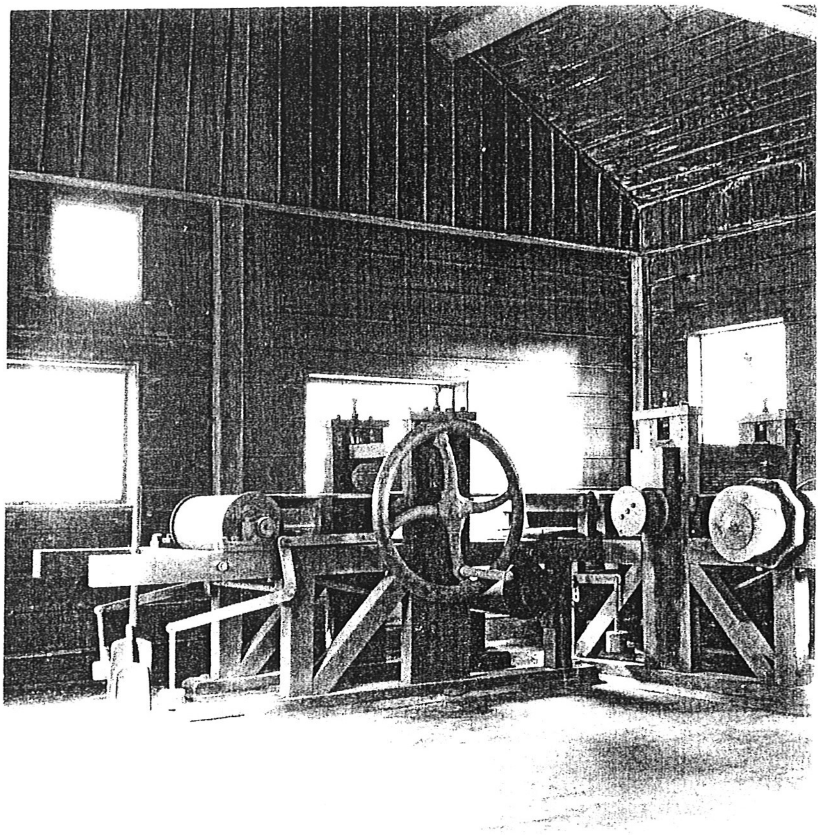




Press side view
1940

Press House No.1
built c1856
as it was in 1940

Plate 19
Breaking Down
Machine
(prior to pressing)
1940



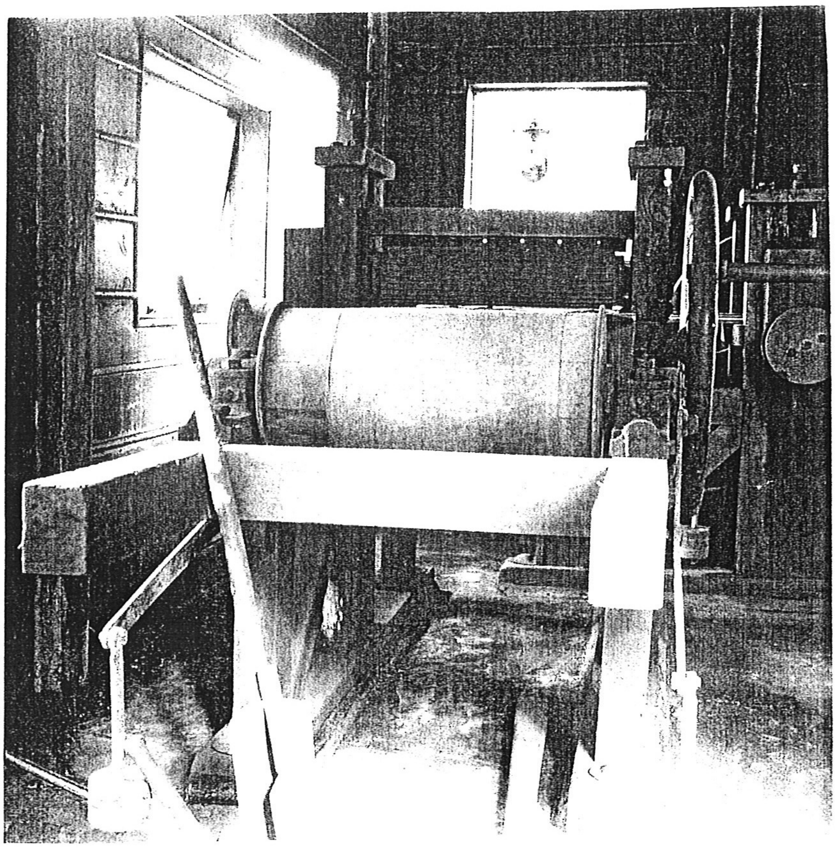
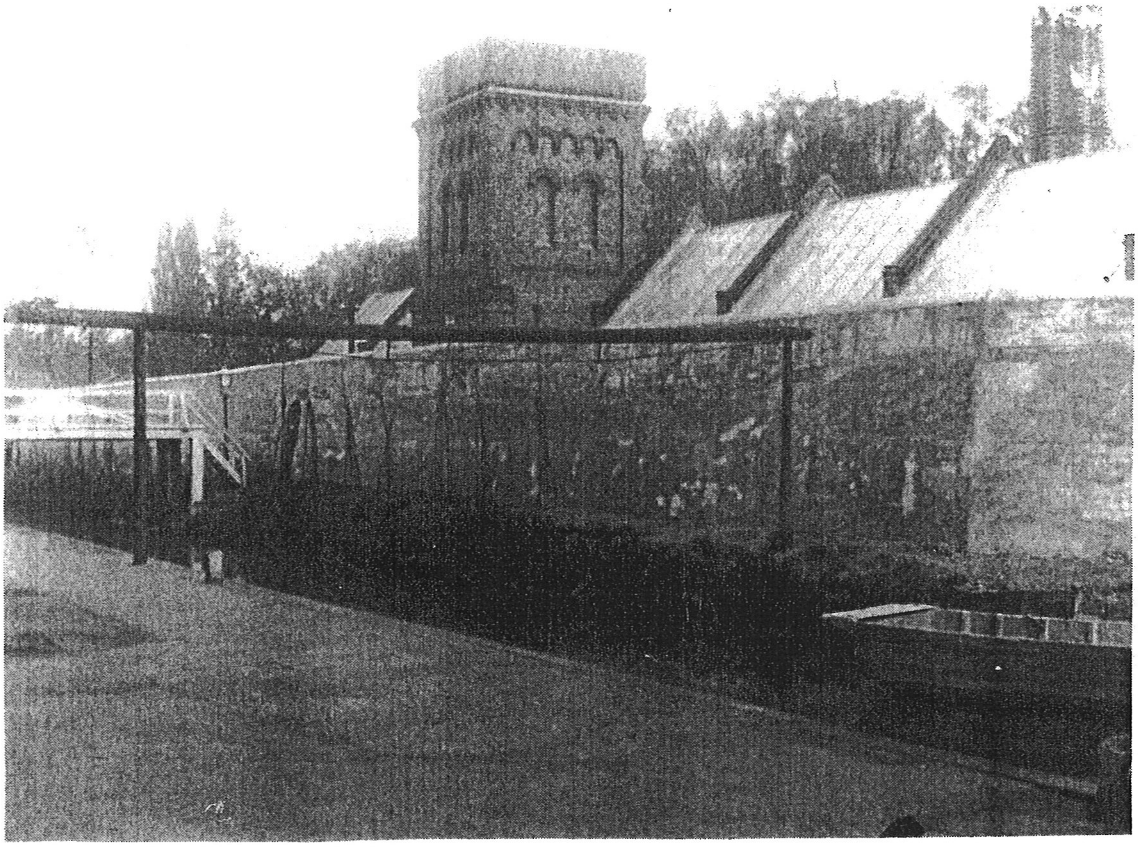


Plate 20
Breaking Down
Machine
1940
(In background -
Danger Building
exterior lighting)

Plate 21
Group E Mills L149
built 1869
with Traverse
Accumulator Tower
header tank
transport punt on canal
chimney in background
1904



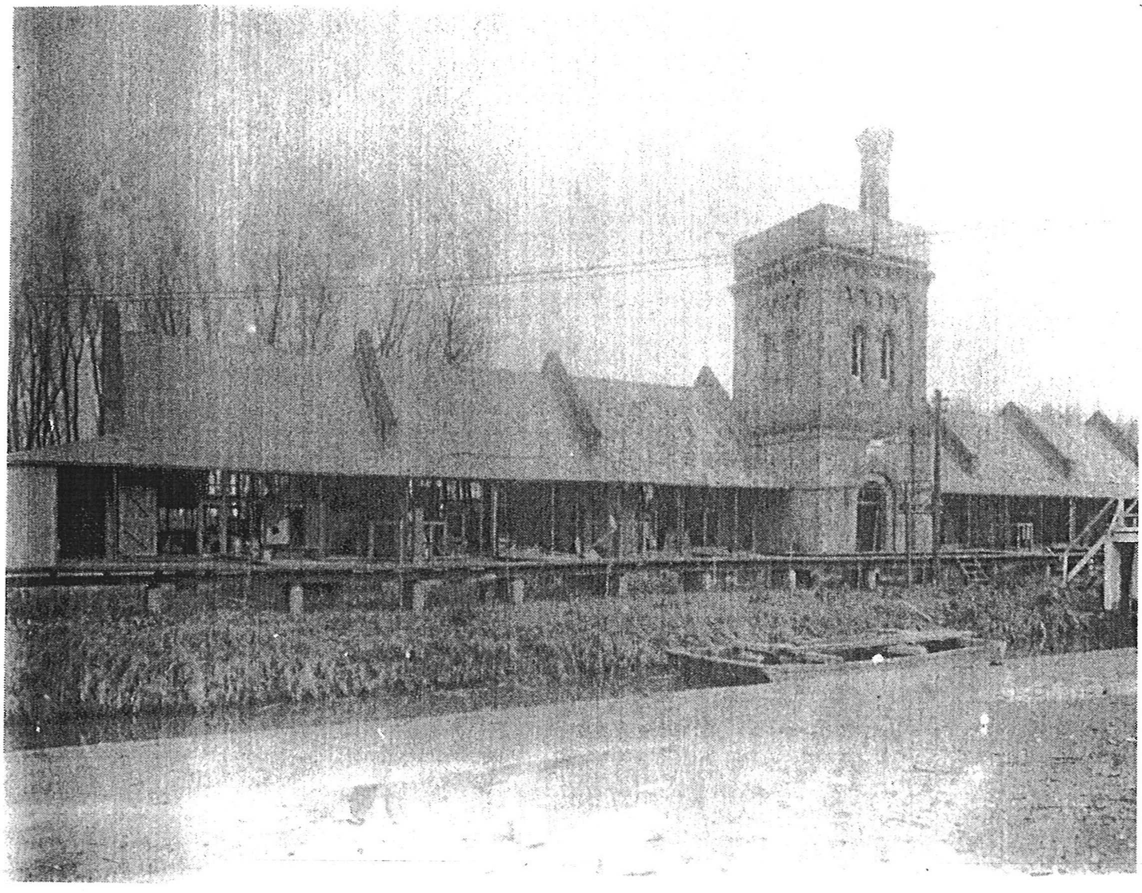
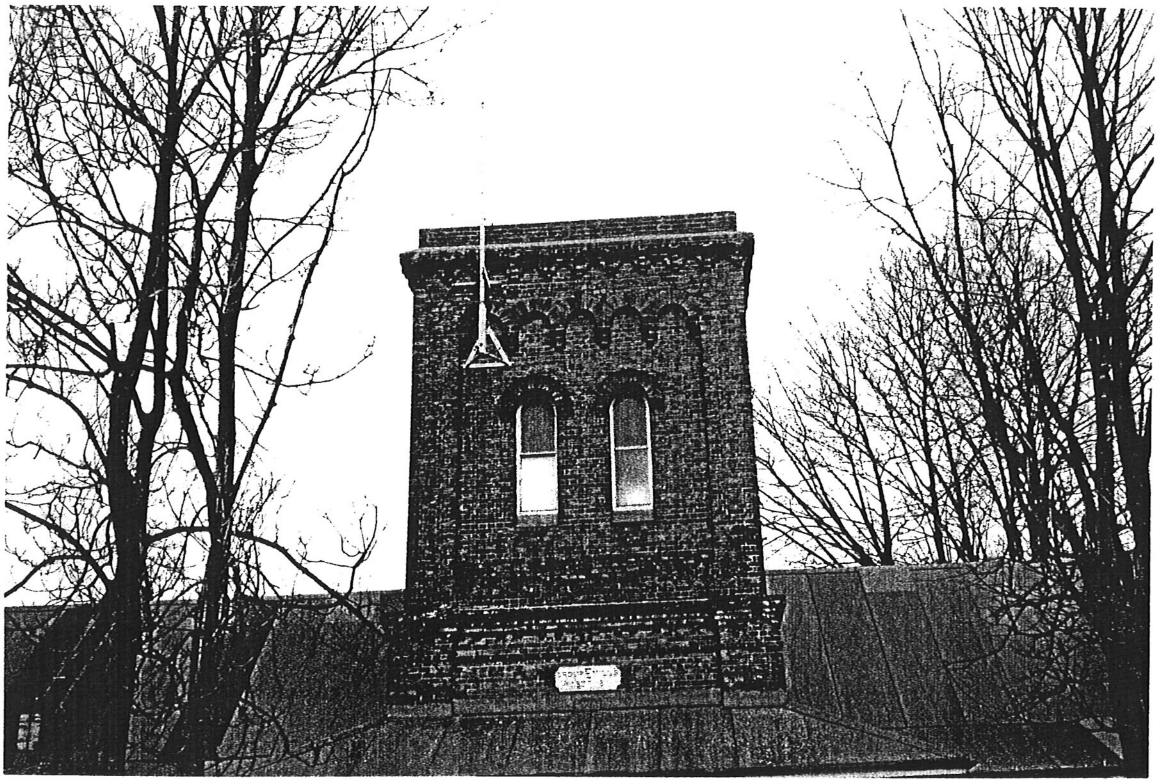


Plate 22
Group E Mills L149
(after explosion)
built 1869
tramway raised trestle
in front
1908

Plate 23
Group E Mills L149
built 1869
Accumulator Tower
2002



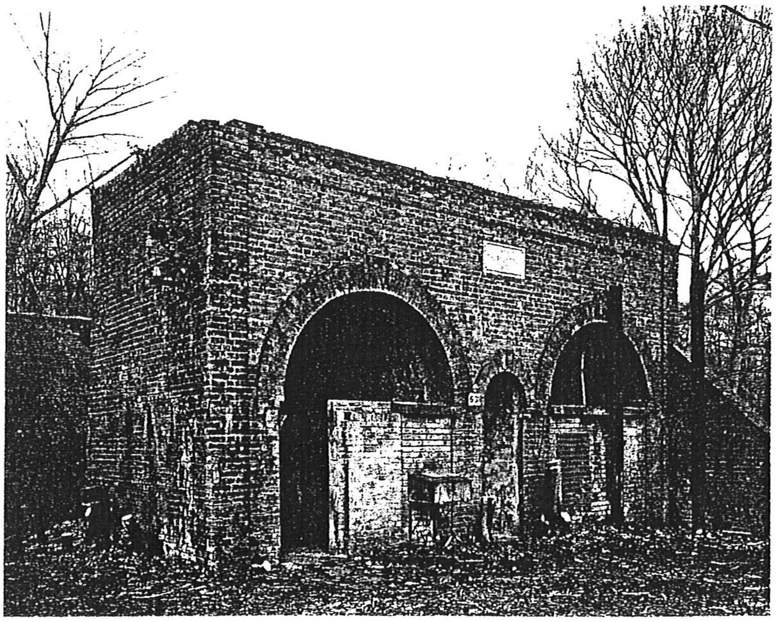


Plate 24
Facade
Press House No. 4 S31
built 1879
(iron stanchions
to right)
2002

Plate 26
Hydraulic prismatic
powder moulding
machine
1888

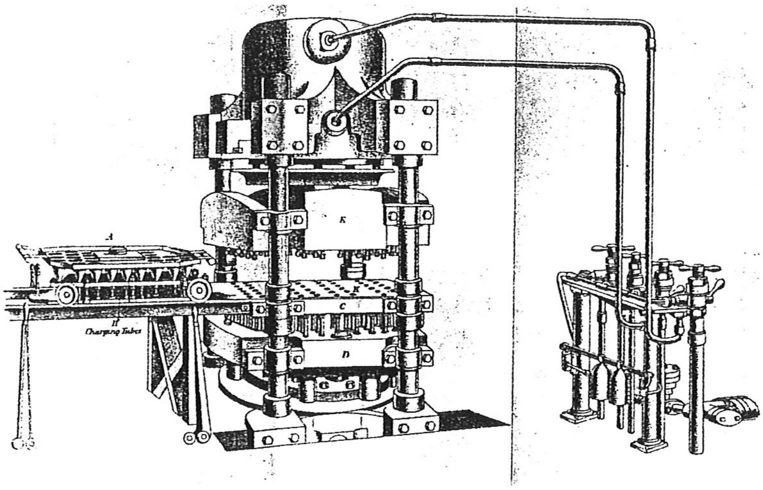


Plate 25
Remote Accumulator
Tower L136
built 1879
refurbished as observation
tower
expense magazine and canal
bridge on right
2002

1869 - Group E Mills - Gunpowder and Hydraulic technology advance - the steam powered weight loaded Accumulator

From the middle of the 19th century the pace of advance in Victorian technology was exponential. Across the whole spectrum of manufacturing,engineering,construction, transport and so on there was a ferment of innovation and expansion. In armaments improvements in metallurgy and engineering techniques made possible ever larger guns,which required larger charges. However this brought with it the danger of damage to the guns. It was deduced that what was required of the propellant was a slower and more controlled rate of burning,taking a greater time to exert maximum pressure. The solution lay in greater grain size and it was determined that this could be achieved by what was termed pellet powder,consisting of cylinders of gunpowder with a small indentation in the top surface.

At this point advances in gunpowder and hydraulic technology came togegther. The essence of production of pellet powder was the pressing process. Unlike other grades no further processing,apart from drying, was required. There was therefore a requirement for the most effective pressing facilities and state of the art hydraulic power provided the solution. In 1851 William Armstrong had vastly increased the potential of hydraulic machinery by the introduction of the weight loaded accumulator (See P. 13) and its availability and incorporation in new facilities built at Waltham Abbey in 1869 for pellet powder pressing - the Group E steam Mills L149 (Plates 21 -23) (Figs.6,7) - represented an excellent example of synergy between two newly developing technologies. Further, the pump power medium changed from water to steam.

In the 1860's Moulding House L130 was built,also utilising the Group E accumulator.

Physical Evidence:- The Group E Mills with accumulator tower,minus header tank,survive (Plate 23) and still form an impressive frontage reflective of the clear statement of power and efficiency which the steam Mills were intended to convey.

RCHME Report Condition Description - Good

Moulding House L130 has been demolished.

1879 - Pebble Powders - hydraulic distribution - Remote Accumulator

However in two years such was the pace of development that it was decided that pellet powder production should be terminated in favour of pebble powders,which were seen to be superior in large charge application. These comprised presscake cut into cubes 5/8" up to 2". This created a need for more powerful and expanded press facilities. This brought with it an engineering problem,arising out of the unique needs of gunpowder manufacture. For safety reasons manufacture,apart from incorporation, was in separated small scale buildings. These required power. This had been provided by individual water wheels. Steam was however now the power source. But to attempt to install scattered steam engines would be both unsafe,particularly when applied to the inherently risky pressing process, and uneconomic. Once again developments in hydraulic power provided the answer.

The idea of a hydraulic power distribution system powered by a centralised power source had been included by Bramah in an 1812 patent and it came to fruition in the 1860's and 1870's when Armstrong exploited the logic of his weight loaded accumulator technology by expanding it,in conjunction with remote accumulator towers,to encompass distribution of hydraulic power,with the remote tower performing a balancing and regulating function - 'taking the strain'.(See P.15). At Waltham Abbey the steam facilities of the Group E previous pellet powder mill were utilised for the accumulator pump and remote accumulator tower L136 was erected in 1879,serving a new Press House No.4 S31.

(Plates 24,25).

Physical Evidence:-

The facade of Press House No.4 S31 survives (Plate 24)together with two iron stanchions in front. It seems possible that these supported a subsidiary hydraulic accumulator.

RCHME Report Condition Description - Fair

Remote Accumulator Tower L136 survives (Plate 25) and has been extensively refurbished as an observation tower.

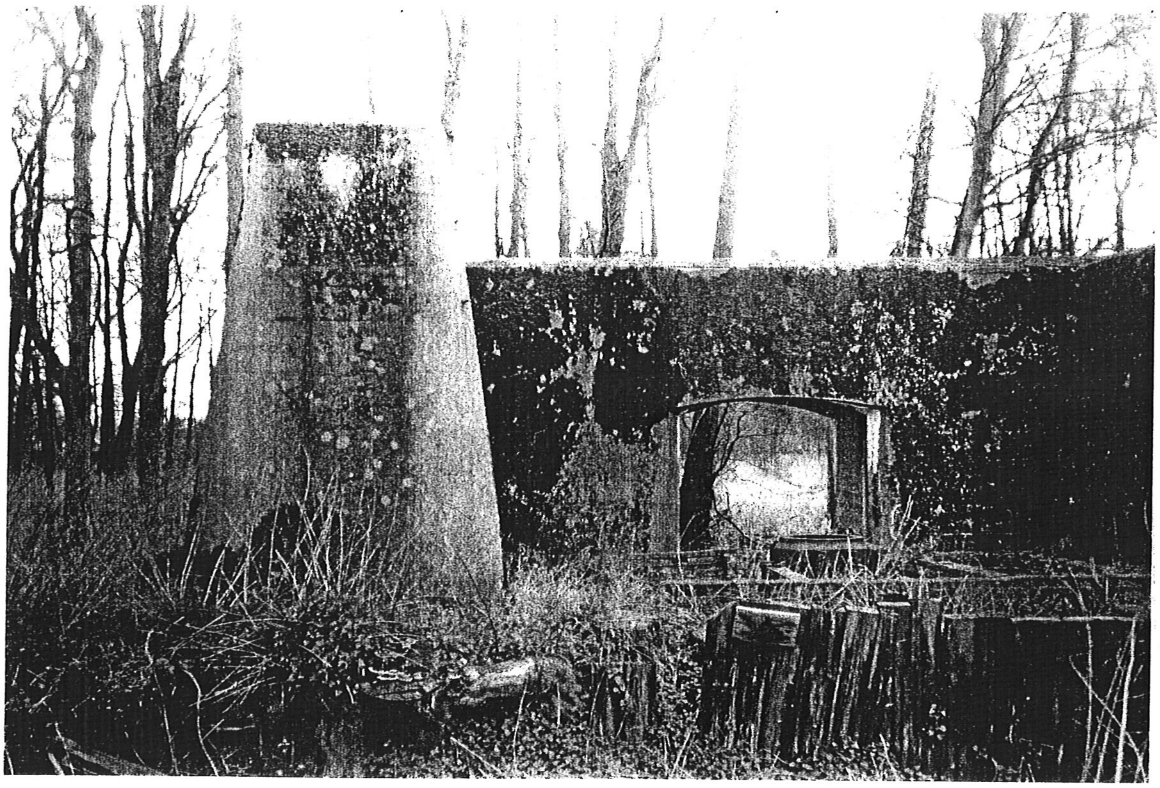


Plate 27
Moulding House
No.4, Traverse
Bldgs 107, 108
Press base in
centre
built 1882-4
2002

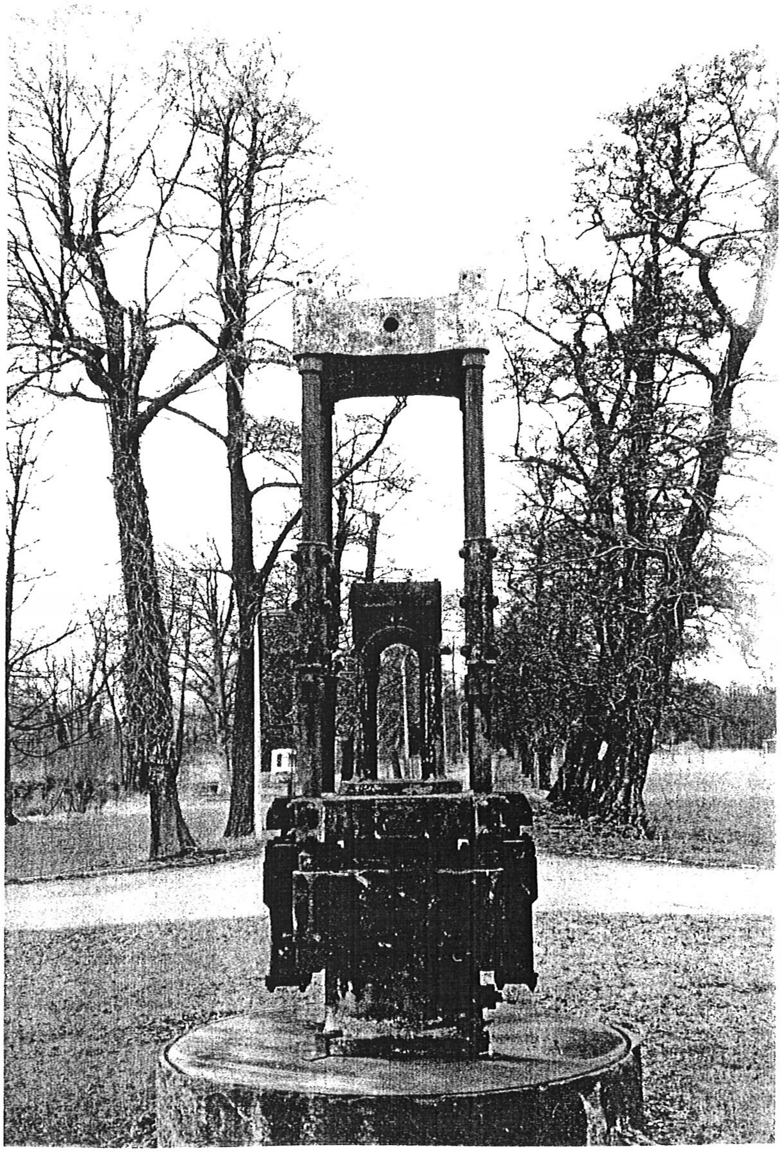


Plate 28
Cordite extrusion
Press
Manufacturer and date
cast on frame-
Tangye 1939
2002

1882-1884 - Prismatic Powders - Extension of Hydraulic Distribution

Large charge technology progressed further with the introduction of prismatic powders,based on earlier American studies. These were pressed hexagonal prisms about 1" high perforated with holes to facilitate gas transmission. Again there was a need for expansion of pressing facilities and again hydraulic power provided the power solution. In 1882 and 1884 Moulding House No.4 Buildings 107 and 108 (when applied to pressing prismatic powders the term moulding was used) was erected (Plates 26,27) and the L149 Group E central accumulator and remote accumulator L136 hydraulic distribution system was extended to the new buildings.

Physical Evidence:-

Buildings 107 and 108 Moulding House No.4 was surrounded by an impressive E shaped concrete traverse,which still stands (Plate 27).

The timber structures between the arms of the traverse have not survived.

RCHME Condition Description - Good

1880's - The first Chemical Base Explosive - Guncotton - hydraulic extension

Whilst the above gunpowder expansion was going on,production of the first chemical base explosive,guncotton,had already commenced at Waltham Abbey (Guncotton was too powerful to be used as a propellant and too sensitive for shell filling and therefore did not supplant gunpowder in these applications). Broadly,chemically based explosives required the same main processes as gunpowder - incorporation,pressing,drying (the term pressing was continued although in the case of the propellant cordite technically the process was extrusion,of cord like strands) (Plate 28).Again the hydraulic system was ideal for pressing and was employed in the guncotton press house L137 erected in the early 1880's.

Physical Evidence:

L137 was converted to a laboratory and survives.

RCHME Report Condition Description - Good

1898,1908 - Inception of Cordite - Hydraulic Power again extended

At the end of the 19th century science finally succeeded in producing a chemical base propellant,cordite,and its rapid replacement of gunpowder brought fresh demand for increased press facilities. In 1898 the steam incorporating mills Group D L153 and Group C L157 were converted to cordite press houses and in 1908 cordite Press House No.6 L169 was erected.

All were connected to the existing Group E L149 hydraulic system.

Physical Evidence:- Group C L157 (Plate 1)and Group D L153 mills survive as part of the steam powered complex. Group C has been extensively refurbished.

Group D RCHME Condition Description - Fair

Press House No. 6 was demolished in the early 1960's.

1915 - Cordite - WW1 expansion - New Hydraulic system

WW1 brought a massive expansion of cordite output at Waltham Abbey - from 26 tons pw previously to 140 tons.

To achieve this what was virtually a new cordite factory was built between 1914 and 1916,including three large Press Houses - Nos. 2 L134,No.5 L159, and No. 10 H16 (Plate 29). Again expanded hydraulic capacity was the sine qua non. However it is apparent that the existing Group E L149 facility was considered inadequate to cope with the significant new demand. In 1915 a new hydraulic accumulator tower and pump house A214 was built served by engine/boiler house A210 (termed the Power House) (Plates 30,31) (Figs8,9). This accumulator served all the new press facilities detailed in this paragraph and the converted Group C and Group D press houses.

Physical Evidence:-

Press House No.2 L134 was converted to a laboratory and survives

RCHME Report Condition Description - Fair

Press House No. L159 Detail as for Press House No.2

Press House No.10 was demolished

A214 Accumulator Tower/Pump House and A210 Engine/Boiler House survive (Plates 30,31) RCHME Report Condition Description - Good

22

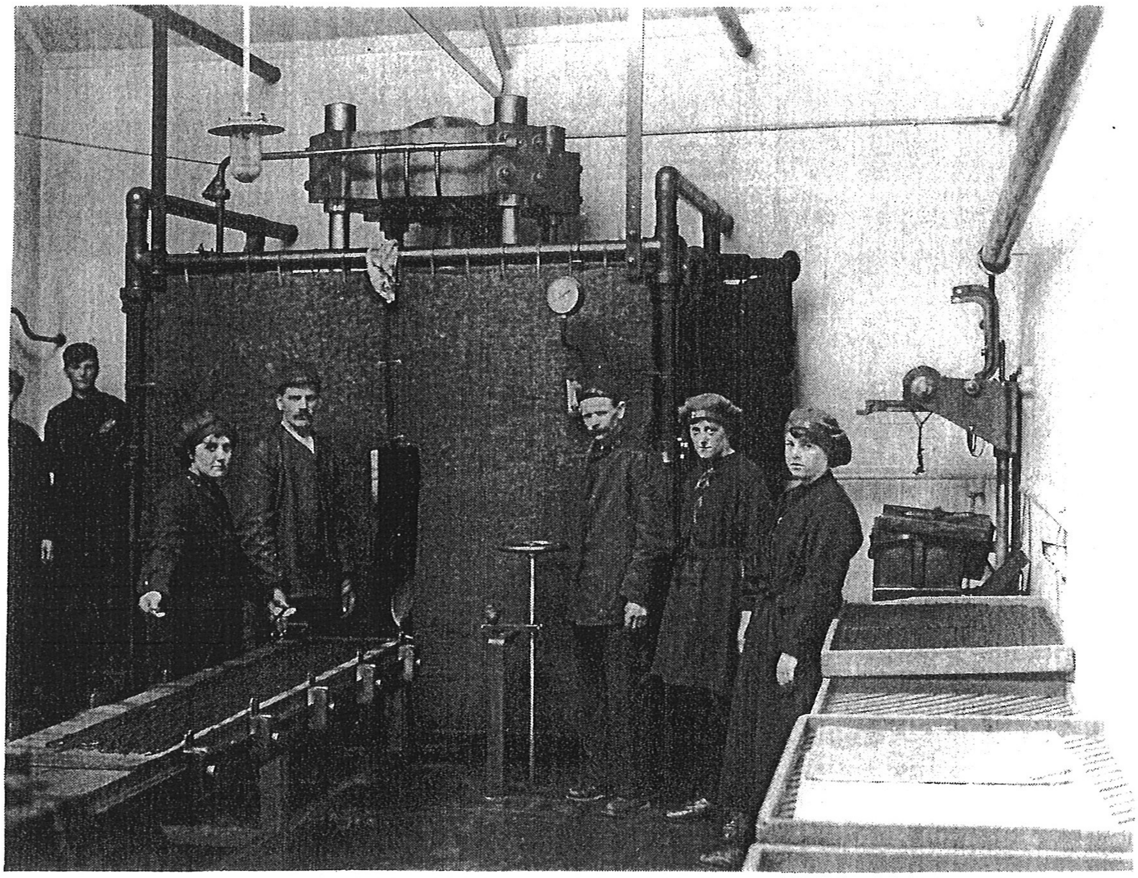
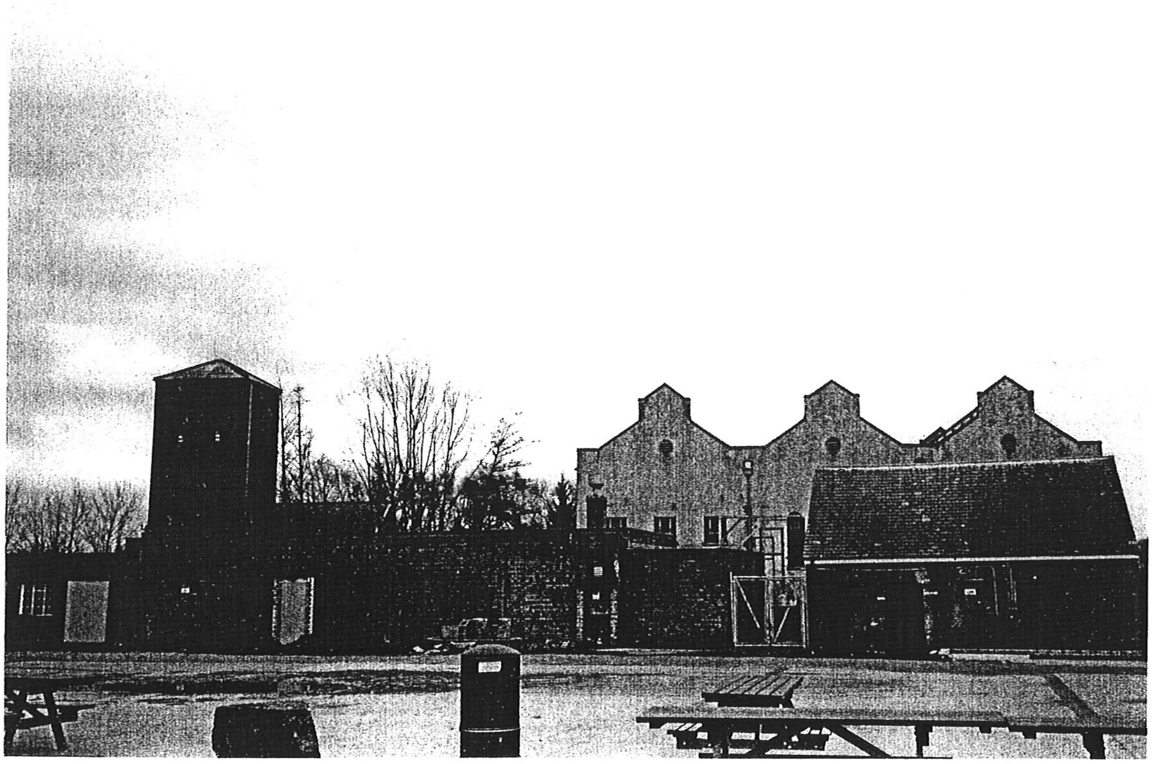


Plate 29
Interior Cordite
Press House
(Safety - Press screened
by rope mantlet with
aperture for egress of
cordite strands)
1917

Plate 30
Accumulator Tower and
Pump House A214 on left
built 1915
Power house A210 on right
built 1905
2002



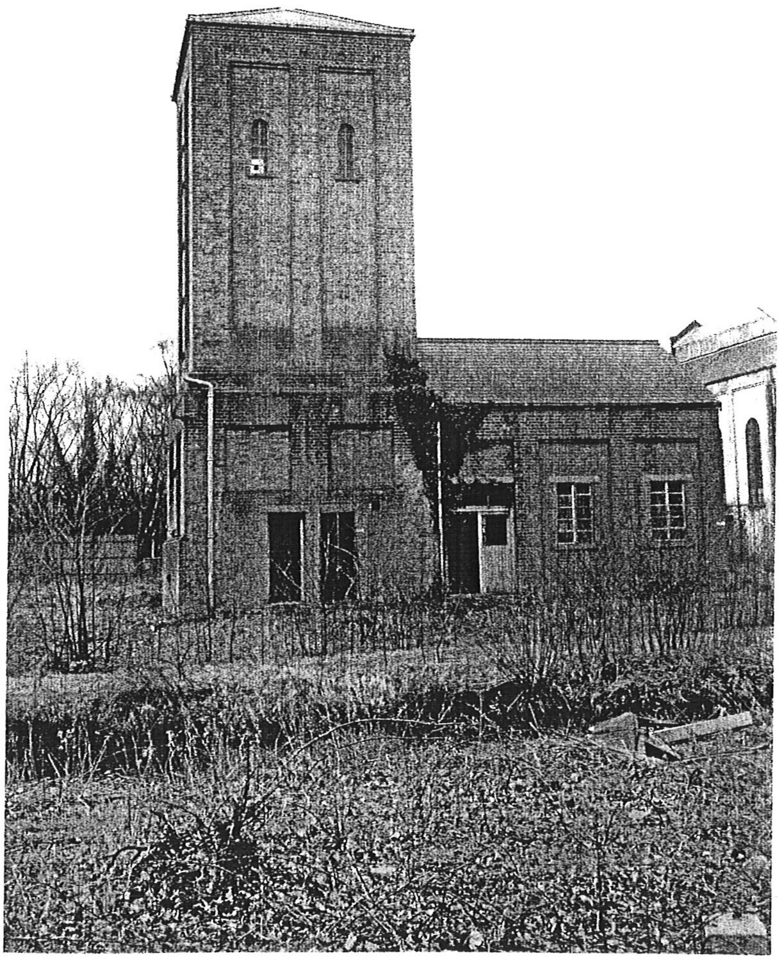


Plate 31
Accumulator Tower and
Pump House A214
built 1915
2002

6. Summary and Conclusions

From its beginnings in British military use as a propellant in the 14th century gunpowder and later types of explosive and propellant have been key instruments in furthering national political goals,whether expansive or defensive,and have also played a vital role in civil constructional and associated activities. For over 200 years of Crown ownership the Waltham Abbey Mills were one of the foremost centres of production and research,national and international.

In the manufacturing process pressing played a crucial part. From the inception by Joseph Bramah of the hand lever hydraulic pump the primary power source for pressing at Waltham Abbey was water pressure hydrostatic hydraulic power. There were several points in the progression of product type at Waltham Abbey where the availability of developing hydraulic technology enabled the Mills to avoid what could have become serious manufacturing bottlenecks,and it is difficult to imagine that the Waltham Abbey production process could have achieved anything like the safety,efficiency and productivity at which it operated without the application of hydraulic power to the vital pressing operation.

The main structures of the Waltham Abbey hydraulic system have survived. Together they comprise in scale and number of buildings a major and coherent expression of the development over a century of Victorian hydraulic engineering,made all the more valuable as the remains of systems in the outside world are rapidly disappearing with the progressive redevelopment of dock and railway goods areas.

The interest of the system is doubly enhanced by the survival of all the key components of the No.1 Press House which together represent a possibly unique example in one setting of the operation and artefacts of intermediate hydraulic technology where kinetic water power was employed to produce hydrostatic water pressure power (but see Recommendations below).

Overall the Waltham Abbey system is a memorial to the genius of Bramah and Armstrong who saw the hidden potential of hydrostatic pressure,and who have perhaps not been given the recognition they deserve in the engineering pantheon for development of this unobtrusive but hugely effective power source.

7. Recommendations

Conservation/Restoration

Of the hydraulic connected buildings Group C Mills L157,originally steam incorporating and later cordite press house,and remote accumulator tower L136 have been extensively refurbished .

The balance,excluding No.1 Press House,have the RCHME Report Condition Description Good or Fair. As unoccupied buildings they will be subject to the usual risks of ingress of water etc. It is assumed that the maintenance capital allotted under the arrangements setting up the Mills as an interpretative centre will have included provision for this.

No.1 Press House gives great cause for concern. It is not listed and although within the Scheduled Ancient Monument Area there is a danger that it will fall victim to insidious decay. All of the following aspects require urgent remedial / restorative action :

The Pump House is roofless,exposing the pump and associated ironwork to the elements

Threat of recolonisation by sycamore

Thick roots embedded in top of traverse

Large area of traverse rendering lost and exposed brickwork spalling

Water wheel float boards largely rusted away

Inlet leat sluice gate similar

Press exposed to the elements. Large areas of flaking rust with water gathering underneath

Pump,pipes and gearing require derusting

If this action is not taken urgently this unique monument will be lost and if funds are not available from Mills resources they should be immediately sought from English Heritage on the grounds that a part of the national engineering heritage is at risk

Hydraulic History - Education

An important part of the Mills function is education.
Apart from normal interpretation,consideration should be given to preparation of an engineering history educational resource based on what could be termed a 'hydraulic trail'taking pupils round the buildings with the ongoing development and importance of hydraulic power explained as they tour the circuit. This could be particularly relevant to those taking science /physics.

Engineering Record

Within their varied function the Institution of Civil Engineers maintains a historical and archival activity. Contact should be made with a view to compiling a full detailed record of the structure,machinery and operation of the No.1 Press House,to be lodged in their archives and included in their historical building record.

Waltham Abbey as an interpretative centre for Hydraulics

Although much has been written on those aspects of hydraulic engineering involving water movement and storage - harbour works,dams,sluices,locks etc.,very little published material exists on hydraulic machines and the systems which powered them and the physical evidence tends to be obscured.
Consequently there is considerable room for raising awareness of the historical importance of hydraulic machinery and systems and consideration could be given to establishing the importance of this and of the Mills as a notable example in Waltham Abbey publicity material.
Also,it would seem appropriate to consider liaising with the Institution of Civil Engineers with a view to establishing some form of joint publicity on the Waltham Abbey system.

L.F.Tucker

April 2002

Appendix 1 - Technical

Gunpowder and chemical base explosives and propellants

Gunpowder

Gunpowder is an explosive. An explosion is a rapid chemical reaction accompanied by the sudden liberation of a large amount of heat energy and simultaneous formation of a large volume of gaseous products. The process involved is combustion or burning which is a consequence of rapid oxidation - combination with oxygen . Explosives usually rely on the element nitrogen,which is fundamental to the oxidation process. Combustion relies on oxygen and fuel. Gunpowder consists of a mixture of saltpetre (potassium nitrate)-the oxidant,charcoal and sulphur the fuels,normally in the ratio 75/15/10,the sulphur speeding the process of combustion through its quality of igniting at a low temperature.

Gunpowder was used either in the military function as a propellant i.e.for the firing of musket or cannon balls and for demolition charges and in the civil function similarly for sporting guns and for blasting in mines,quarries and construction - canals,railways, ports,harbours etc. As such it played a major role in the massive civil engineering and constructional activity of the 19th century .

The prime requirements of gunpowder were that it had to :

Be of predictable uniform performance at as high a level as possible,i.e.exerting the most power

At the same time reduce as far as possible wear and tear on armaments when in military application

Be durable,i.e. resistant to break up and to moisture in transport and storage

To achieve these aims gunpowder passed through up to 11 separate processes,on a batch basis :

Raw material preparation - saltpetre,charcoal,sulphur

Mixing the raw materials - generally in the ratio 75/15/10

Incorporating - in stamp and later edge runner mills - a grinding and pulverising

Appendix 2 - The Development of Hydraulic Power at Waltham Abbey

Diagrammatic scheme attached

Bramah hand lever operated Pump

From 1812 No buildings survive

Water powered Pump

1856 Press House No.1,Building 76
Press House No. 2,later re-numbered No.1,Buildings 103,104

Steam powered Pump

1869 Group E Mills L149 - accumulator and engine
Pellet powder production
Link to : Moulding House L130

1879 Group E Mills L149
converted to gunpowder incorporation
Accumulator retained for centralised hydraulic distribution for pressing
Link to : Remote Accumulator Tower L136
Press House No. 4 S31

1882 - 4 Link to : Moulding House No. 4, Buildings 107,108
Guncotton Press House L137

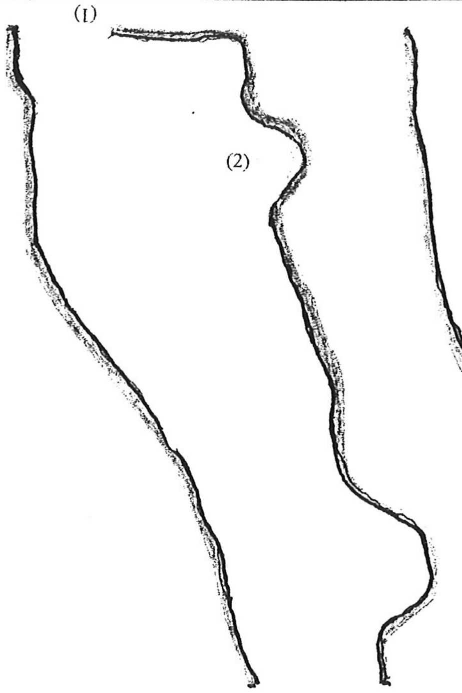
1898 Link to : Group C Mills L157 - converted to cordite Press House
Group D Mills L153 - " " "

1908 Link to : Cordite Press House No. 6

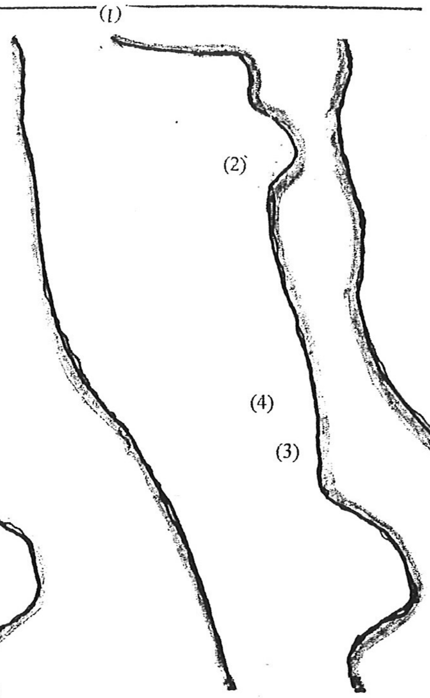
1915 Accumulator A214
Engine/Boiler House A210

Link to : Group C Press House L157
Group D Press House L153
Press House No.2 L134
Press House No.5 L159
Press House No.6 L169
Press House No.10 H16

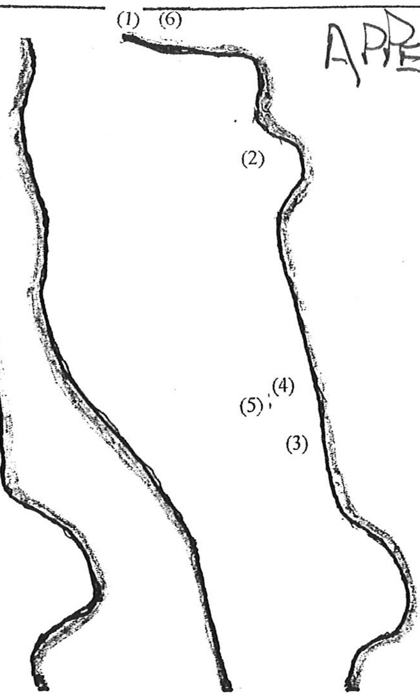
APPENDIX 2



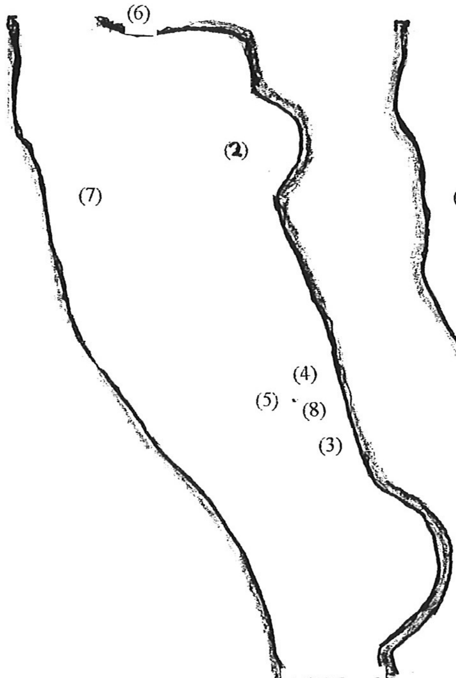
1856



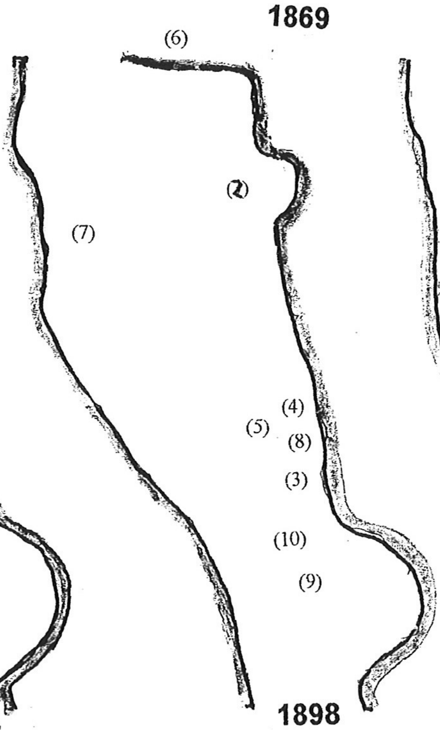
1869



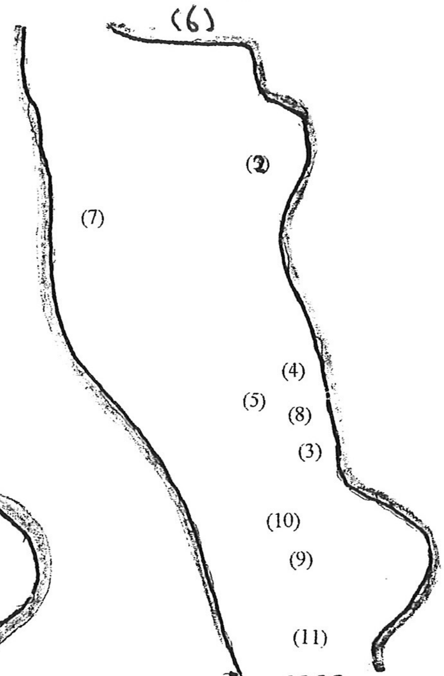
1879



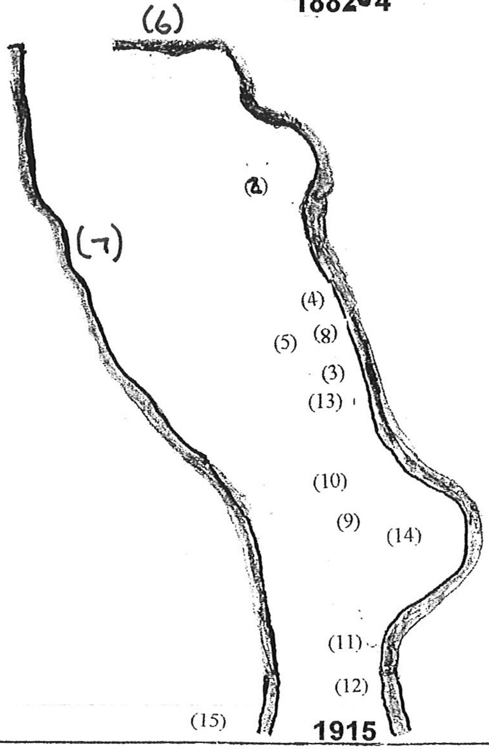
1882-4



1898



1908



1915

Development of Hydraulic System at Waltham Abbey

1856 (1) Press House No.1,Bldg 76
(2) Press House No.2,Bldgs 103,104
(re-number No.1)

1869 (3) Group E,L149
Central Accumulator
(4) Moulding House L130

1879 (5) Remote Accumulator L136
(6) Press House No.4,S31

1882-4 (7) Moulding House No. 4,Bldgs 107,108
(8) Guncotton Press House L137

1898 (9) Group C L157
(10) Group D L153
converted to Cordite Press Houses

1908 (11) Press House
No.6 L169

1915 (12) Accumulator A214
(9) Gp.C L157
(10) Gp.D L153
(13) Press House
No.2 L134
(14) Press House
No.5 L159
(11) Press House
No.6 L169
(15) Press House
No.10 H16

Notes to the Text

(1) JARVIS, Adrian, *Hydraulic Machines,* Shire Publications, Aylesbury, 1985, 3

(2) BADDELEY, Fraser, Major, *Pamphlet on the Manufacture of Gunpowder as carried on at the Government Factory, Waltham Abbey,* Private publication by the Author, Waltham Abbey, 1857, 15

(3) BUCHANAN, Brenda (ed.), *Gunpowder,The History of an international Technology,* Bath, 1966, 12

(4) DRAYSON, Frederick, *Treatise on Gunpowder* 1830. Privately published for the Honourable Board of Ordnancc, London

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<u>*Official Publications*</u>

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The Royal Gunpowder Factory, Waltham Abbey, Essex An RCHME Survey, 1993 Royal Commission on the Historical Monuments of England, Swindon, 1994 .

Fig. 1

ROYAL GUNPOWDER MILLS WALTHAM ABBEY

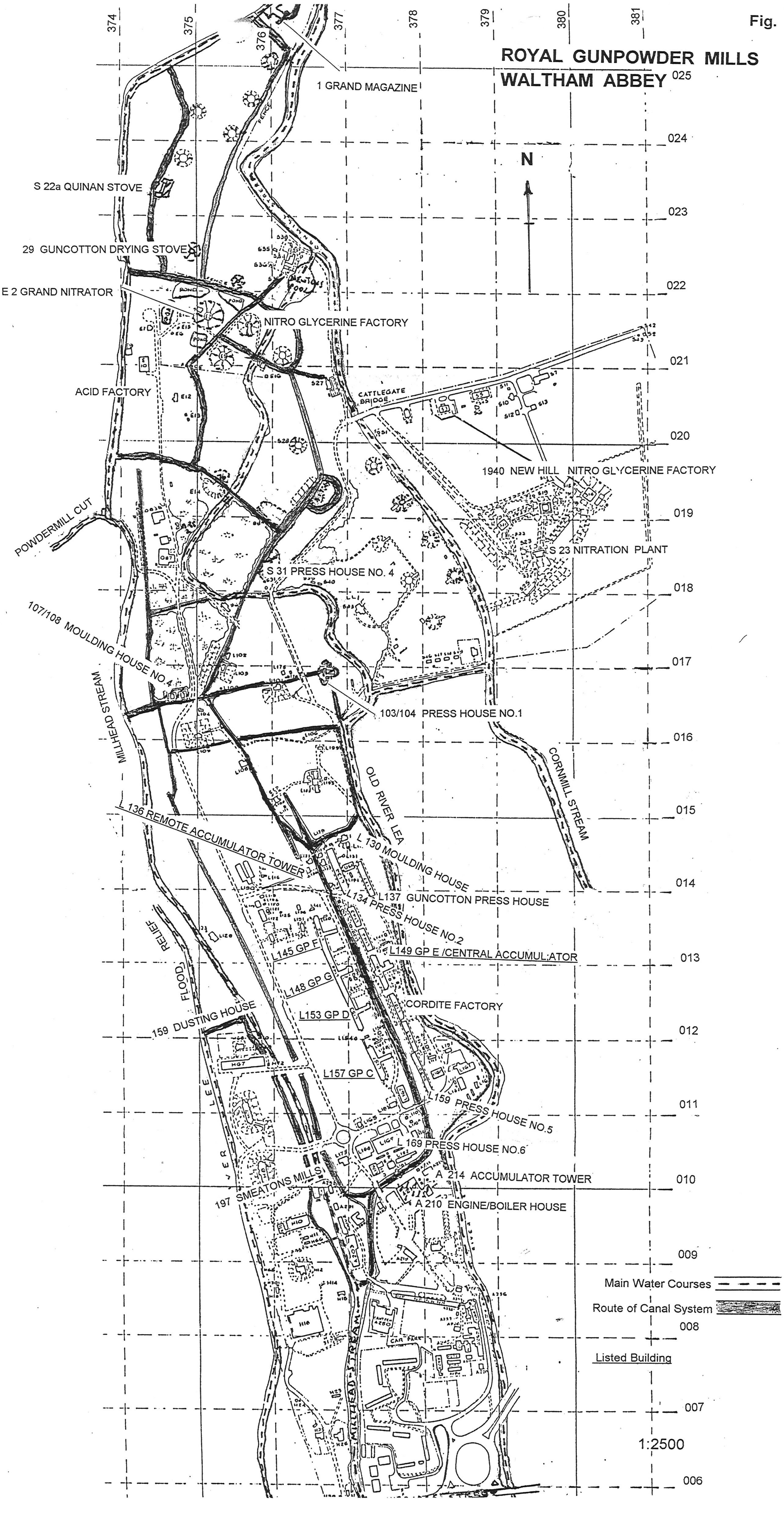
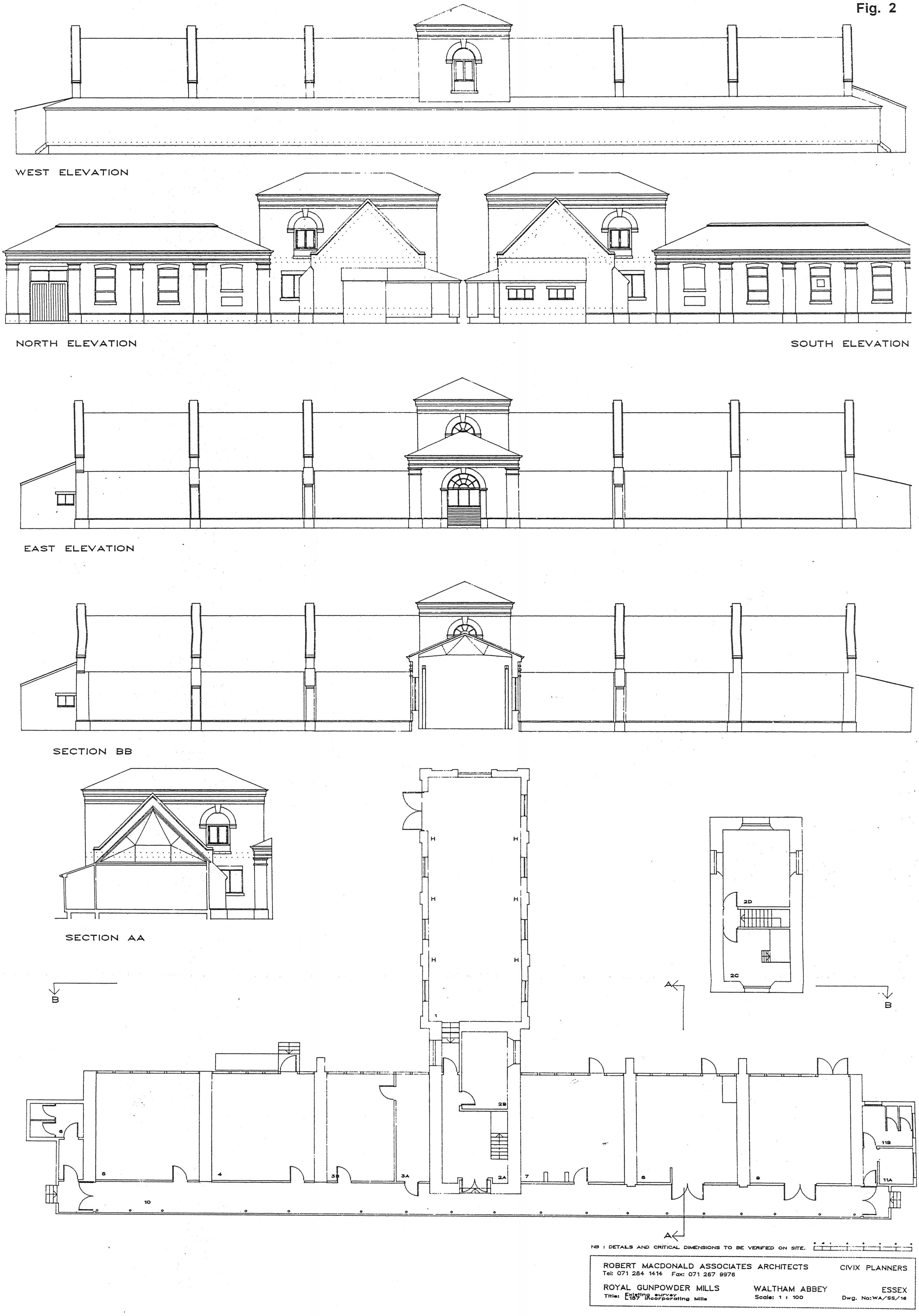
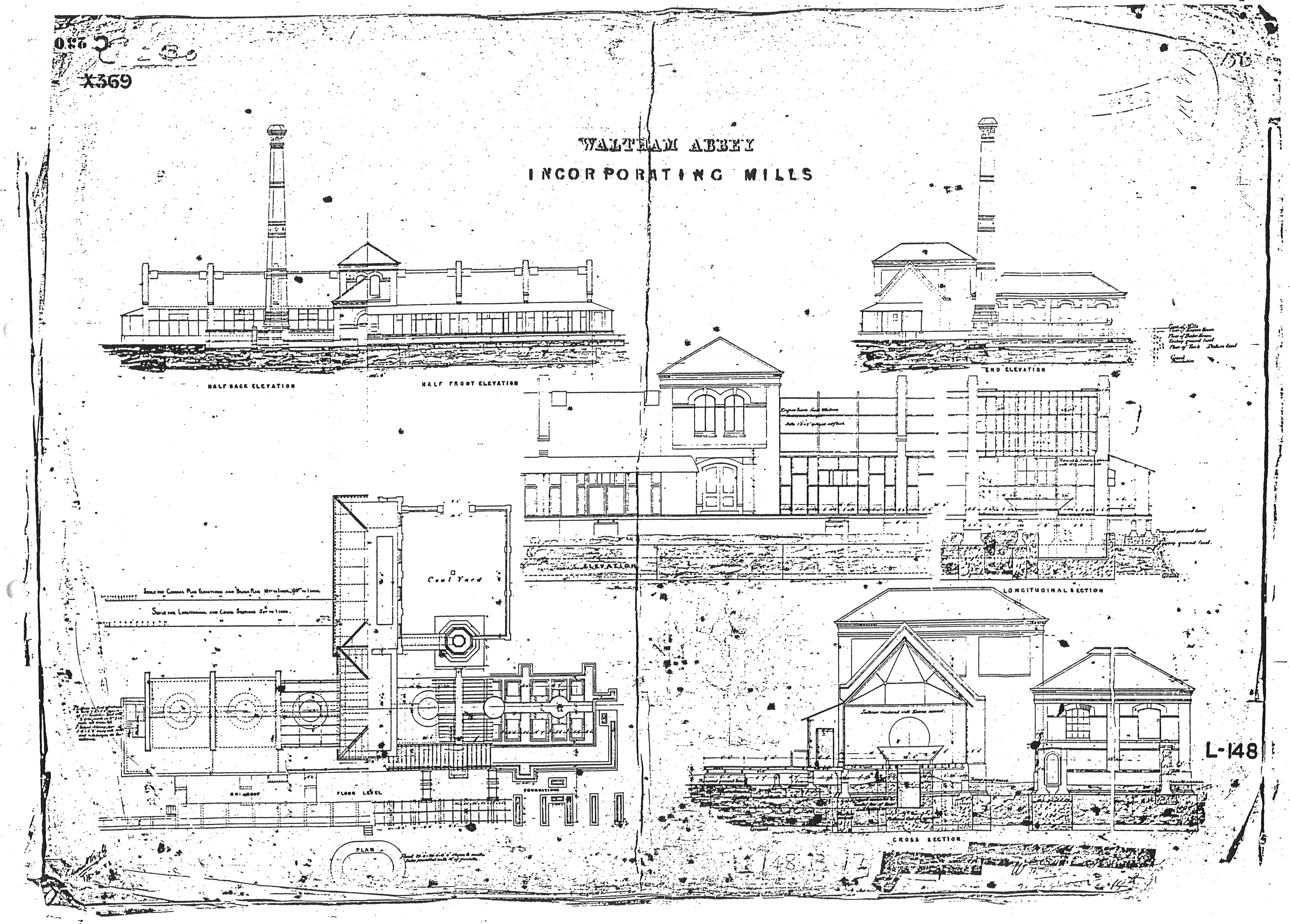


Fig. 2



WEST ELEVATION
NORTH ELEVATION
SOUTH ELEVATION
EAST ELEVATION
SECTION BB
SECTION AA
2D
2C
1
2B
2A
3A
3B
4
5
6
7
8
9
10
11A
11B
A
B
NB : DETAILS AND CRITICAL DIMENSIONS TO BE VERIFIED ON SITE.
ROBERT MACDONALD ASSOCIATES ARCHITECTS
Tel: 071 284 1414 Fax: 071 267 9976
CIVIX PLANNERS
ROYAL GUNPOWDER MILLS
Title: Existing survey L157 incorporating Mills
WALTHAM ABBEY
Scale: 1 : 100
ESSEX
Dwg. No:WA/SS/16

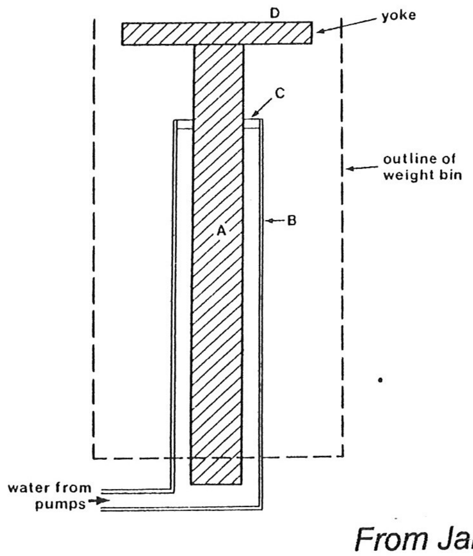
Fig. 3

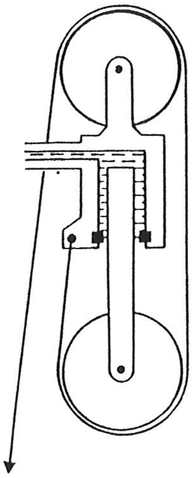

X369
WALTHAM ABBEY
INCORPORATING MILLS
HALF BACK ELEVATION
HALF FRONT ELEVATION
END ELEVATION
ELEVATION
LONGITUDINAL SECTION
Coal Yard
FLOOR LEVEL
FOUNDATIONS
PLAN
CROSS SECTION
L-148

363

Fig. 4

BELOW, LEFT: *A representational diagram of a hydraulic accumulator. The ram, A, stands in cylinder B, the water being contained by the seals, C. Attached to the top of the ram is the yoke (D) which supports the weight bin (shown in outline). Filled with heavy waste material, this acts on the ram, creating an artificial head of water and thus controlled hydraulic power. As the ram is forced down, a control chain, attached to the weight bin, slackened and restarted pumps in order to maintain the head of water.*
BELOW, RIGHT: *A representational diagram of a jigger, a device used to magnify the stroke of a piston and used for lifts, cranes and other machines with long travels. The pulley system attached to the ram increases the length of chain or wire paid out relative to its own travel.*



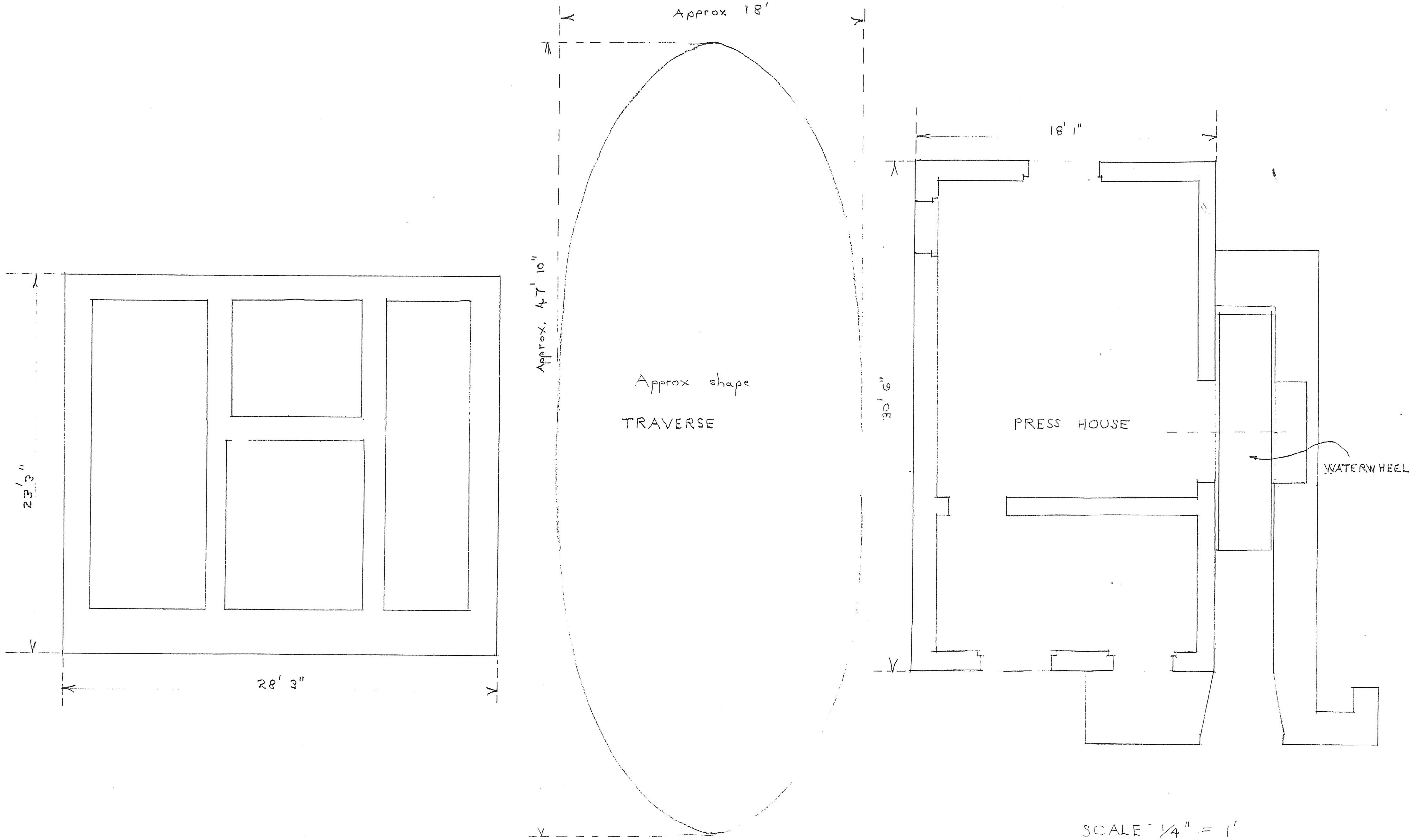


From Jarvis
Hydraulic Machines
1985

ROYAL GUNPOWDER MILLS WALTHAM ABBEY

PLAN OF NO. 1 PRESS HOUSE c 1856

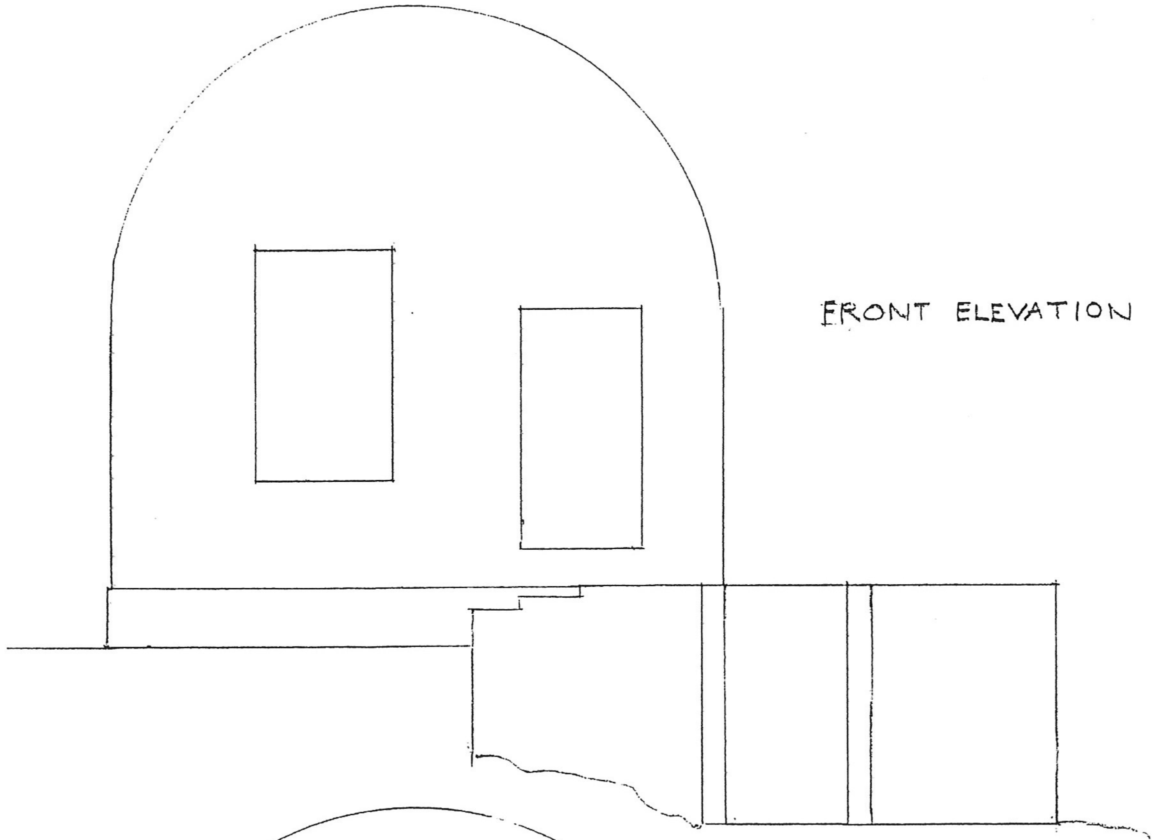
Fig. 5



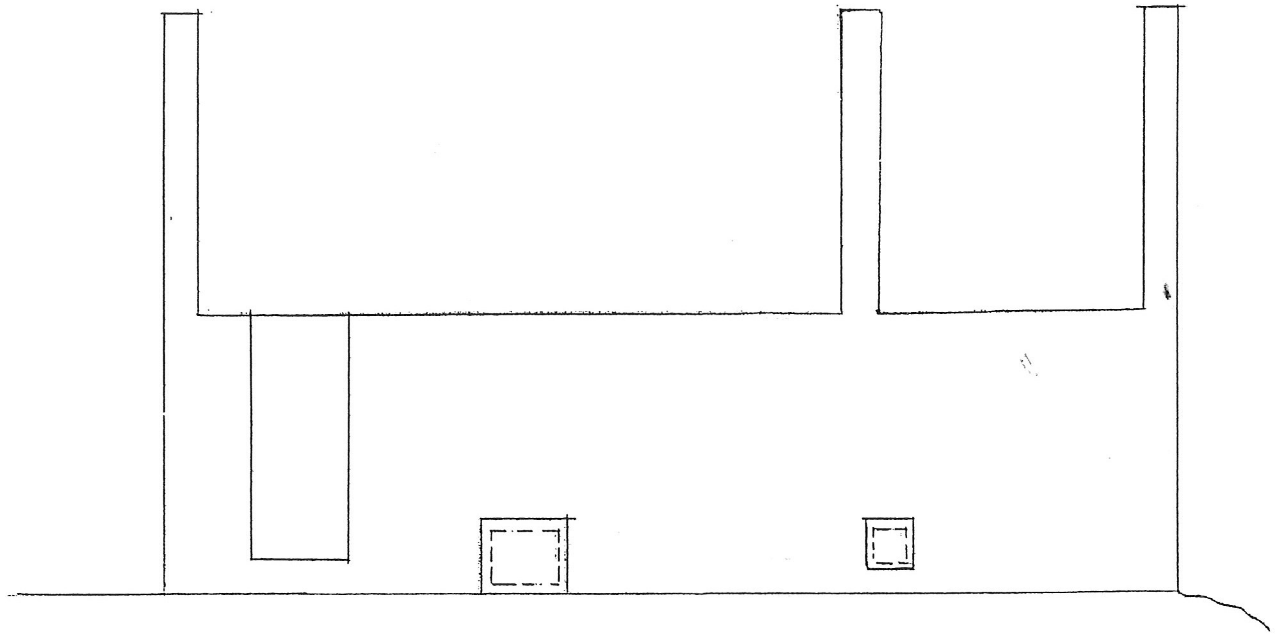
SCALE 1/4" = 1'

REG WEST 30/01/02

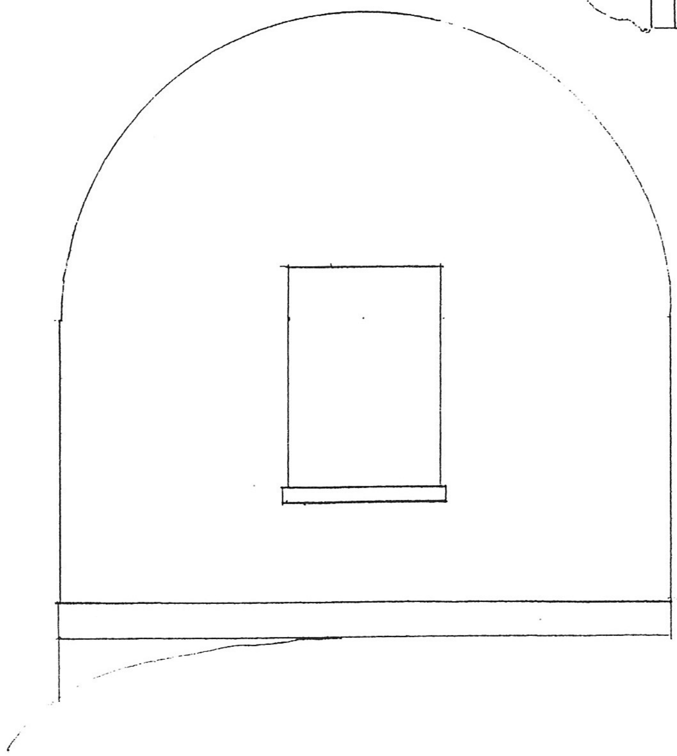
ROYAL GUNPOWDER MILLS · WALTHAM ABBEY
ELEVATIONS OF 'NO. 1 PRESS HOUSE c 1856



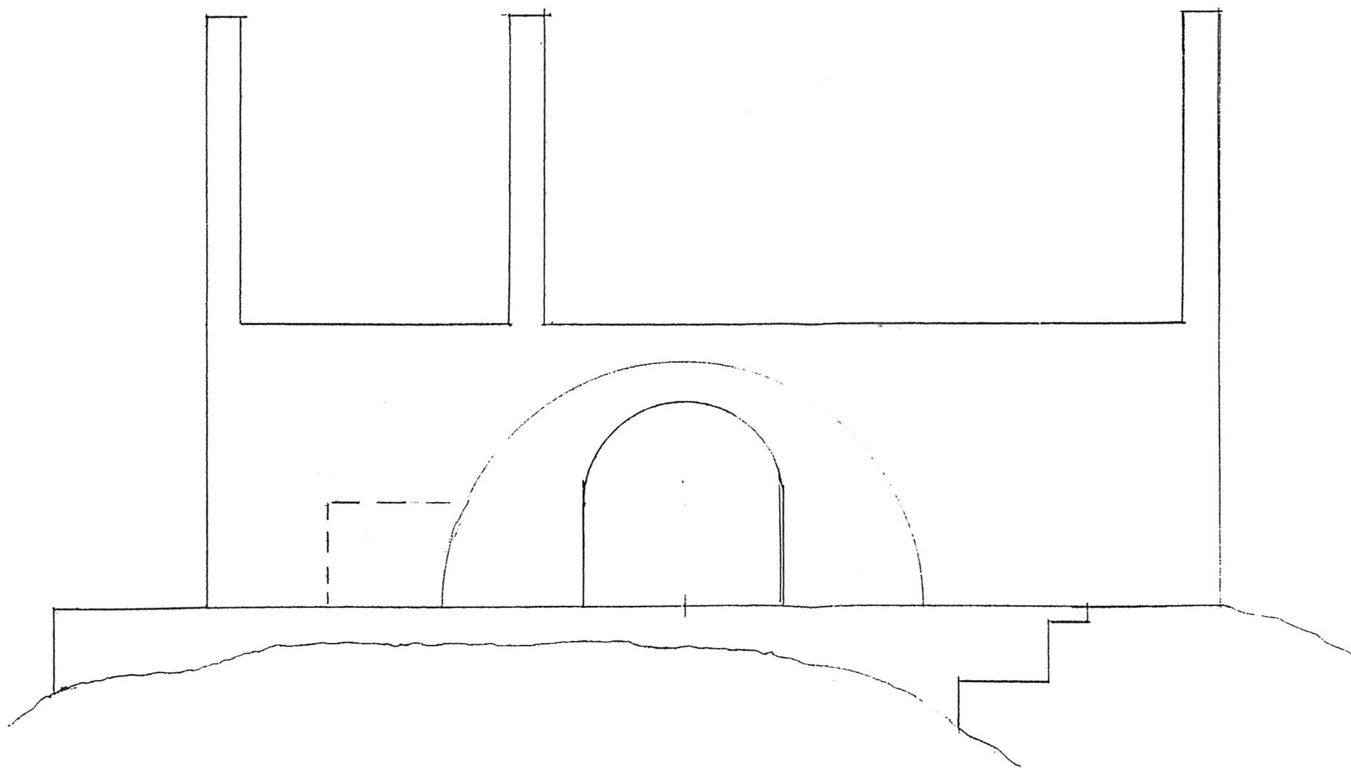
FRONT ELEVATION



SIDE ELEVATION



REAR ELEVATION



SIDE ELEVATION

SCALE 1/4" = 1'

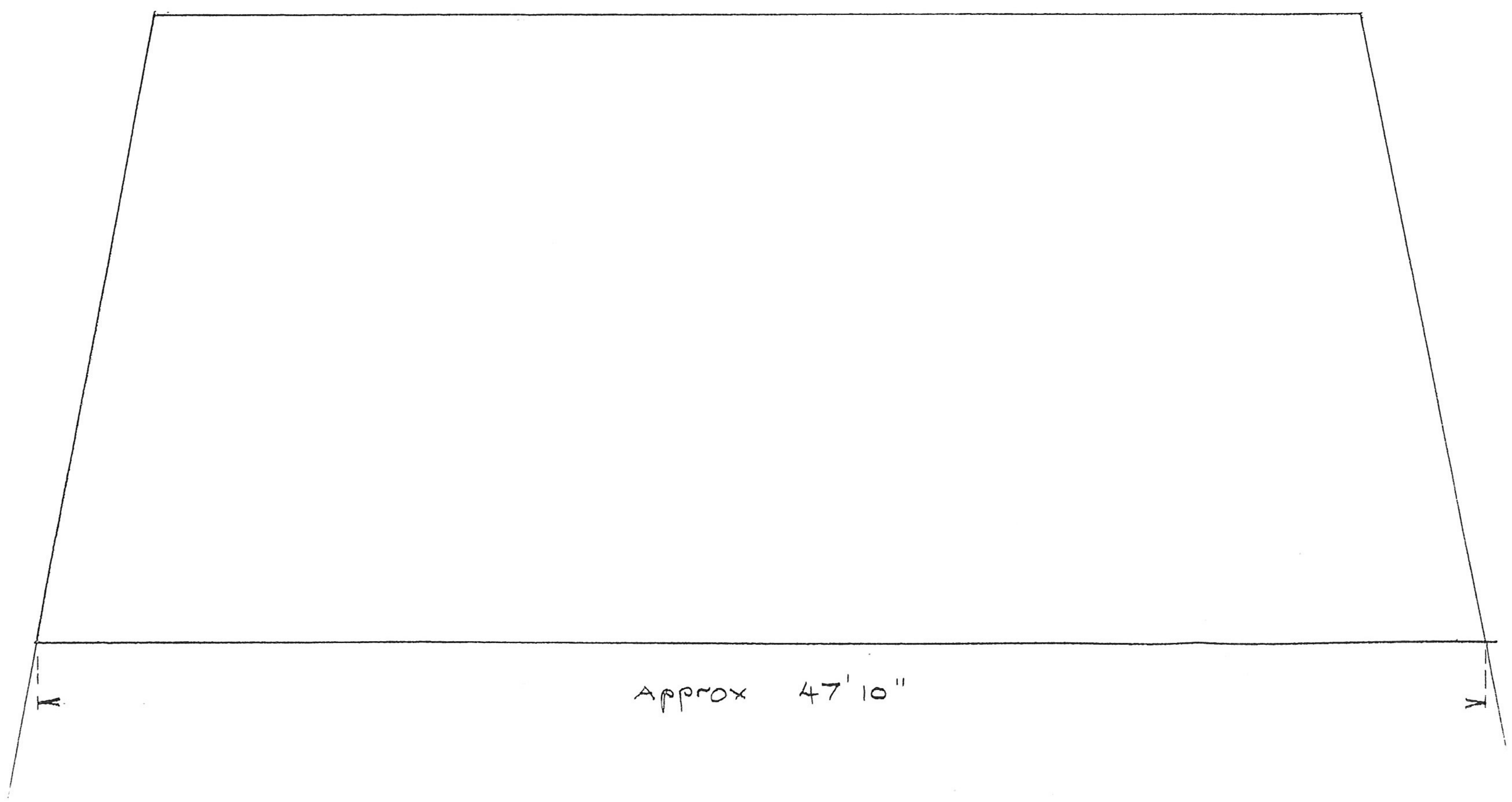
REG WEST 30/01/02

ROYAL GUNPOWDER MILLS WALTHAM ABBEY

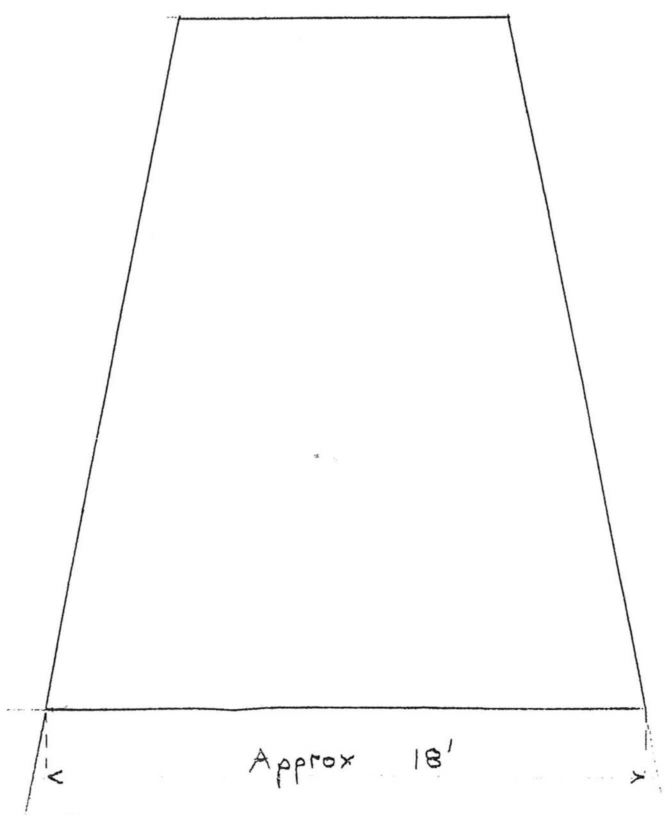
ELEVATIONS OF TRAVERSE

NO. 1 PRESS HOUSE c1856

SIDE ELEVATION



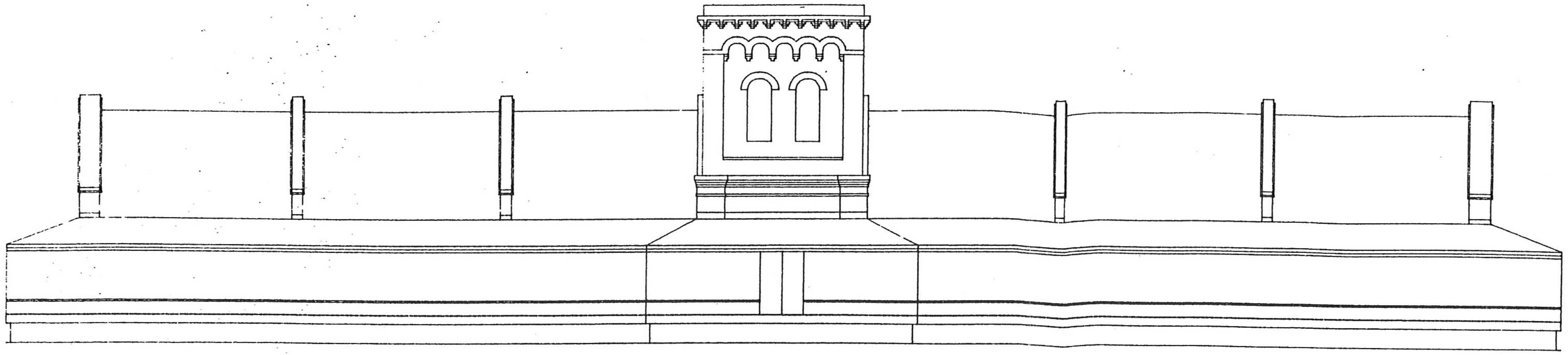
END ELEVATION



APPROX SIZE & SHAPE

REG WEST 30/01/02

Fig. 6



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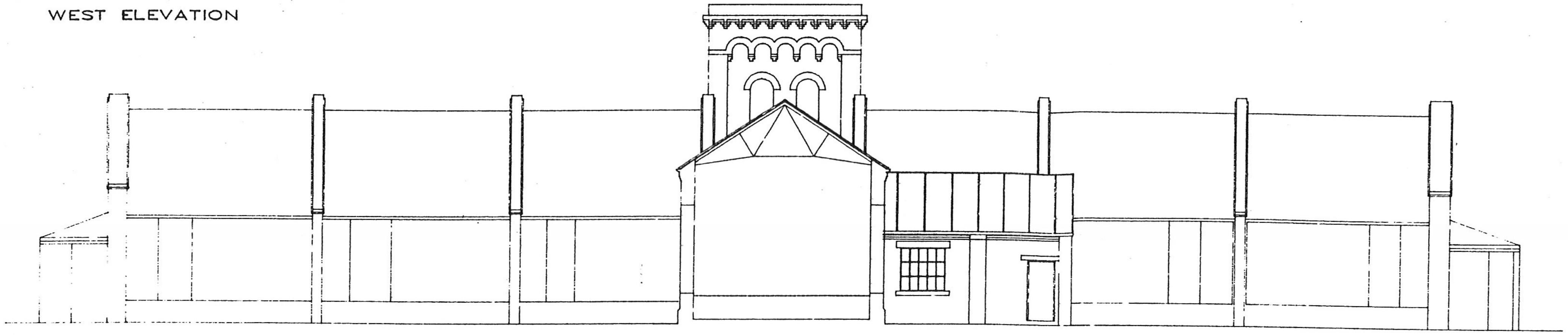
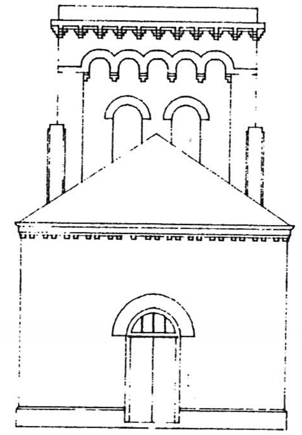
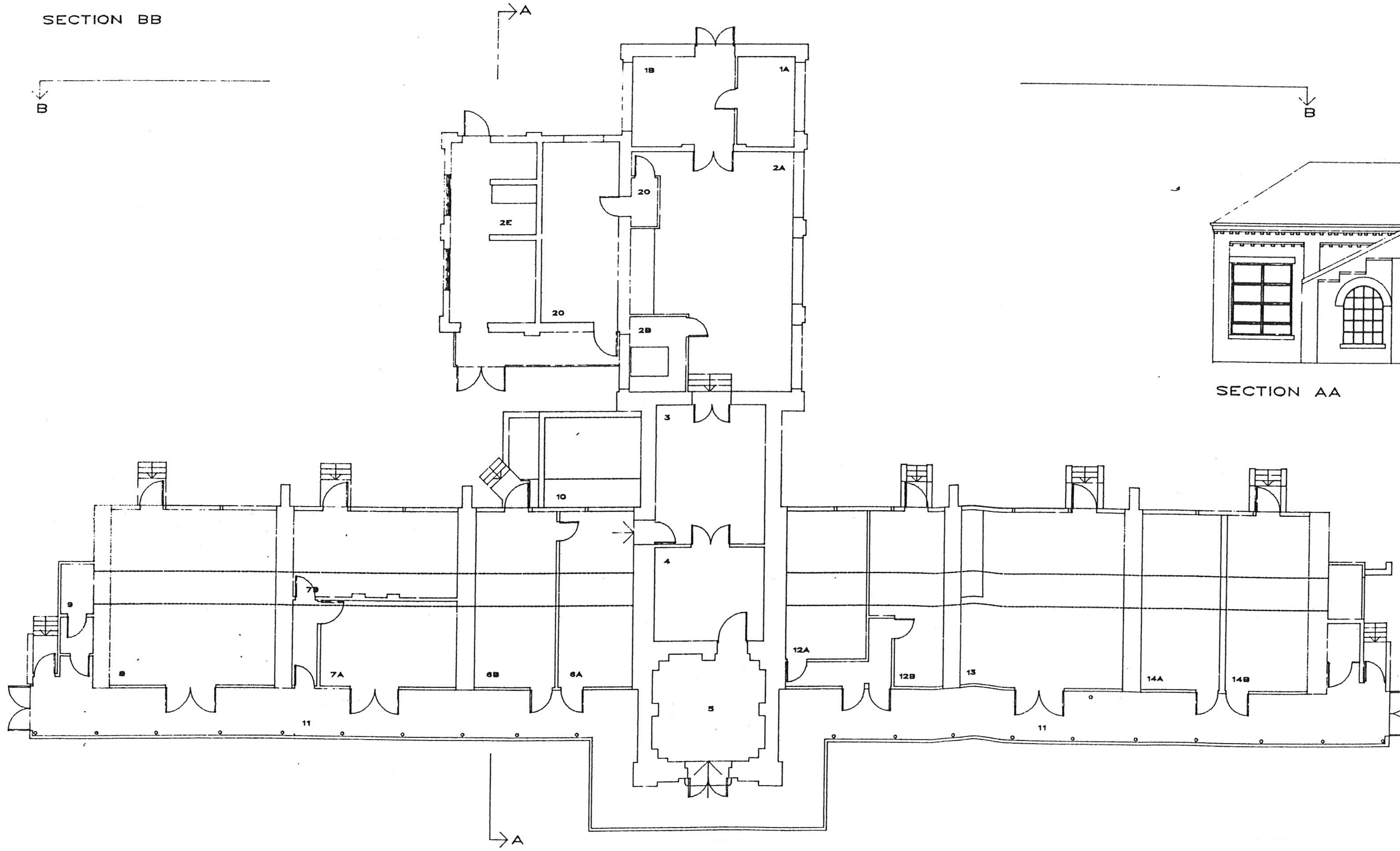
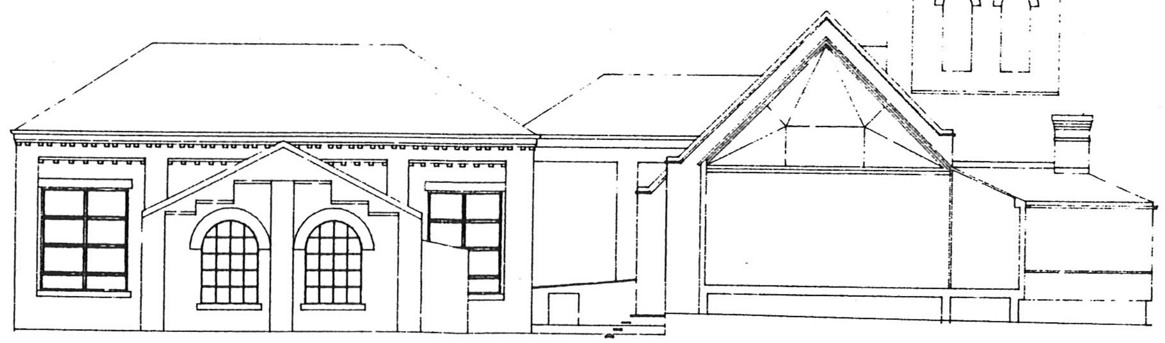


SECTION BB



EAST GABLE





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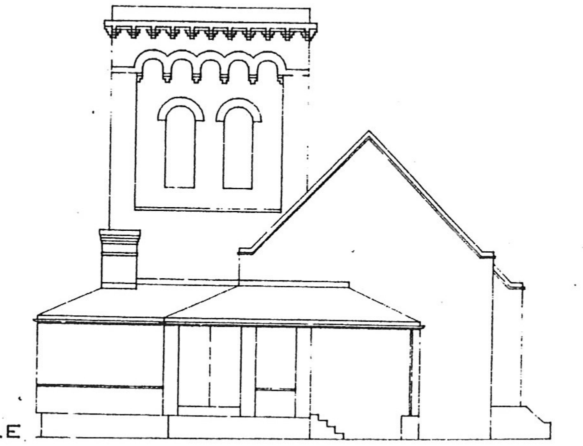

SOUTH GABLE

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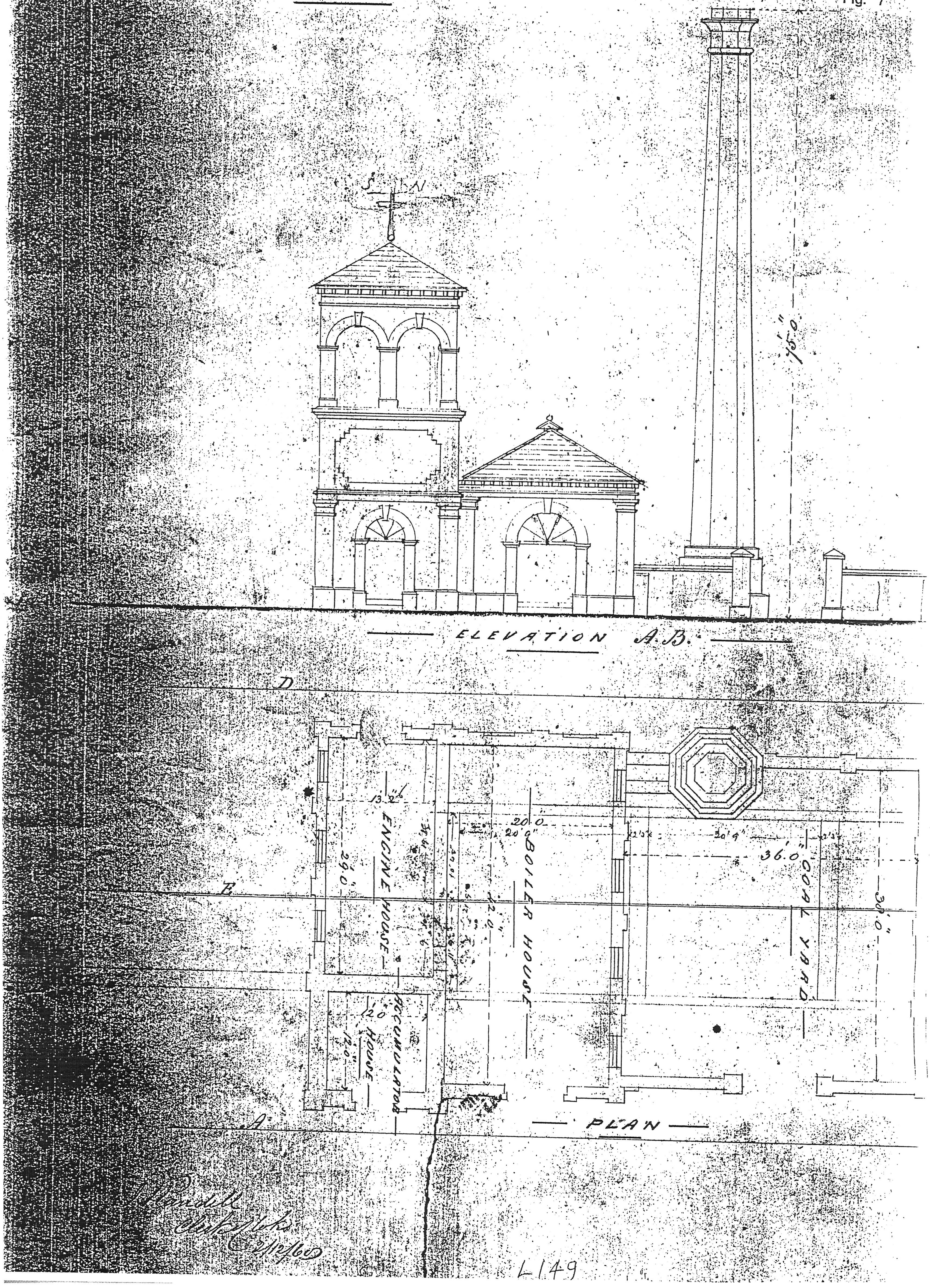
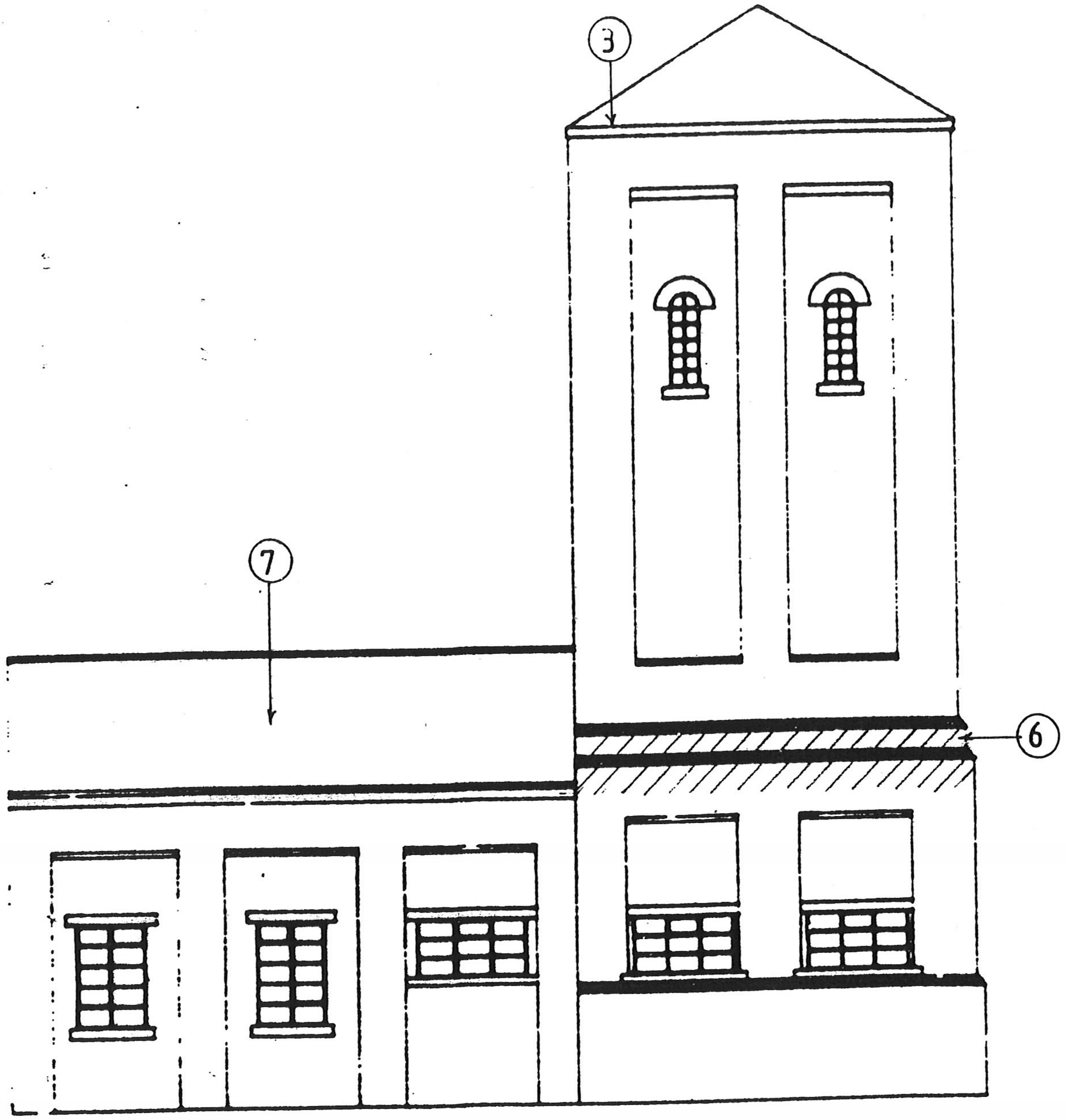
ROYAL GUNPOWDER MILLS WALTHAM ABBEY ESSEX
Title: Existing survey L149 Incorporating Mills
Scale: 1 : 100 Dwg. No: WA/SS/14

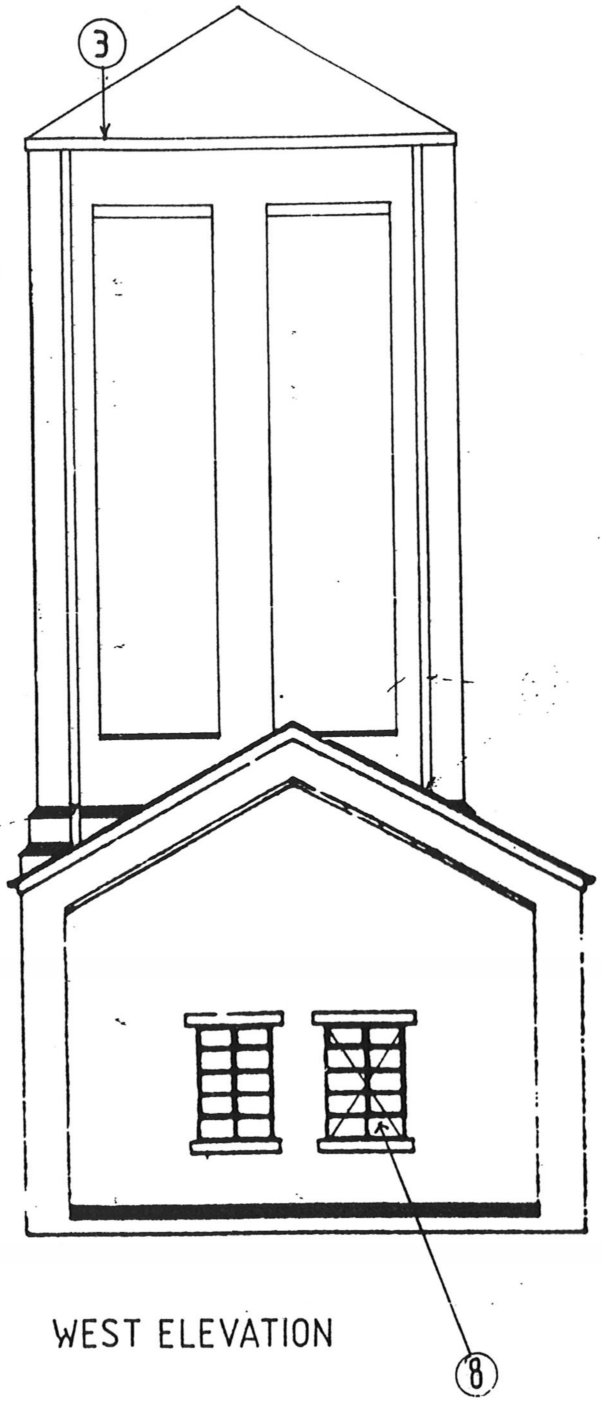
Fig. 7

PELLET POWDER BUILDINGS -





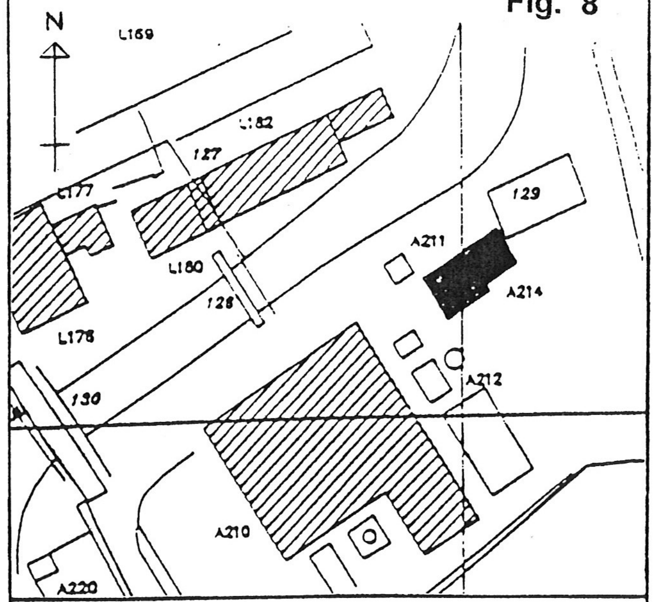
SOUTH ELEVATION



WEST ELEVATION

LOCATION PLAN

Fig. 8



Key

- Repoint area of brickwork
- Rebuild defective brickwork
- New brickwork
- Replace render finish
- Repair natural stone
- Replace individual brick(s)
- Repoint joint in stonework

Supported by the **Heritage Lottery Fund**

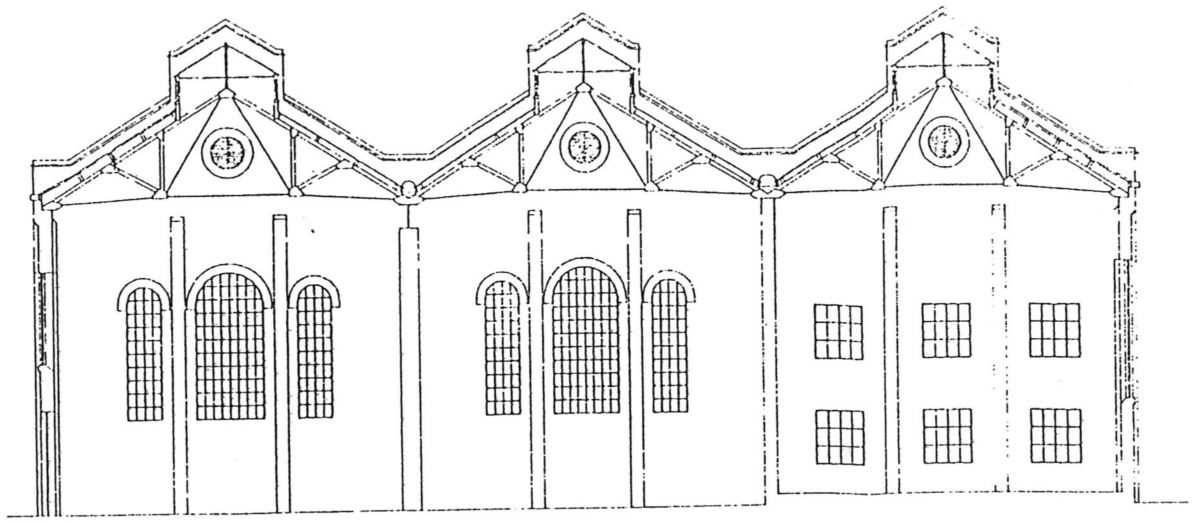
WALTHAM ABBEY
ROYAL GUNPOWDER MILLS

Structure Name
Shift House / Water Tower

Structure No.
A 214 (sheet 2)

Scale	Drg No.
1:100	753 201 / A214-02

Fig. 9



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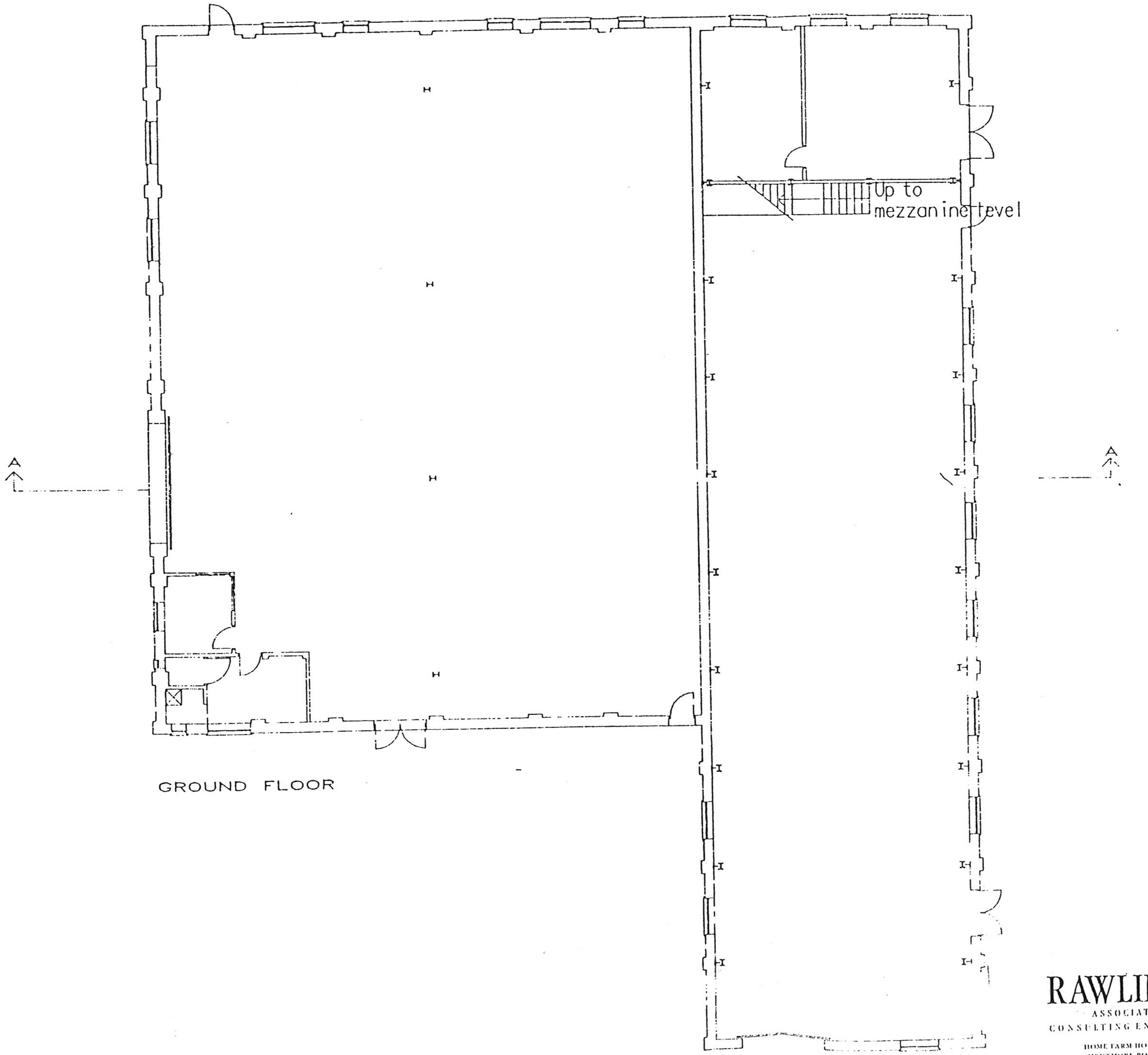

GROUND FLOOR

RAWLINGS
ASSOCIATES
CONSULTING ENGINEERS
HOME FARM HOUSE
MENTMORE ROAD
LEIGHTON BUZZARD
BEDS · LU7 [illegible]
TEL & FAX 0525 [illegible]

NB : DETAILS AND CRITICAL DIMENSIONS TO BE VERIFIED ON SITE.

ROBERT MACDONALD ASSOCIATES ARCHITECTS — CIVIX PLANNERS
Tel: 071 284 1414 Fax: 071 267 9976
ROYAL GUNPOWDER MILLS — WALTHAM ABBEY — ESSEX
Title: Existing plan, section A210 Powerhouse
Scale: 1 : 100
Dwg No:WA/SS/04