ROYAL GUNPOWDER FACTORY

THE MANUFACTURE Of CORDITE

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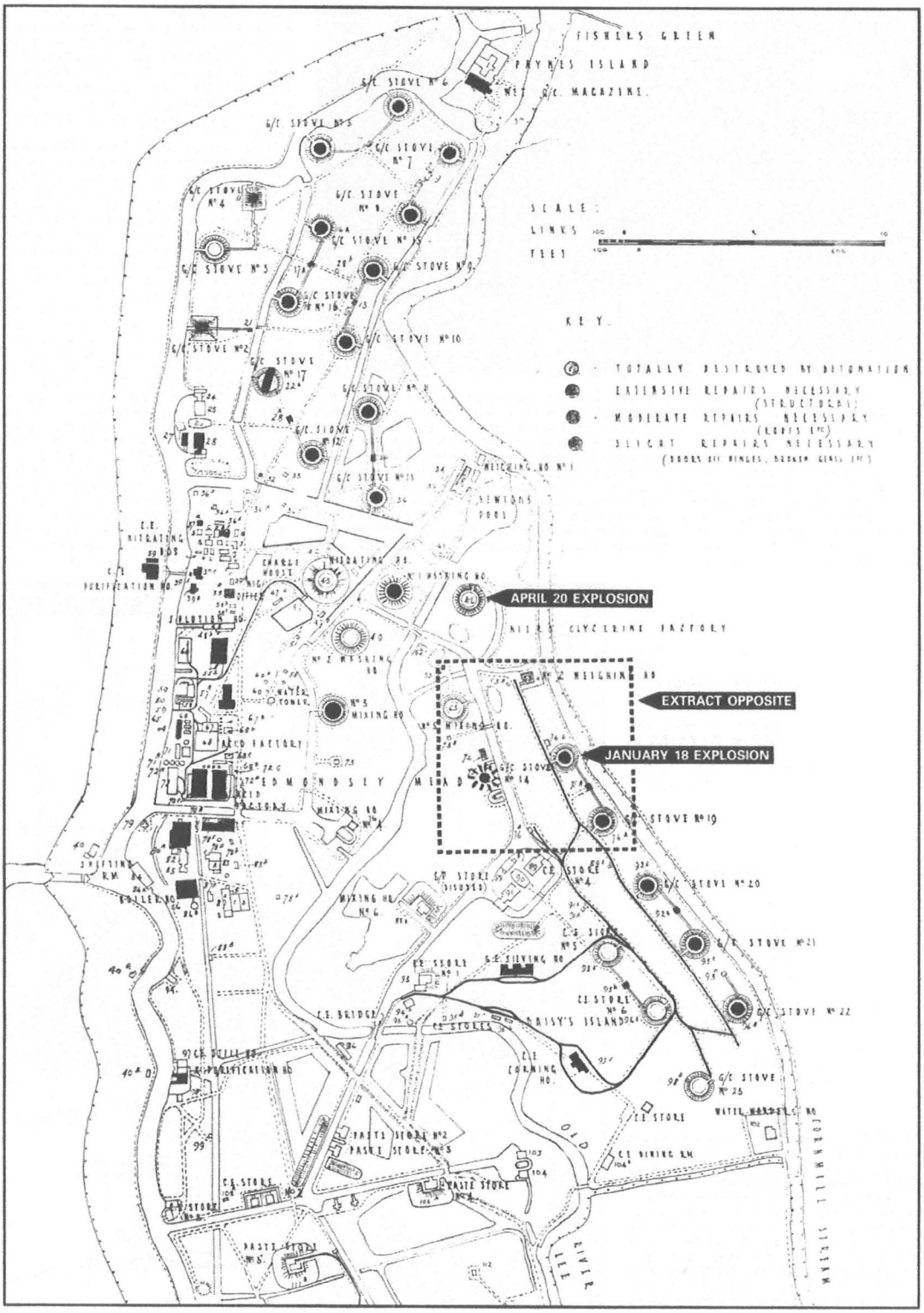
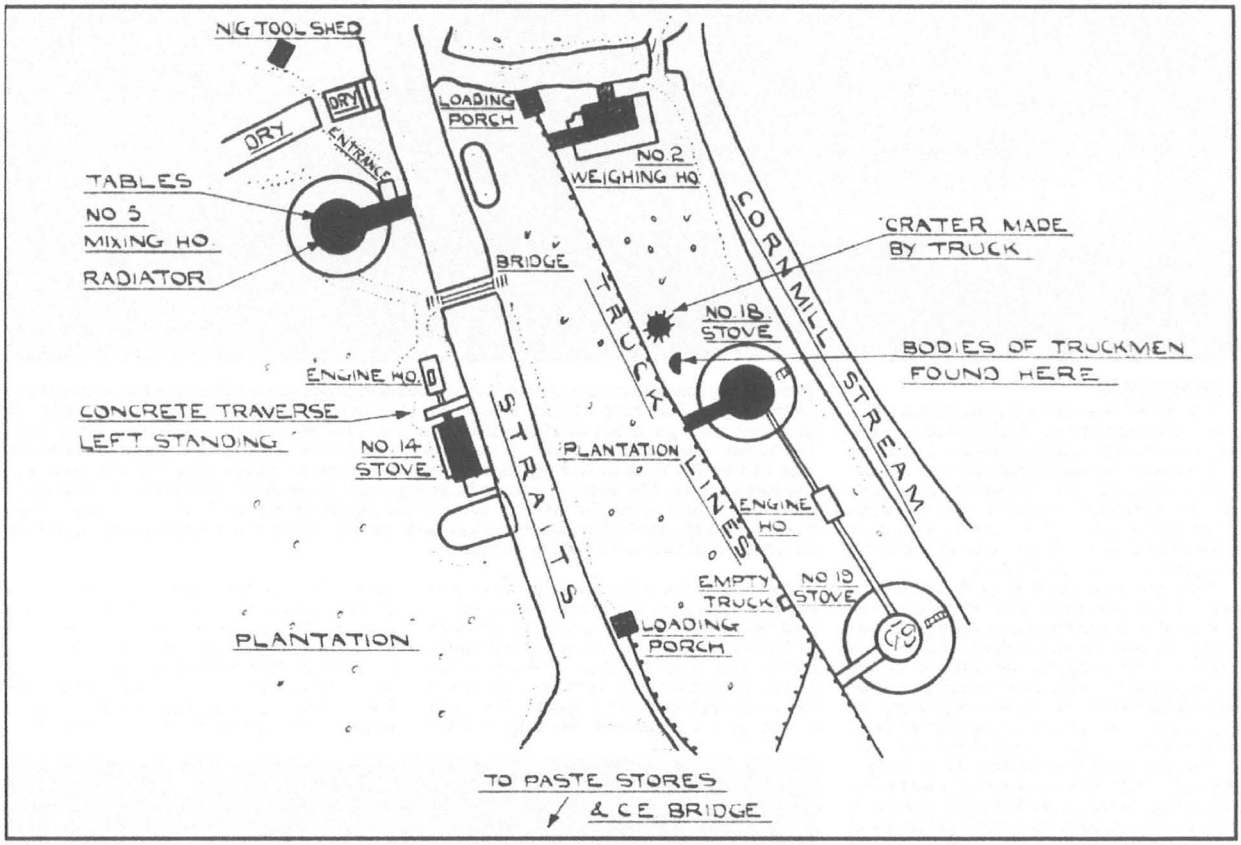
ROYAL GUNPOWDER FACTORY EXPLOSIONS. 1940.



The explosions which are described in this article took place on North Site where nitro-glycerine was manufactured.

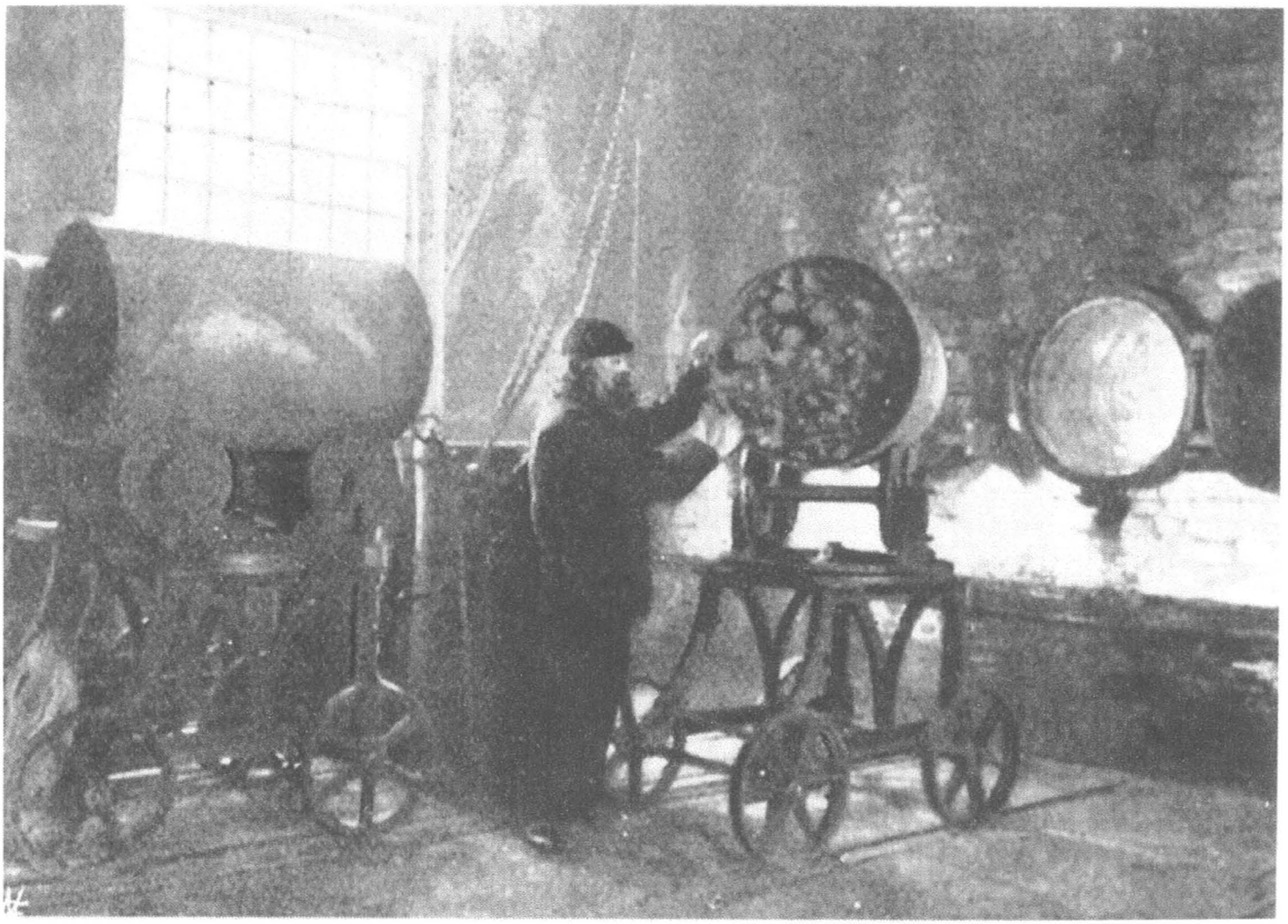
ROYAL GUNPOWDER FACTORY EXPLOSIONS.
1940.



ROYAL GUNPOWDER FACTORY.

CHARCOAL.

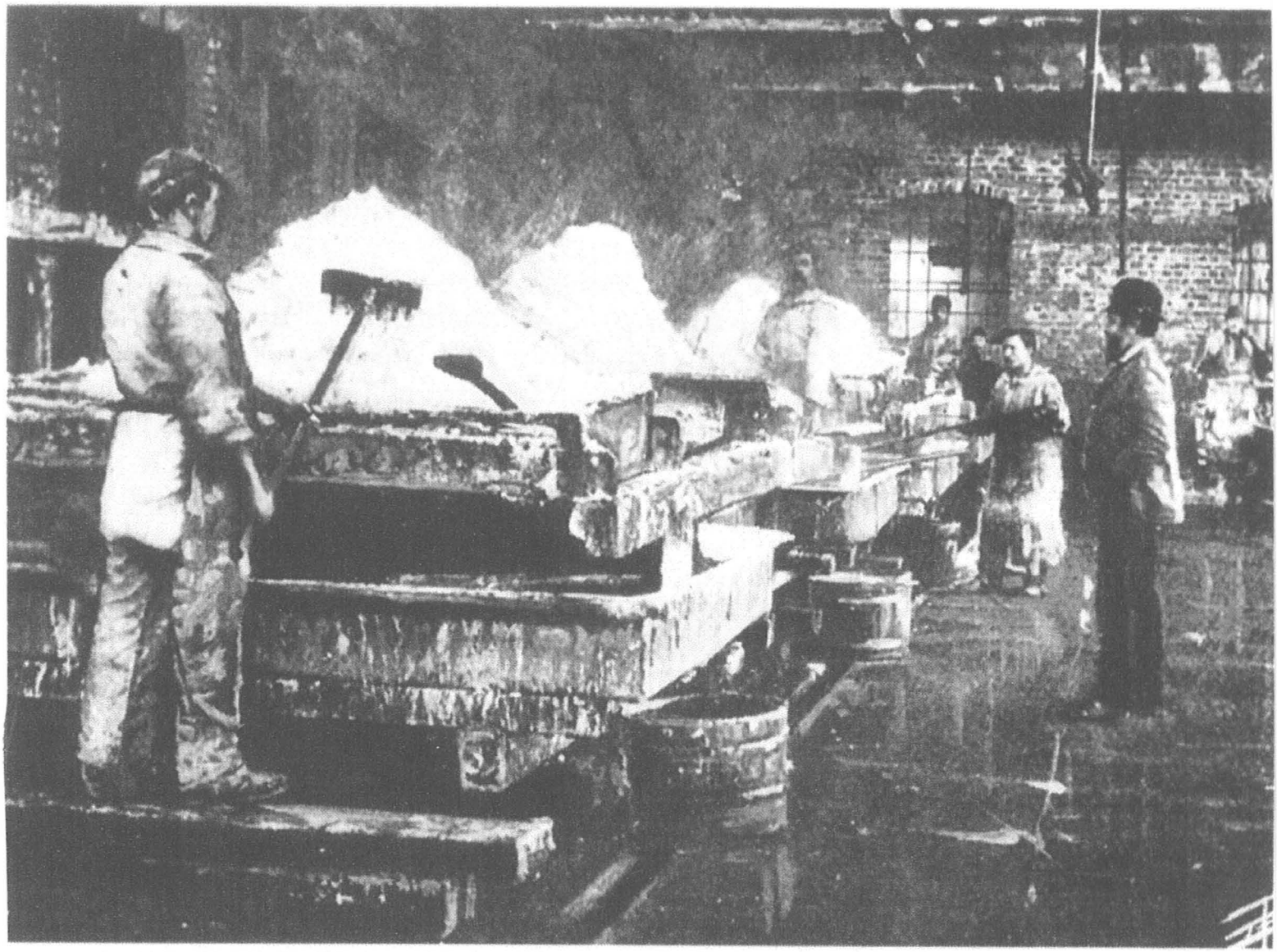
Making cylinder charcoal in 1895. The charring of wood in airtight cylinders, from which the by-products of combustion were extracted, was developed for the government factories in the late eighteenth century by Richard Watson, Professor of Chemistry at Cambridge.



ROYAL GUNPOWDER FACTORY.

SALTPETRE REFINERY 1895.

The saltpetre refinery. 'Grough' saltpetre was dissolved in water in 500 gallon coppers, boiled, skimmed and run through filter bags into the cooling vessels shown here. The solution was agitated as it cooled so that small pure crystals formed. These are being raked out on to drainers before being transferred to washing vats. The liquors produced at each stage were retained and recycled.



ROYAL GUNPOWDER FACTORY.

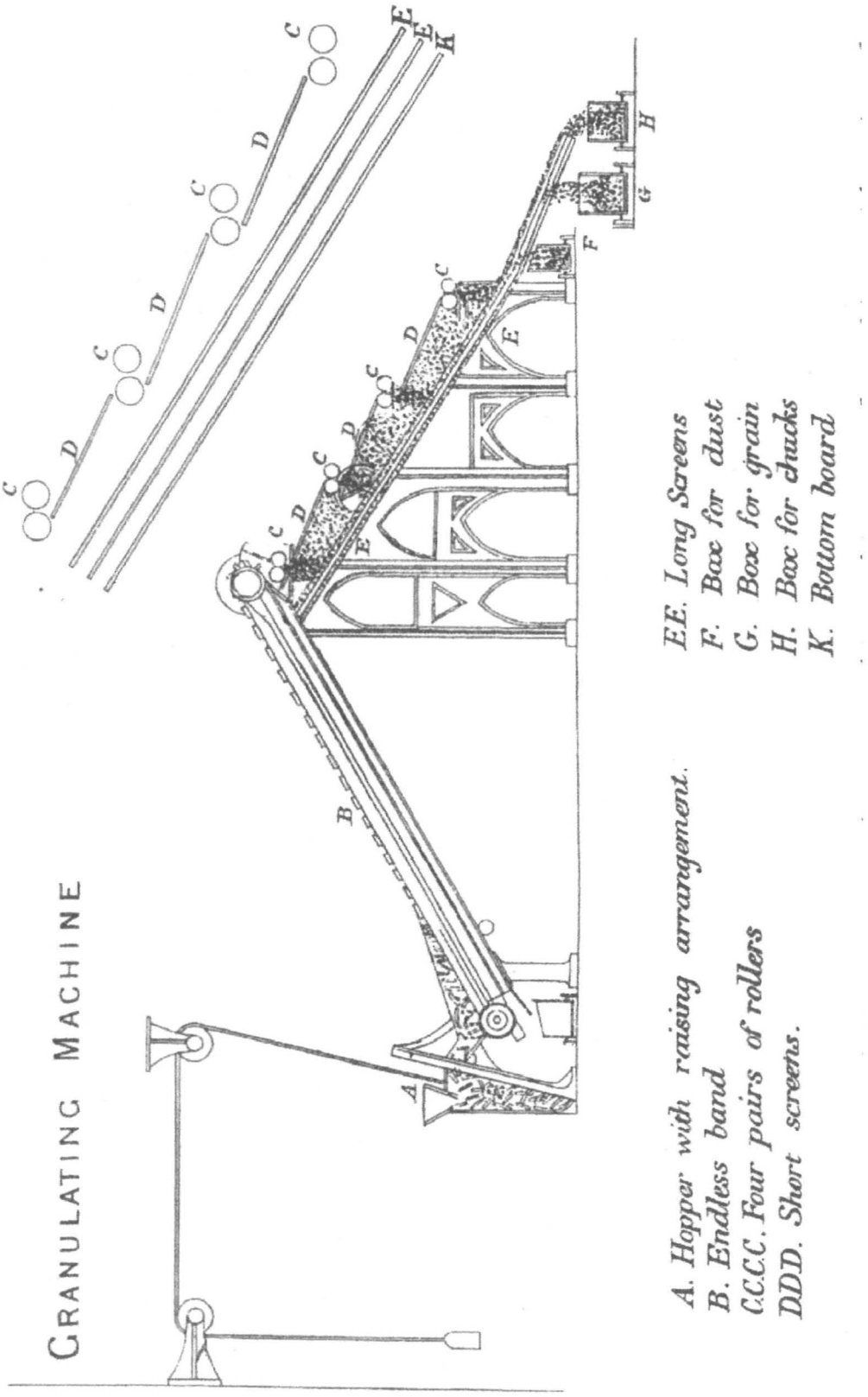
GLAZING MACHINE.

Glazing barrels at Waltham Abbey, late nineteenth century. The barrels were 5-feet long, and each held 400-lbs., of powder. Some types of powder were tumbled for three or four hours at 34 revolutions per minute. Black lead was added towards the end of the process to coat the grains and make them moisture resistant.

ROYAL GUNPOWDER FACTORY.

GRANULATING MACHINE.

A nineteenth-century granulating machine. This type of machine, with pairs of toothed gunmetal rollers, was designed by William Congreve the younger in 1815. Press cake was cut and automatically sorted into grain, dust and chucks, which went through the process again.



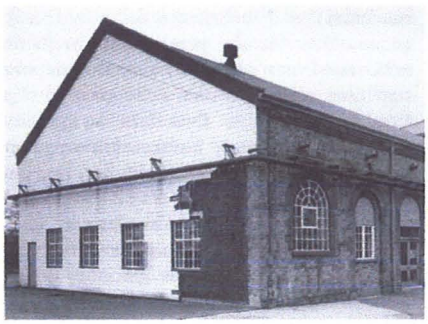
ROYAL GUNPOWDER FACTORY.

SULPHUR.

Ladling liquid sulphur into wooden tubs from the receiving pot of the distilling plant.
1895.

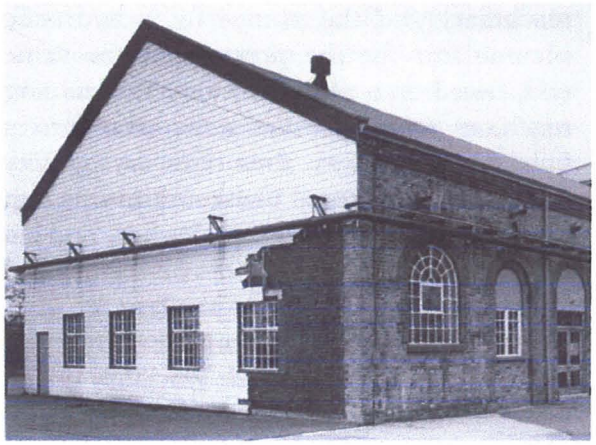
Ladling liquid sulphur into wooden tubs from the receiving pot of the distilling plant at Waltham Abbey, 1895.

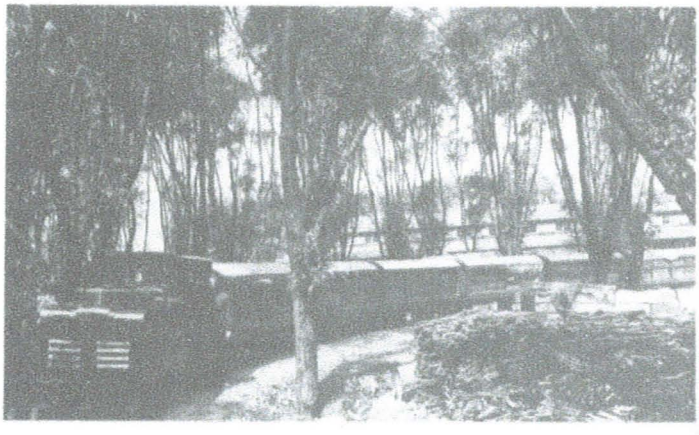
Fig



The buildings were constructed in a

Figure 5.8 (top left) RGPF Waltham Abbey. So





– World War 1

THE ROYAL GUNPOWDER FACTORY WALTHAM ABBEY.
DEVELOPMENT OF CHEMICAL EXPLOSIVES.

Background.

The reign of gunpowder with its three natural material constituents; saltpetre,sulphur and charcoal, as the sole world explosive for military and civil use lasted for around five centuries up to around the last quarter of the 19th century. From this point, over a very short space of time and accelerating at the end of the century, gunpowder was supplanted by the product of the new science of organic chemistry; in the military field by single base nitrocellulose (guncotton) and later the so called smokeless powders such as cordite combining nitrocellilose and nitroglycerine (double base) with civil use dominated by the nitrocellulose and nitroglycerine based materials developed originally by Nobel- dynamite, blasting gelatine and their many derivatives.

GUNCOTTON.

Schonbein had sent samples to Faraday, Herschel and Grove in England describing the material as a dangerous rival to gunpowder.

Grove had already introduced guncotton to the British Association at their meeting in Southhampton in 1846, and Schonbein arrived in August to add to the saleforce. He gave demonstrations at Woolwich, and was received by Queen Victoria and the Prince Consort, to whom he presented the first brace of partridge to be shot using guncotton. So much interest was aroused among gunpowder manufacturers, mining companies and military establishments that the government granted £1,500 to pay for further demonstrations. At that time Cornwall was one of the world's major mining areas, and Schonbein, accompanied by a senior partner from the international mining firm of John Taylor & Sons, went to the Penryn granite quarry to show off the blasting powers of guncotton. The local hard-headed miners were highly sceptical that what looked just like cotton wool could blow anything up. One even offered to sit on top of the borehole when it was fired if rewarded by a pint of beer. But scepticism soon turned to amazement when they saw what the guncotton could do, and they quickly realized that it was indeed far more effective and much cleaner than gunpowder.

Schonbein agreed to pass on the details of how to make the explosive to the Taylor firm and these were revealed for the first time in a patent taken out by John Taylor in October 1846 to cover,

Improvements in the manufacturing of Explosive compounds communicated to me from a certain foreigner residing abroad. The invention consists of the manufacture of an explosive compound applicable to mining purposes, the throwing of projectiles, or otherwise, as a substitute for gunpowder, by treating or combining matters of vegetable origin with acids. The vegetable matter which is found best suited for the purpose of the invention is cotton....

The cotton, after cleaning and drying, had to be immersed in a mixture of 1 part of concentrated nitric acid and 3 parts of concentrated sulphuric acid, at 15-degrees C, for 1 hour. The product was then washed thoroughly until free from acid, pressed as dry as possible and then spread out and warmed to 65 degrees C for final drying.

Taylor signed an agreement with John Hall & Sons, well-established manufacturers of gunpowder at Faversham, giving them the sole rights to operate the process for three years. In return they were to pay one-third of the net profit, with a minimum down payment of £1,000 and the same amount annually. Halls built the first ever factory for making guncotton at Faversham and advertised their new product as being six times more powerful than gunpowder.

It was, alas, soon to show its power, for on 14 July 1847 two buildings in the new factory were completely demolished and 21 people were killed. An eyewitness account was published in The Times.

The roofs of all the buildings within about a quarter of a mile of the explosion are completely stripped of their tiles, and the walls are much shaken. Even in the town of Faversham, fully a mile distance from the scene of the disaster, windows were broken, and the houses otherwise damaged in some instances. On the opposite side of the stream which forms the northern boundry of the Marsh Works is a field of wheat of some extent. The explosion has completely blasted this over a space of about two acres, and the ears, drooping and discoloured, present a scene of desolation in perfect character with the adjoining ruins. The willow-trees which skirt the bank of the stream referred to, indeed, all the trees within about fifty yards of the buildings Nos 3 and 4, are torn up by the roots, and scattered about in all directions.

John Hall & Sons wrote to Schonbein in August.

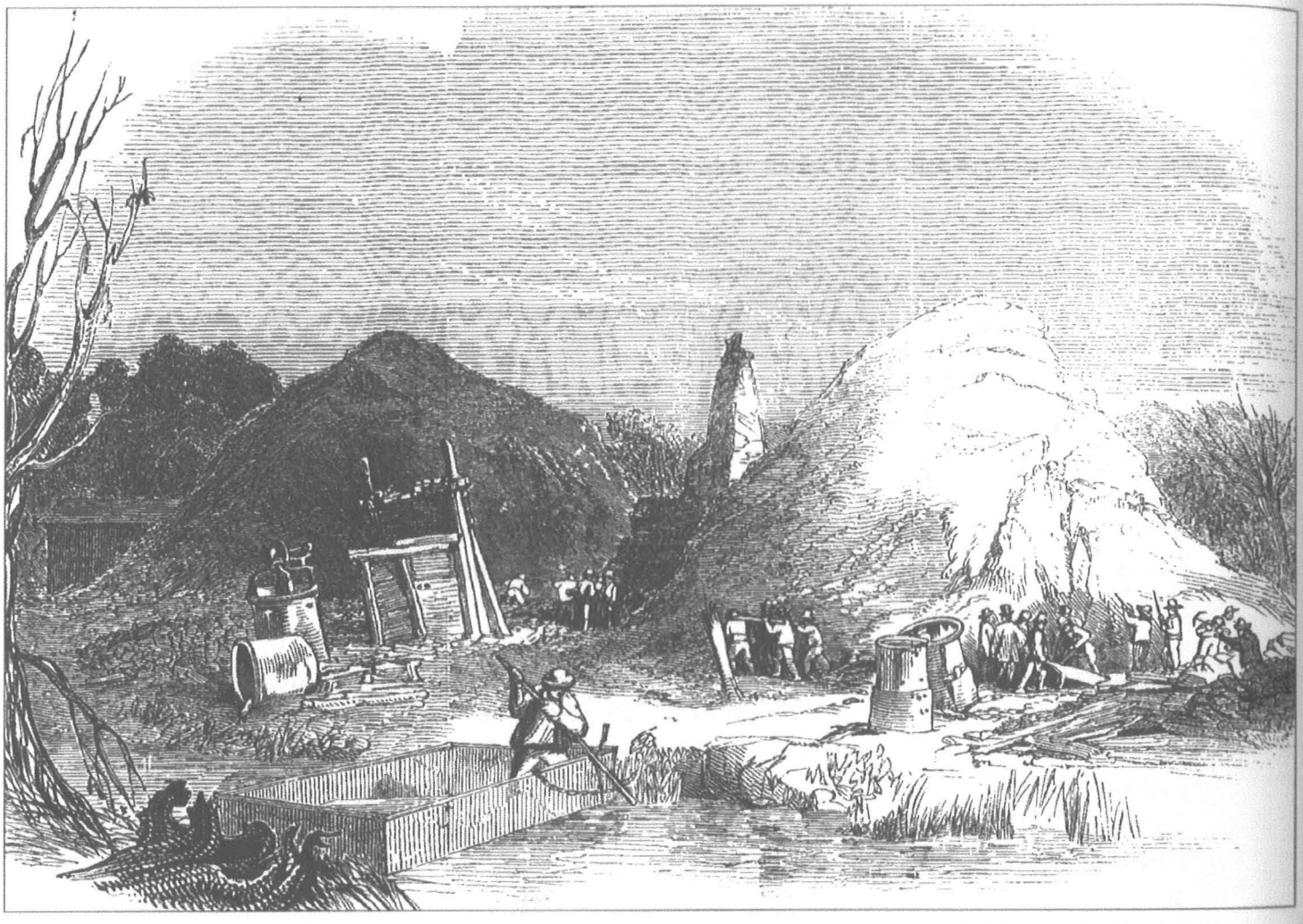
The circumstances attending the late awful explosion of our guncotton establishment and the awful sacrifice of life connected with the destruction of so much property, have so

overwhelmed us with trouble, and difficulty, that we have hardly been able to settle our minds, so as to be able to make any detailed communication to you on the subject...Eighteen persons were killed by that explosion, ten only could be recognised, the remainder were literally blown to atoms and scattered with the materials in every possible direction. One other person who inhaled the fumes of the acid, and who acted incautiously in not attending to medical advice, also died on the evening of the explosion. Of the survivors, fourteen in number, who suffered dreadfully by broken limbs, contusions, and being burnt by the acids, one has since died and we fear one or two more will hardly recover. Some are mained, and we are obliged by principles of sympathy to maintain them, and furnish medical advice and assistance.

There were also some awkward financial details.

The cause of the distaster was never ascertained, and Schonbein had neither the money nor the inclination to start a legal battle but it had not been a very propitious entry for him into the commercial world. He replied to Hall's letter in October, suggesting that the guncotton had been overheated in the drying process and expressing his condolence.

Meanwhile there were other explosions at Vincennes and Le Bouchet, and these events put an end to the manufacture of the material in both England and France for about sixteen years.



The aftermath of the explosion at Hall's Marsh Works in Faversham on 24 July 1847 (From The Illustrated London News, *24 July 1847)*

THE FIRST SMOKELESS POWDER.

Poudre B-Guncotton based-Vielle 1886.

It fell to the Frenchman Vielle to produce the first chemically bases propellant- smokeless powder- guncotton bases, termed Poudre B after the Minister of War General Boulanger, for use in the Lebel rifle. The excessive rate of combustion of guncotton was caused by the porosity of the fibrous material and Vielle discovered that gelatinising with the solvent mixture ether /alcohol rendered it non porous. Guncotton does not completely dissolve in ether/alcohol and Vieille used a mixture of guncotton and collodion gelatinised, working and the resultant paste into small squares of a dry horn like material. Collodion cotton is totally soluble in ether/alcohol. It is of a lower nitrogen content than guncotton- for smokeless powders 11.5-12.7% as opposed to guncotton 13.0-13.5%.

WALTHAM ABBEY GUNPOWDER FACTORY.

NITROGLYCERINE.

The evident superiority of nitroglycerine to gunpowder in explosive power and economy, making it a patently very attractive, and profitable to the supplier, product for the ever expanding construction, mining, quarrying, tunnelling, railway building etc. activities of the 19th century led the Nobel family on a quest to make the material a practicable commercial proposition. By the end of the 1860's Alfred Nobel had produced a safe and effective medium for nitroglycerine in the form of dynamite, later in the mid 1870's combining nitroglycerine and nitrocellulose (guncotton) in blasting gelatine - these developments leading to a huge commercial success worldwide. Nitroglycerine development was therefore driven initially by the civil application. In the late 1880's Nobel produced a military propellant based on nitroglycerine and nitrocellulose, ballistite, and this was followed by the British cordite in 1889. This rapidly replaced gunpowder, creating the need for a governmental nitroglycerine production facility for military purposes and in 1890 a nitroglycerine factory was erected on newly purchased land at Quinton Hill to the south of Waltham centre, the existing powder factory lying to the north.

ALFRED NOBEL.

Alfred Nobel and an early trade mark. (Crown copyright: Royal Commission on the Ancient and Historical Monuments of Scotland)

Alfred Nobel's

NOBEL'S EXPLOSIVES COMPANY LIMITED.

TRADE MARK

GLASGOW

ALFRED NOBEL
(1836-1896).

Swedish inventor of dynamite and founder of the Nobel Peace Prize.

3a ALFRED NOBEL (1836-1896) Swedish inventor of dynamite and founder of the Nobel Peace Prize

SIR FREDERICK ABEL.

Born in 1827 in Woolwich, where he was destined to spend much of his working life. Chief Chemist to the War Office, occupying this position for 34 years.
His two main achievements were, first, the devising in 1863 of an improved method of manufacturing guncotton and, second the invention of Cordite in 1899, in association with Sir James Dewar; Cordite would eventually replace gunpowder as the main propellant explosive. He was knighted in 1883 for his services to military science.

ROYAL GUNPOWDER FACTORY.

AN EXTRACT FROM ABEL'S PATENT APPLICATION, 1865.

A.D. 1865, *20th April.* N° 1102.

Preparing Gun Cotton.

LETTERS PATENT to Frederick Augustus Abel, of the Royal Arsenal, Woolwich, in the County of Kent, for the Invention of "IMPROVEMENTS IN THE PREPARATION AND TREATMENT OF GUN COTTON."

Sealed the 13th October 1865, and dated the 20th April 1865.

PROVISIONAL SPECIFICATION left by the said Frederick Augustus Abel at the Office of the Commissioners of Patents, with his Petition, on the 20th April 1865.

I, FREDERICK AUGUSTUS ABEL, of the Royal Arsenal, Woolwich, in the County of Kent, do hereby declare the nature of the said Invention for "IMPROVEMENTS IN THE PREPARATION AND TREATMENT OF GUN COTTON," to be as follows:—

My Invention has reference to the explosive compound known as gun cotton. Such compound has heretofore been employed either in a loose, fibrous, or woolly state, or of late it has been spun into the form of rovings, yarn, or thread, and has then been formed into cartridges, either by winding, braiding, or weaving.

Now my Invention has for its object to assimilate the physical condition of gun cotton as nearly as possible to that of gunpowder, by mechanically converting it into a solid homogeneous state, and imparting to it either a granular or other suitable form that will present the exact amount of surface and compactness required for obtaining a certain rapidity or intensity of combustion.

The method of treating the gun cotton which I prefer to employ in carrying

An extract from Abel's patent application, 1865. (The Patent Office)

THE ROYAL GUNPOWDER FACTORY.

Gunpowder had been made in Waltham Abbey since the 17th century, first as a private venture, then from 1787 as a government establishment. It became the Royal Gunpowder Factory in 1832. From that time until 1934 the Superindent was always a Military man, usually from the Royal Artillery, carrying the rank of Major, Captain, or Colonel.

GENERAL W.H.NOBLE.

He was Superintendant of the Gunpowder Mills from 1885 to 1892.

THRIFT HALL.

This was the home of General WH Noble RA
Situated on the Sewardstone Road.

Memorial to Major General William Henry Noble
Royal Artillery.
Superintendant of the Royal Gunpowder Factory.
Born 14th October 1834-Died 17th May 1892.

Erected as a mark of esteem by the members of the Royal Gunpowder Factory of which he was Suprintendant from July 1885 until his death.

Grave and Memorial in Waltham Abbey Cemetery.

Memorial to Major General William Henry Noble
Royal Artillery.
Superintendant of the Royal Gunpowder Factory.

COL SIR FREDERIC NATHAN.
Superintendent RGPF 1900-1909.

ROYAL GUNPOWDER FACTORY.

The first decade of the 20th century saw the introduction, under the direction of Colonel Sir Frederic Natham, of a number of significant advances in the processing of guncotton and cordite, including the solvent recovery process for the recovery of acetone from the stoving of cordite, the acid concentration process for waste acid, the redesign of the nitration process in the manufacture of NG and the displacement process for the manufacture of guncotton. A plant was also set up for the small scale manufacture of tetryl, a booster explosive.

The benifits of these advances were very much in evidence during the early years of the First World War when the Royal Gunpowder Factory remained the only Government manufacturing site. Both production and employment mounted and by 1917 the workforce was over 5,000, half of whom were women. A special bus service was introduced to bring the women workers from the railway stations and from outlying districts in Essex. For two and a half years the RGPF was operating on a "round the clock" basis seven days a week.

Eventually other Factories were set up elsewhere and not only did Waltham Abbey provide essential training for explosives workers elsewhere but many of the RGPF staff were transferred to supervise the new operations.

WALTHAM ABBEY

POWDER &

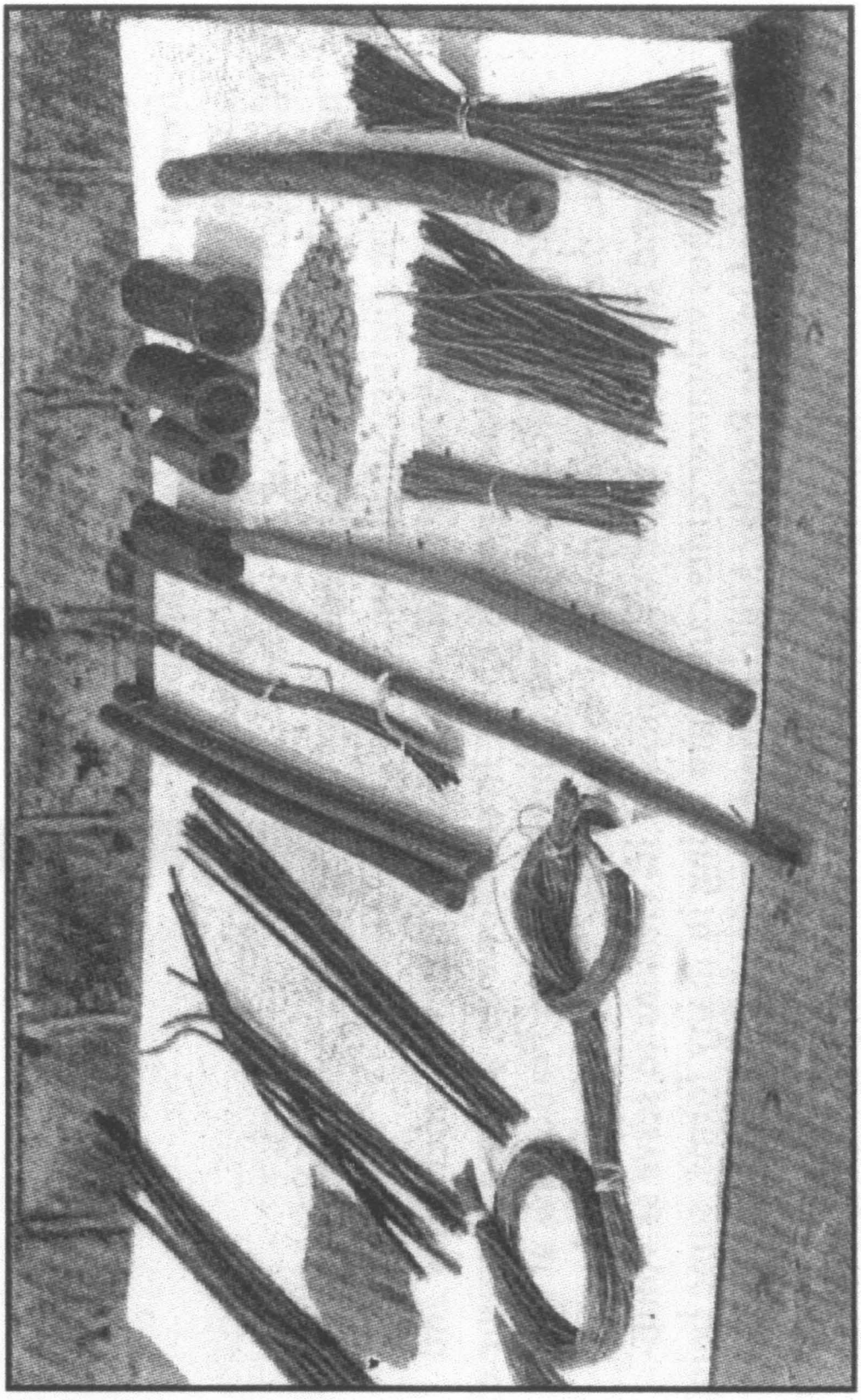
CORDITE FACTORY

1899.

ROYAL GUNPOWDER FACTORY.

A brown, cord-like substance, having as its base nitro-glycerine and guncotton, forced into a mixture by the addition of acetone it was drawn out in a variety of sizes and shapes.

In the illustration, a number of these can be seen, from .01-inch in diameter, for use in pistol cartridges, up to the .5-inch rope used for the charge of the 12-inch breech loading wire-wound naval gun. All components for the production of the cordite, with the exception of acetone, were manufactured within the factory.



GUNCOTTON.

ROYAL GUNPOWDER FACTORY.

A NEW GUNCOTTON FACTORY.

By the 1880s the demand for guncotton prompted the decision to erect a new purpose-built factory at Waltham Abbey, and in 1885 a site covering 100 acres was purchased on Quinton Hill Farm, south of the original works. The factory was laid out with the intention of bringing the whole manufacturing process into a single complex of up-to-date buildings.

Within, there was a clear production flow from east to west, the process employed differing only slightly from the Stowmarket. Contemporary photographs indicate at least five boilers in the factory to provide steam for heating and power for the teasing, pulping, and potching machines, the blending tanks, and the pumps for the hydraulic accumulator. They may also have supplied electricity for lighting. Though an acid separating house was part of the new factory, it remained reliant on outside suppliers for acids and the recycling of waste products.

The buildings were constructed in a similar style to the other buildings in the factory in buff-coloured stock bricks with red facings and cast iron window frames. The roofs were of light metal construction, slated and partly glazed, with vents over the acid-handling sections. There, the floors were paved in blue acid-resistant bricks; elsewhere the floors were concrete. The principle elements of the factory comprised a two-storey building used as a machinery store and for teasing the cotton, an occupation reserved for nine women (the only women employed in the factory at this date). In the end bays adjacent to this two-storey building were the drying and weighing rooms. Next to this was the long single-storey dipping room where the dipping tanks stood along the dividing wall separating it from the weighing room. Above them, earthenware fume towers, supported by a timber latticework, rose through the roof of the building, though in reality they did little to alleviate the unhealthy atmosphere of this room. The remainder of its interior was covered by shallow cooling tanks to hold the earthenware pots, and the floor sloped gently to carry away acid spills. From the cooling tanks the cotton was taken to be spun in a centrifuge to remove excess acid; it was then rapidly immersed in fresh water before being spun once again in a centrifuge and taken from there to the vat house. In this long single-storey building at the rear of the factory, it was boiled for four or five days in large wooden vats. A covered way linked the vat house to the pulping and moulding rooms. At the eastern end of the building was an engine house to power the machinery and the pumps for a hydraulic accumulator for the presses. At the same end, raised on a platform, were the pulping machines to render the guncotton into a fine slurry. It was then run by gravity through a grit trap, blanket and magnet runs to remove any foreign bodies, and on into the poachers or potchers on the ground floor, where it was agitated in a large volume of water to remove any remaining traces of acids; thence to the presses. Ancillary buildings associated with the factory included a police hut, store, stables, chemical laboratory, shifting room, dining room, and small magazine.

GUNCOTTON PRODUCTION.

ROYAL GUNPOWDER FACTORY.
WHAT IS GUNCOTTON?

Celluloses under the action of strong nitric acid (usually with sulphuric acid as a dehydrating agent) form nitric esters known as nitrocellulose; where cotton is the cellulose the result is guncotton. The term nitrocellulose is strictly a misomer, as the compounds formed by the action of nitric acid on celluloses are nitrates or nitricesters and not nitro bodies. A more accurate term for these compounds would be cellulose nitrates; 'nitrocellulose' is enshrined in historic usage, however.

Nitrocellulose may be referred to as 'soluble' or 'insoluble'. Insoluble nitrocellulose contains more than 12.8% nitrogen and is only soluble to a limited extent in ether-alcohol.By contrast, the lower nitrates are entirely soluble in ether-alcohol.

THE ROYAL GUNPOWDER FACTORY.

COTTON.

Fine cotton waste from the textile factories of the North was carefully hand picked and shredded to remove foreign bodies before being placed in a vast oven. Here it was revolved on racks which passed constantly up and down through the drying area for twenty minutes in a temperature of 180 degrees.

On leaving the oven, packs weighing just over 1-lb. were sent in bins to the nitrating plant where they were allowed to fall into baths of mixed acid.

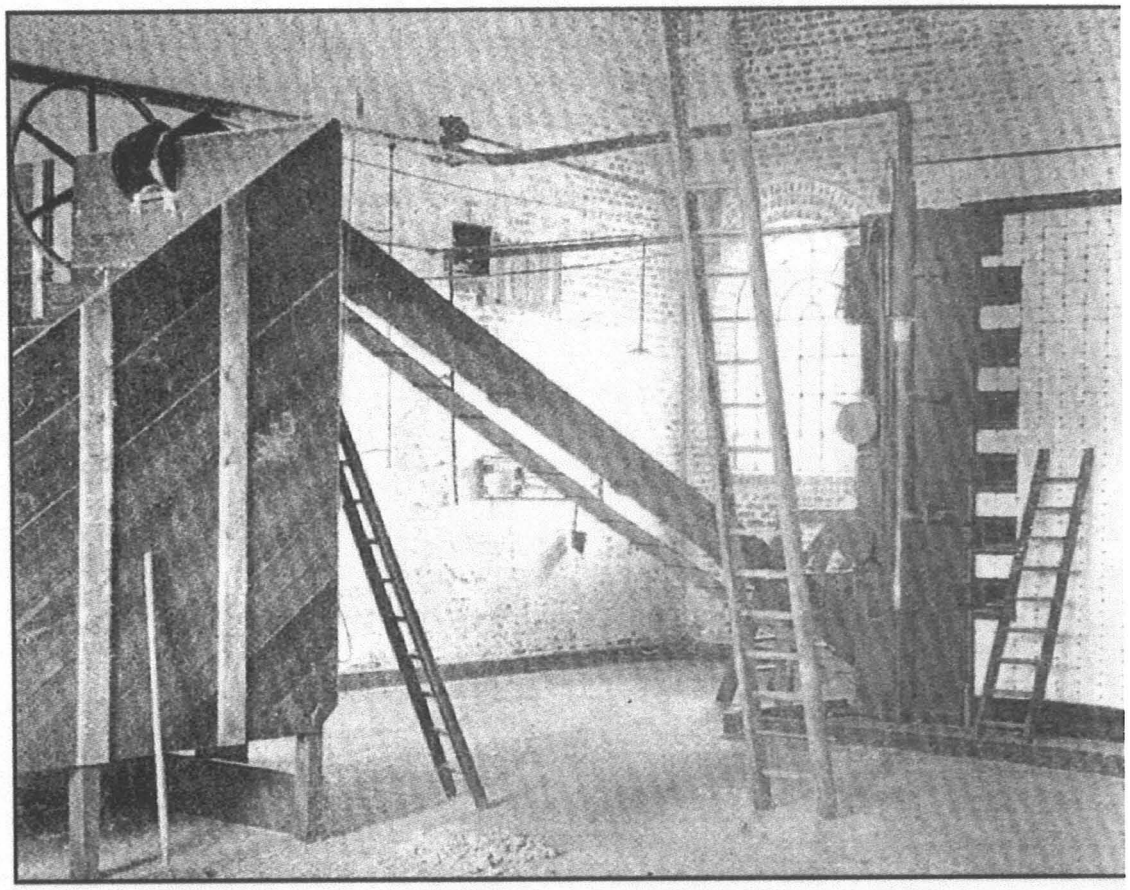
THE ROYAL GUNPOWDER FACTORY.

GUNCOTTON.

Guncotton was produced by the action of nitric and sulphuric acid upon cotton and was in its own right, a powerful explosive.

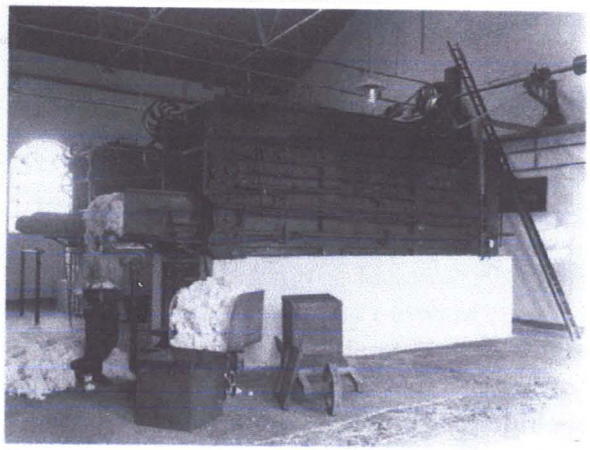
The cotton is picked carefully, in order that fragments of wood, rope, wire, and rag may be removed. The cotton waste is then thrown on to a powerful teasing machine, which rends and tears its fibre; after this it is cut up by another machine, and then it passes on an endless band into a drying-room heated to 180 degrees. The cotton is then weighed up into lots of 1.25-lb., and each lot is placed in a tin cooling box. After twenty-four hours, the lots, or charges, are ready for dipping. Each dipping pan contains 220-lb., of mixed acid - three parts of sulphuric and one of nitric acid.

The operator simply throws the dry cotton into the acid and leaves it there for about five minutes, during which time each charge of 1.25-lb., will have absorbed 13½-lb., of acid.



ROYAL GUNPOWDER FACTORY.

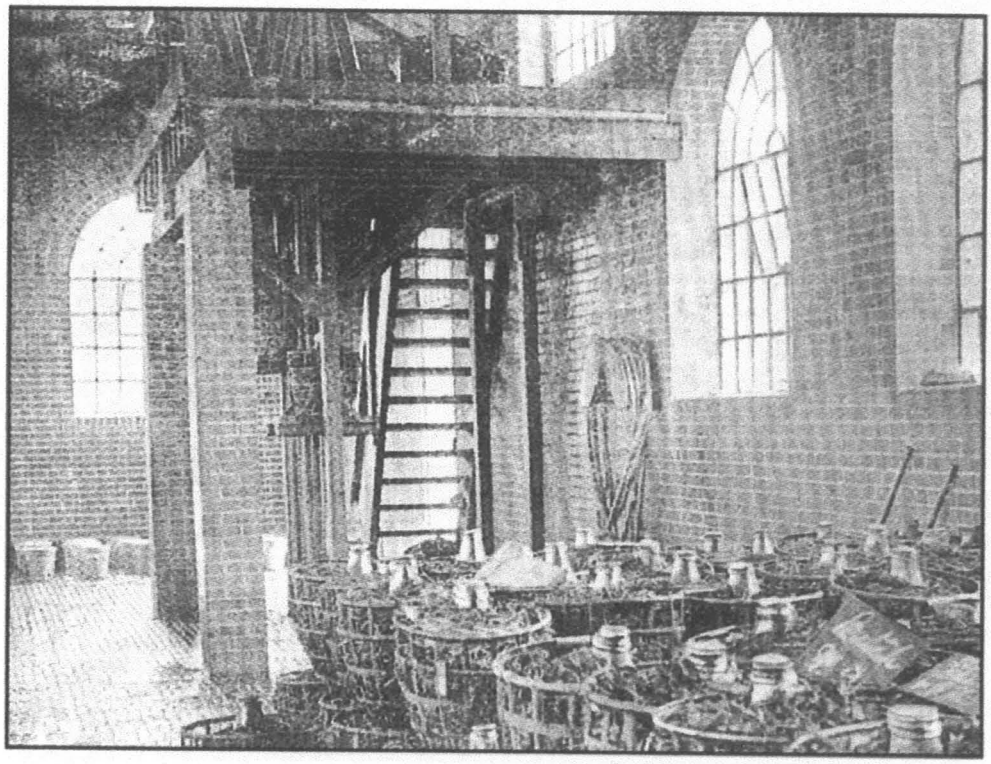
COTTON WASTE DRYING OVEN c 1909.

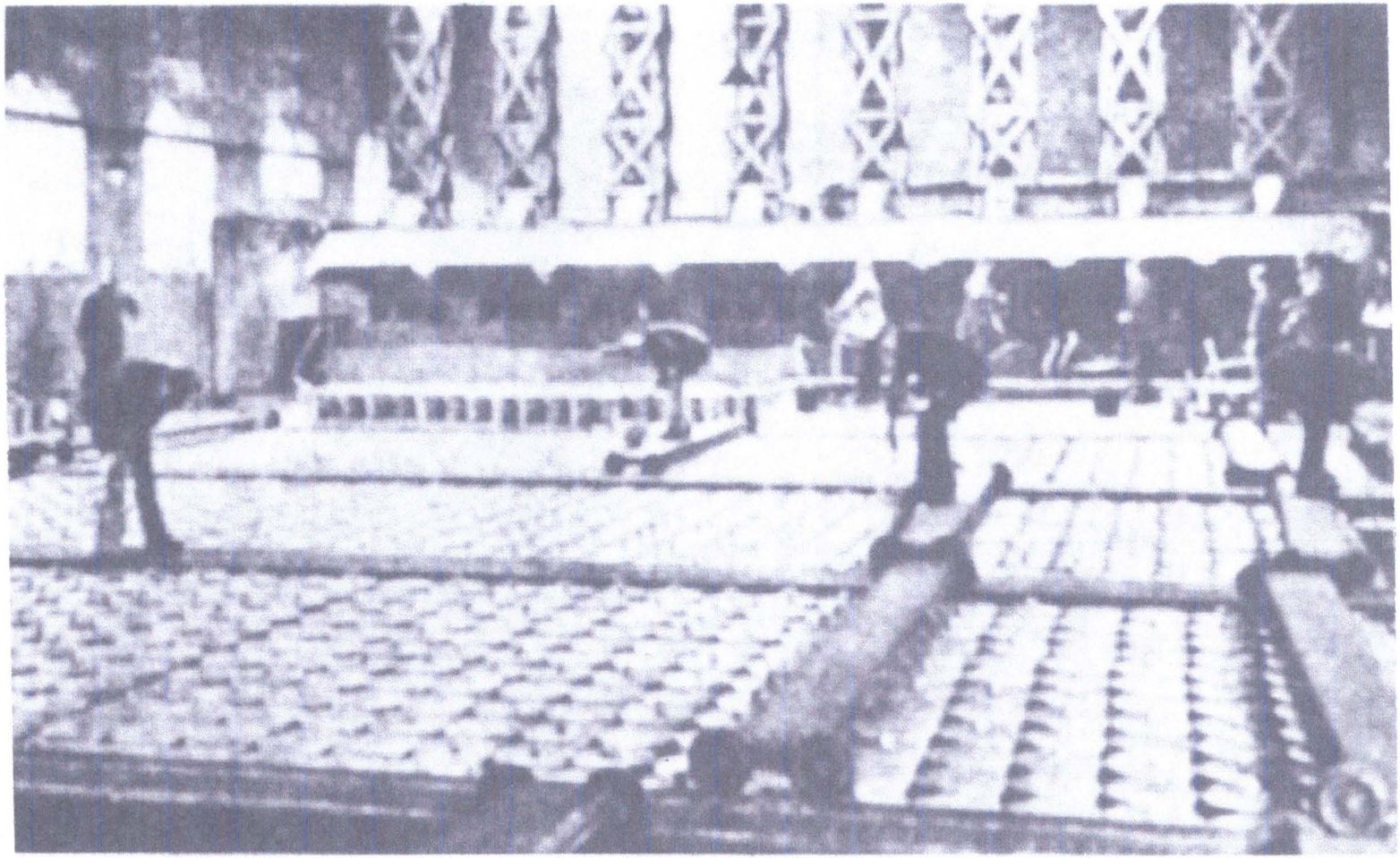


THE ROYAL GUNPOWDER FACTORY.

GUNCOTTON.

To make it, carboys of acid were positioned near to the mixing boilers. Hoisted some 10-feet above ground level, the contents were tipped through a lead conduit, the nitric followed by the sulphuric, both flowing into cylindrical boilers. a jet of compressed air was used to ensure complete and even mixing of the two substances which was then drawn off into baths to receive the raw cotton.



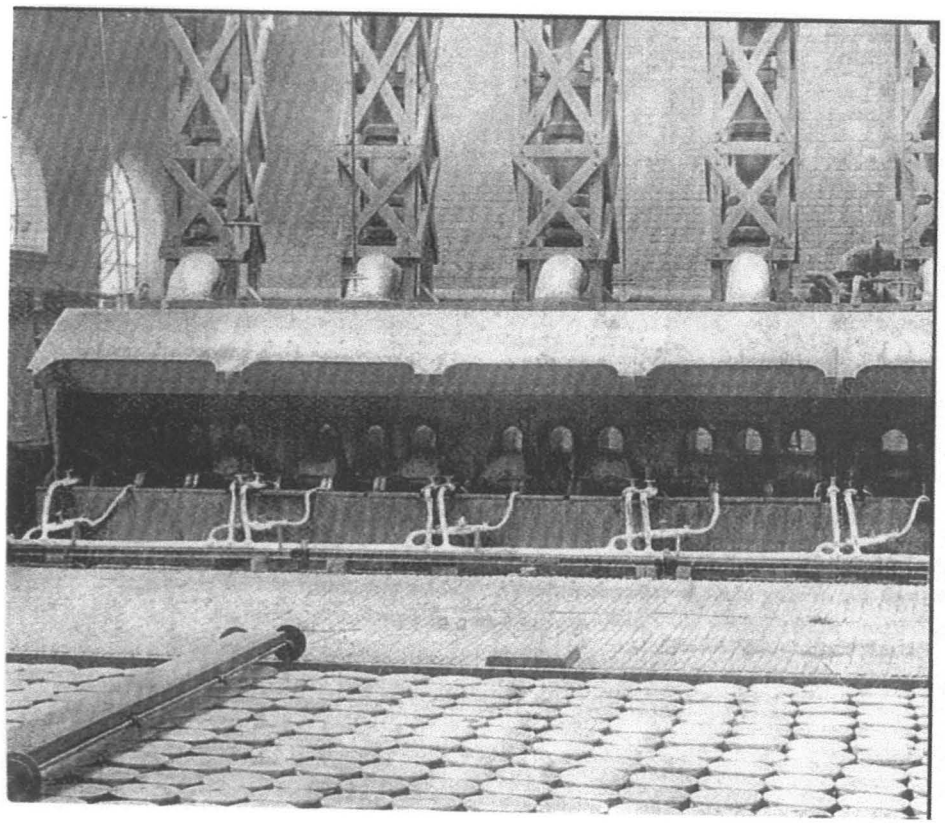


ROYAL GUNPOWDER FACTORY.

DIPPING ROOM 1880s.

Here the dipping tanks stood along the dividing wall separating it from the weighing room. Above them earthenware fume towers, supported by a latticework, rose through the roof of the building, though in reality they did little to alleviate the unhealthy atmosphere of this room.

The remainder of its interior was covered by shallow cooling tanks to hold the earthenware pots, and the floor sloped gently to carry away acid spills.



ROYAL GUNPOWDER FACTORY.

SOUTH SITE.

Interior of dipping room on 1 March 1894 after a minor explosion. Note the earthenware pots in the foreground. The fume towers to the rear were brought down by the explosion.

NITROCELLULOSE.

NITRATING CENTRIFUGAL FOR MAKING NITRO-COTTON.

(Selwig and Lange).

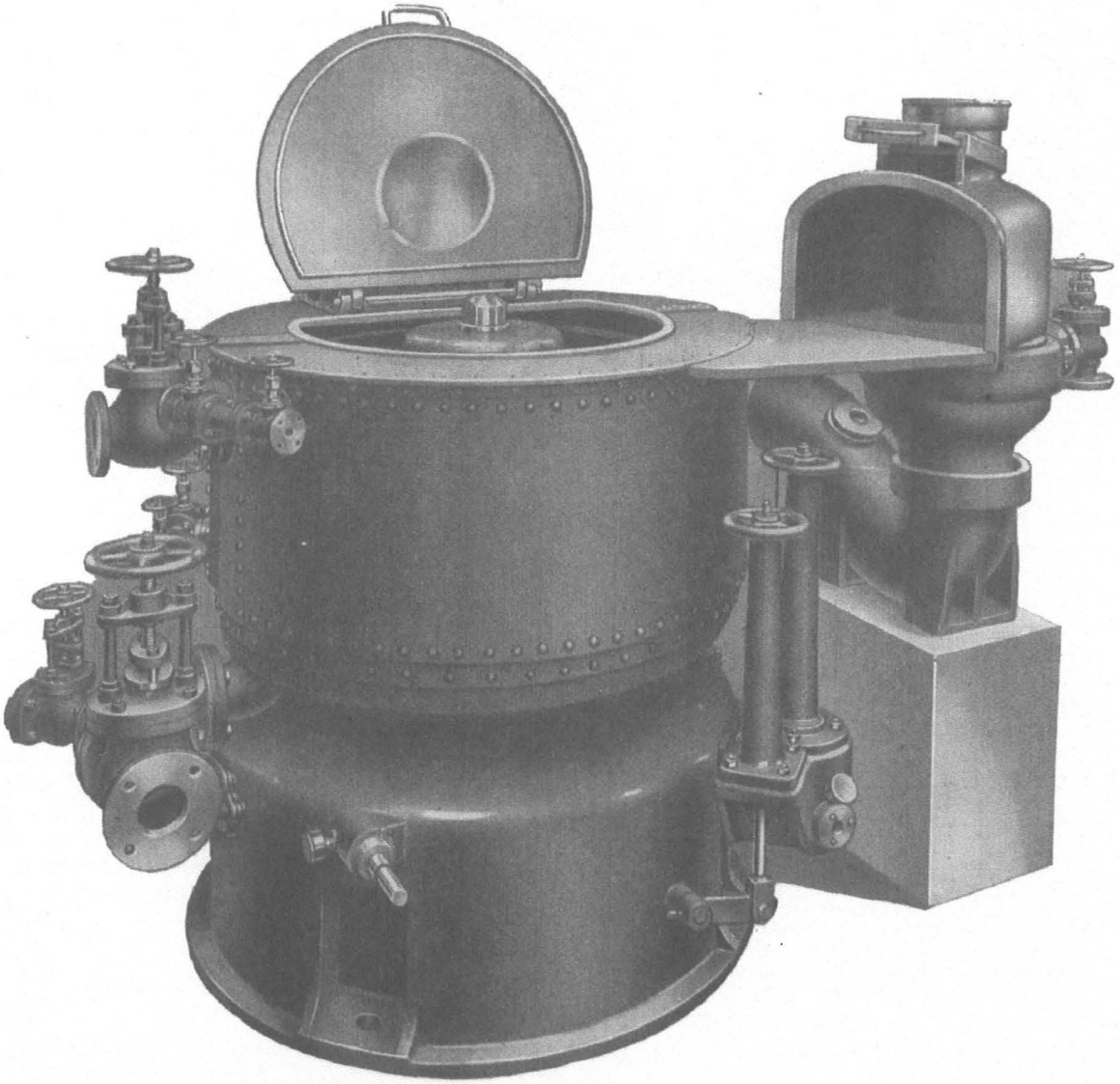


FIG. 2. Nitrating Centrifugal for making Nitro-cotton (Selwig and Lange)

BEATER FOR PULPING GUN-COTTON.

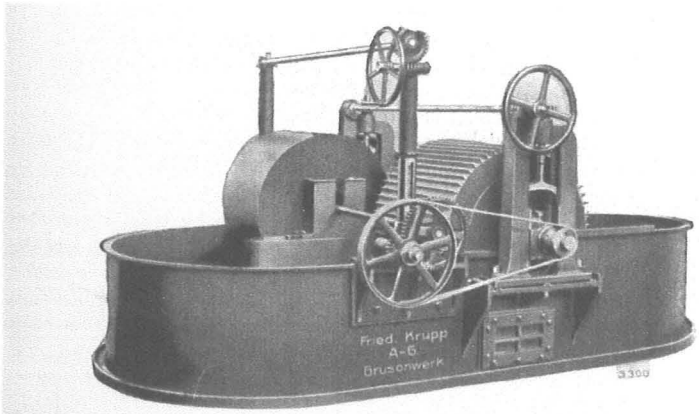


FIG. 5. Beater for Pulping Gun-cotton

ROYAL GUNPOWDER FACTORY.

GUNCOTTON PULPING.

ROYAL GUNPOWDER FACTORY.

PROCESSING GUNCOTTON.

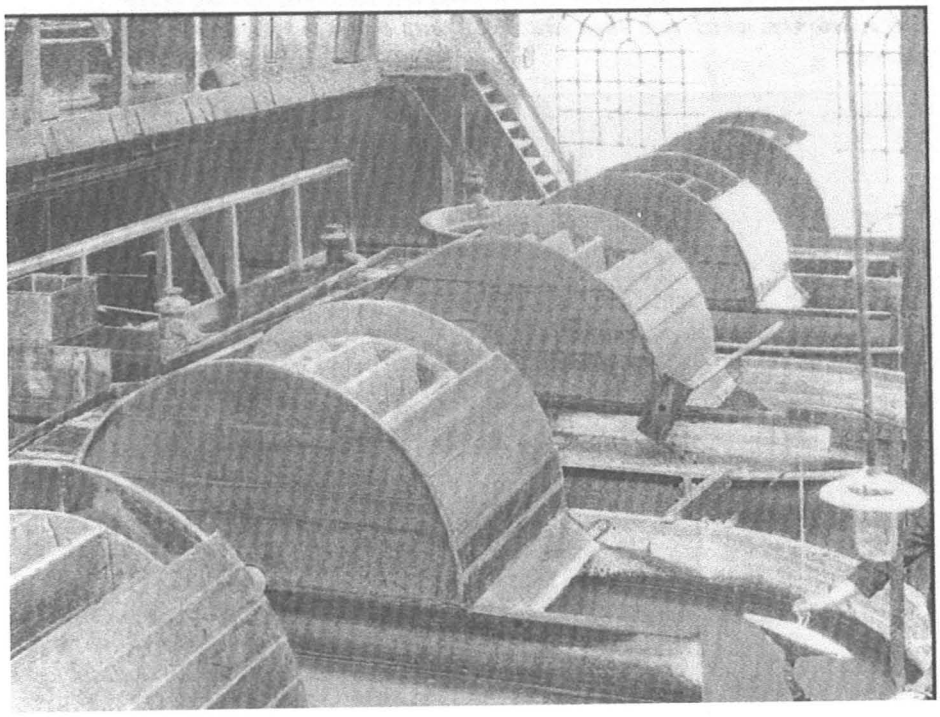
From the cooling tanks the cotton was taken to be spun in a centrifuge to remove excess acid; it was then rapidly immersed in fresh water before being spun again in a centrifuge and taken from there to the vat house.

In this long single-storey building at the rear of the factory, it was boiled for four or five days in large wooden vats. A covered way linked the vat house to the pulping and moulding rooms.

At the eastern end of the building was an engine house to power the machinery and the pumps for a hydraulic accumulator for the for the presses. At the same end, raised on a platform, where the pulping machines to render the guncotton into a fine slurry. It was then run by gravity through a grit trap, blanket and magnet runs to remove any foreign bodies, and on into the poachers or potchers on the ground floor, where it was agitated in a large volume of water to remove any remaining traces of acids, thence to the presses.

ROYAL GUNPOWDER FACTORY.

After boiling the guncotton at this stage differs very little in appearance from the original cotton waste. The fibrous structure is very little affected by the operations of nitrating and boiling. It is next transferred to a beater similar to those used for making paper pulp. This machine consists of an oval trough on one side of which is mounted a drum which rotates on a horizontal axis and carries a large number of knives set radially. In the bottom of the trough there are a number of fixed knives which almost touch the knives on the drum as it rotates, and the guncotton, as it passes together with a large bulk of water between these fixed and moving knives, is cut into short lengths and so is reduced to pulp. The pulp is run through a series of traps which remove grit and other impurities, and between powerful electromagnets which extract particles of iron derived from the knives of the beater or other source. Then the pulp is washed well with several changes of water. Finally the greater part of the water is removed by means of centrifugal machines or special presses, and the guncotton is then ready to be conveyed to another part of the factory where it is converted into the finished explosive.

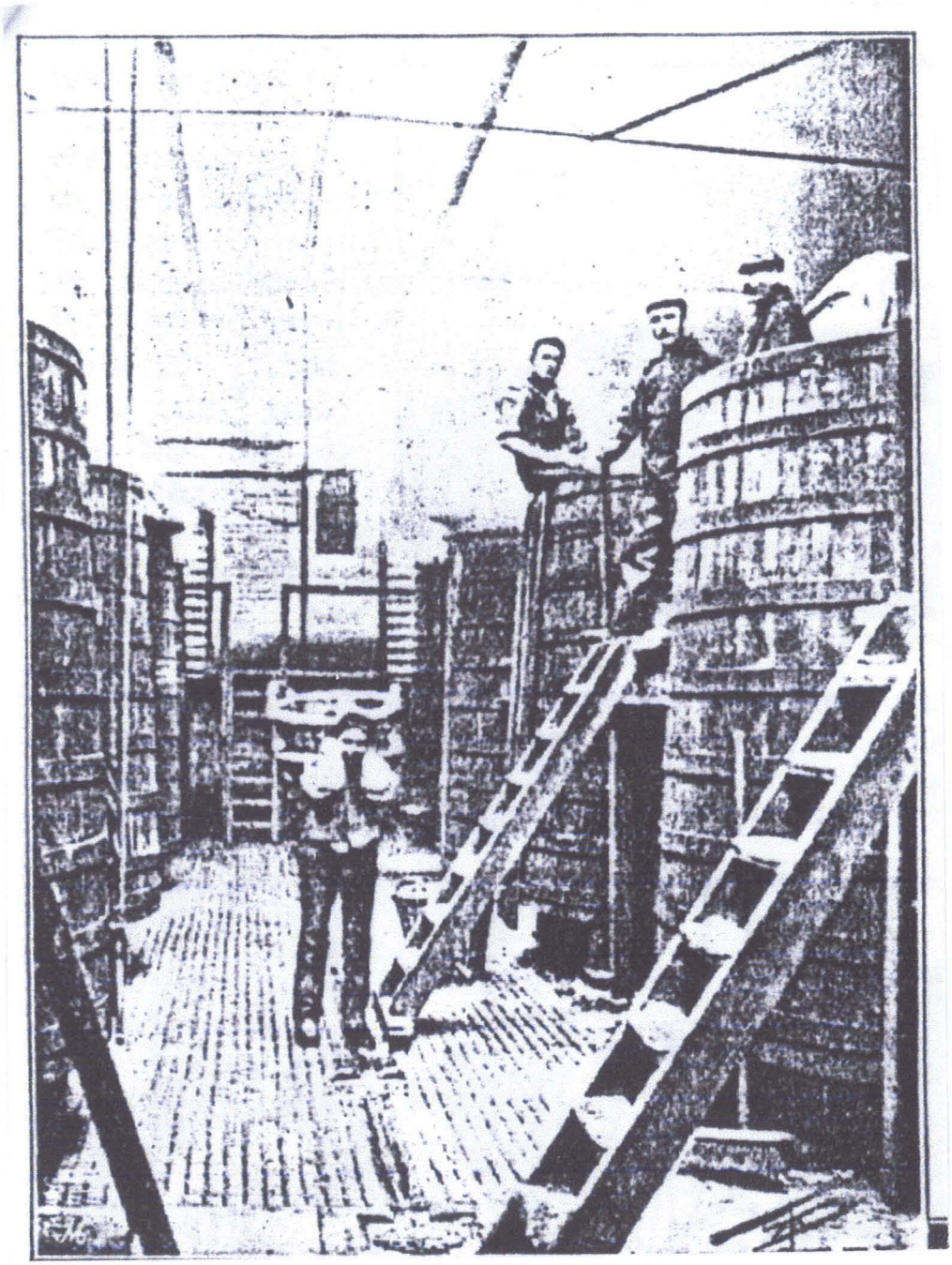


ROYAL GUNPOWDER FACTORY.

BOILING VATS. 1895.

After being spun the cotton is shot into a centrifugal machine, whirling round at a speed of 1,200 revolutions a minute. in a very short time the cotton is comparatively dry, and the waste acid removed by the machine to be reclaimed.

It is then washed in a wooden tank full of water, which is agitated by a revolving bladed wheel. When the foreman thinks the washing is complete, he tastes the cotton, and if no flavour of acid remains, it is taken out and wrung out and then taken to the Vat House, where it is boiled in large vats for 4 or 5 days. Each vat holds about 18_cwt of cotton.



INCORPORATION.

GUNCOTTON AND NITROGLYCERINE.

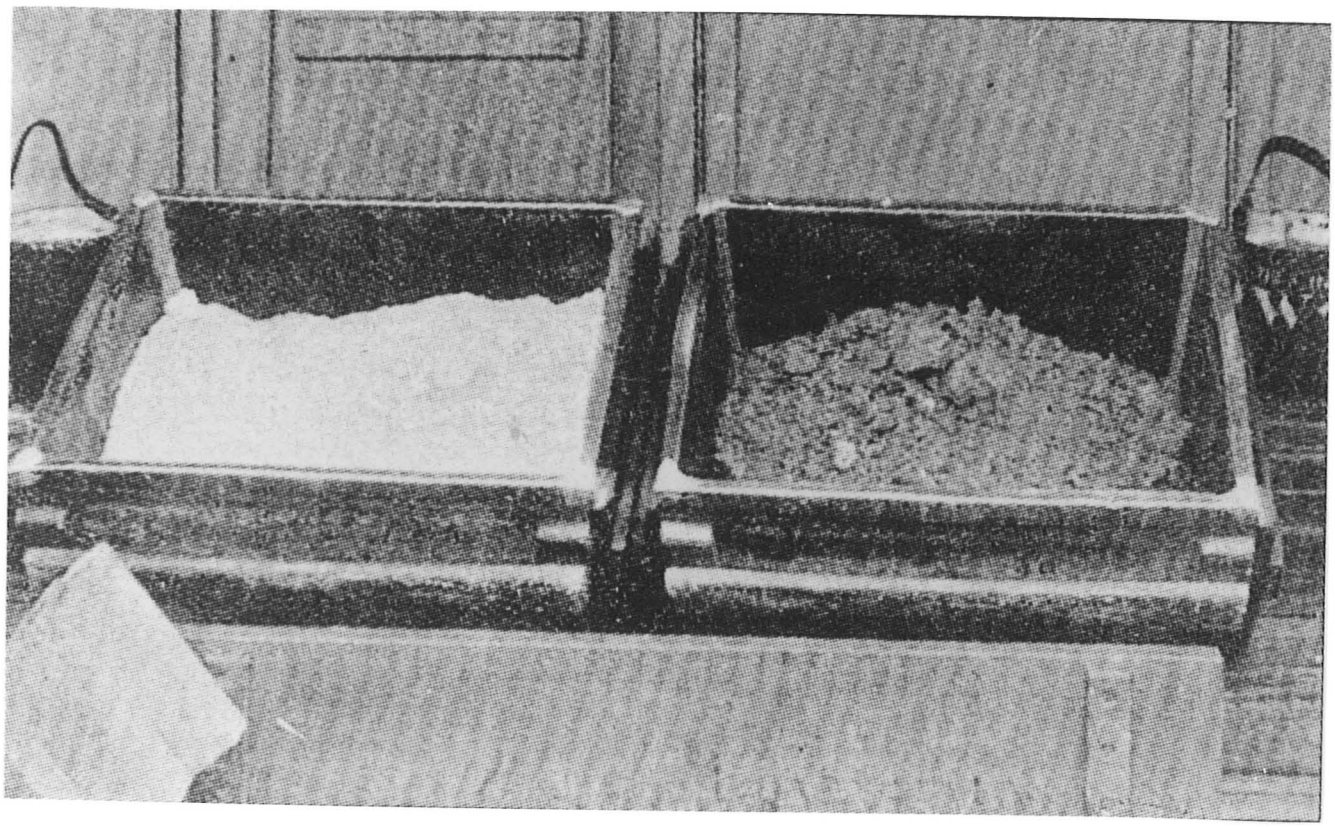
ROYAL GUNPOWDER FACTORY.

HAND MIXING CORDITE DOUGH 1895.

ROYAL GUNPOWDER FACTORY.

INCORPORATION.

Guncotton on the left was mixed wih nitroglycerine to make Cordite.



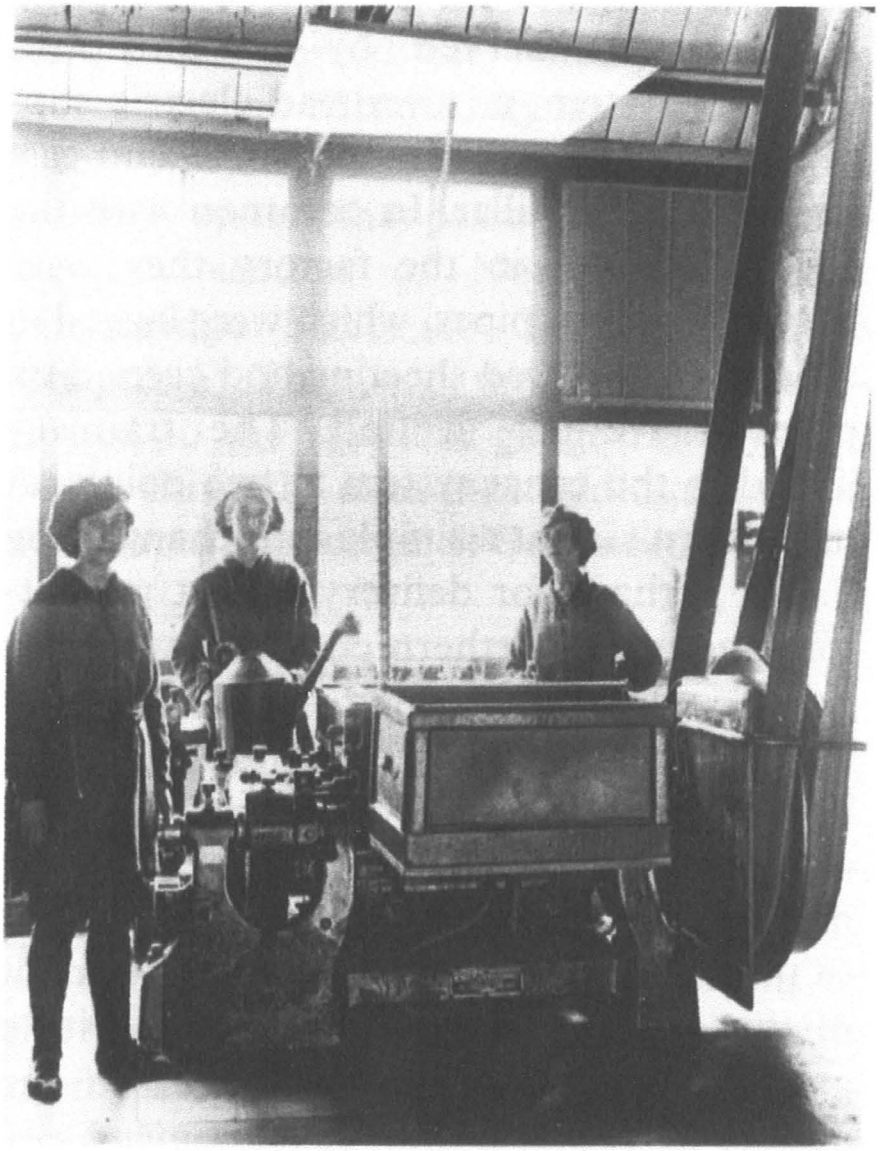
ROYAL GUNPOWDER FACTORY.

INCORPORATION.

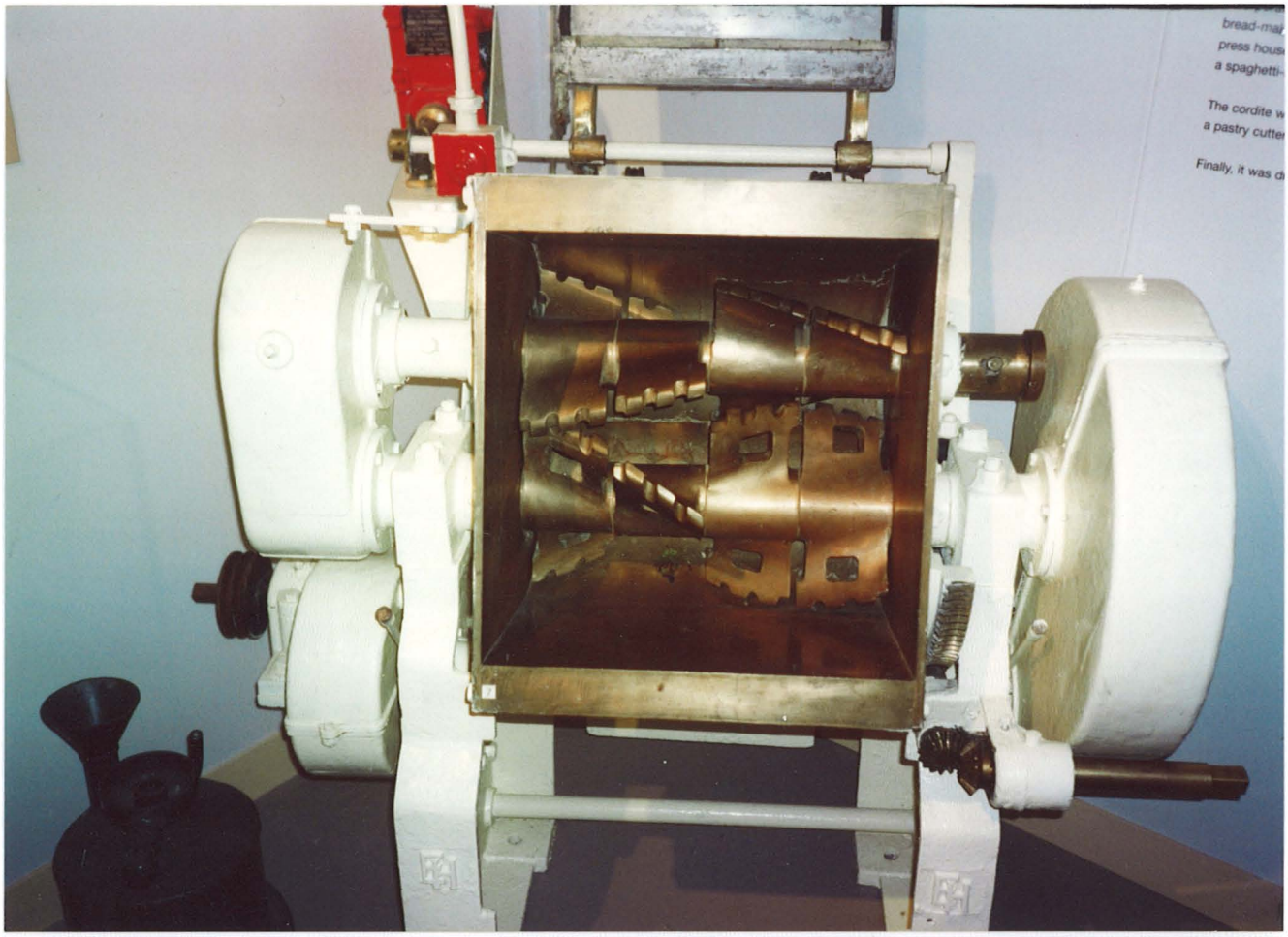
The nitroglycerine part of Cordite was obtained by the action of nitric and sulphuric acid on glycerine, resulting in a heavy, oily fluid, straw-like in colour. Nitroglycerine is exceedingly sensitive to concussion. For ease of handling and to limit possible damage by explosion, relatively small quantities were dealt with in each of the factory buildings. 44-lbs of nitroglycerine was mixed with 28-lbs of guncotton, the resulting compound resembling damp china clay. This was achieved by adding one substance to the other in a machine like a baker's dough mixer, containing a number of spiral knives which cut and mixed the material for 3½-hours. At this point 15-lbs of acetone and 4-lbs of mineral jelly were added and a further three hours of mixing took place.

ROYAL GUNPOWDER FACTORY.

NORTH SITE.
CORDITE INCORPORATING MACHINE.
JULY 1917.

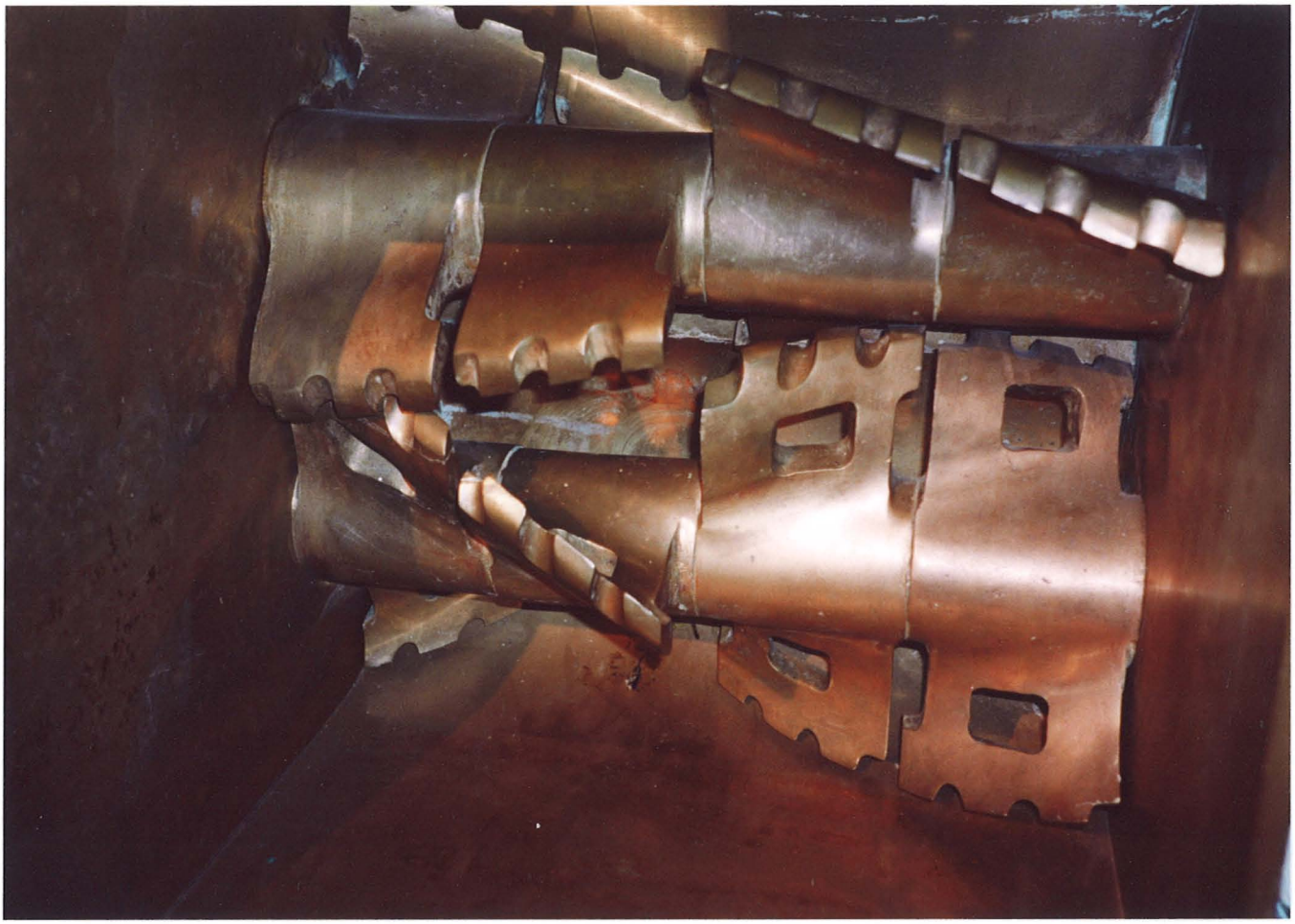


CORDITE INCORPORATING MACHINE.



ROYAL GUNPOWDER FACTORY.

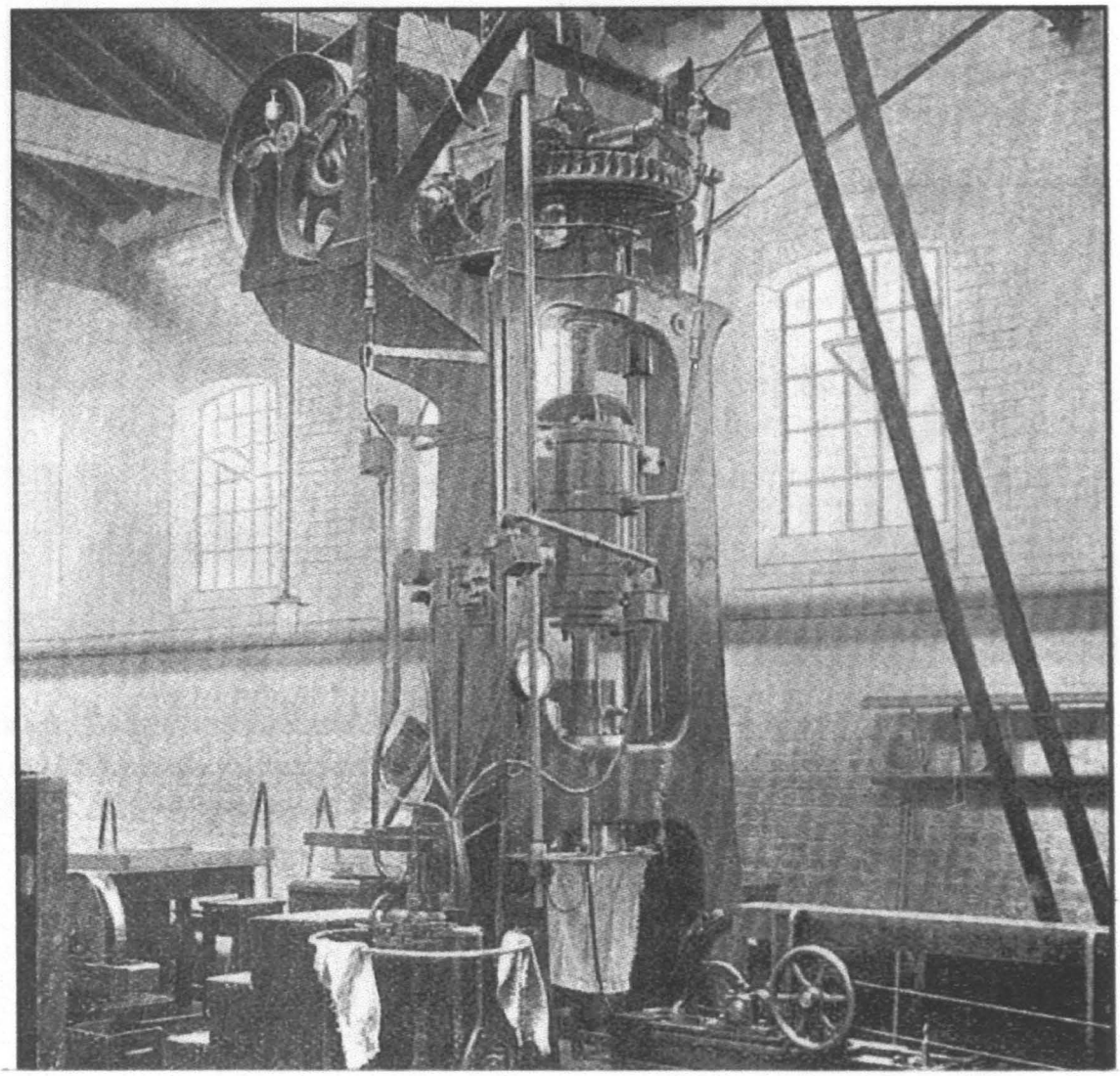
CORDITE INCORPORATING MACHINE
MIXING BLADES.



ROYAL GUNPOWDER FACTORY.

MASSIVE PRESS FOR EXTRUDING CORDITE INTO CORDS.

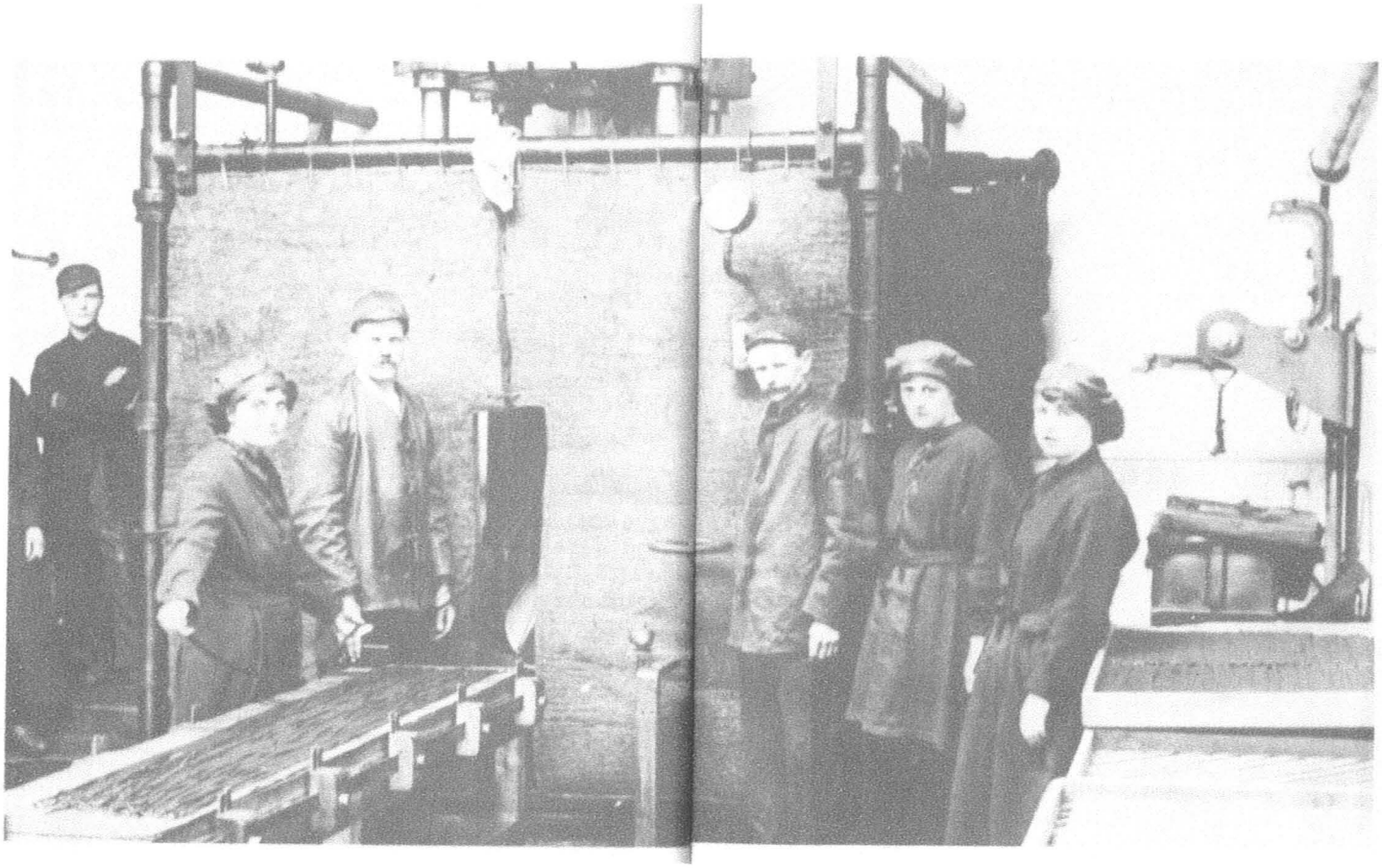
Cordite was taken in lots of 20-lbs weight to the pressing room. Here it was loaded into a cylinder and subjected to hydraulic pressure of 600-lbs per square inch. Escape holes being previously chosen from between .01 to .5 of an inch, the finished cordite was extruded into a grooved block and cut into lengths or wound direct onto drums. In order to remove excess acetone, the cordite was removed to a drying room and exposed to a heat of up to 100 degrees. Half-inch cordite required drying for 15 days, pistol and rifle cordite for 2 days.



ROYAL GUNPOWDER FACTORY.

CORDITE PRESS.

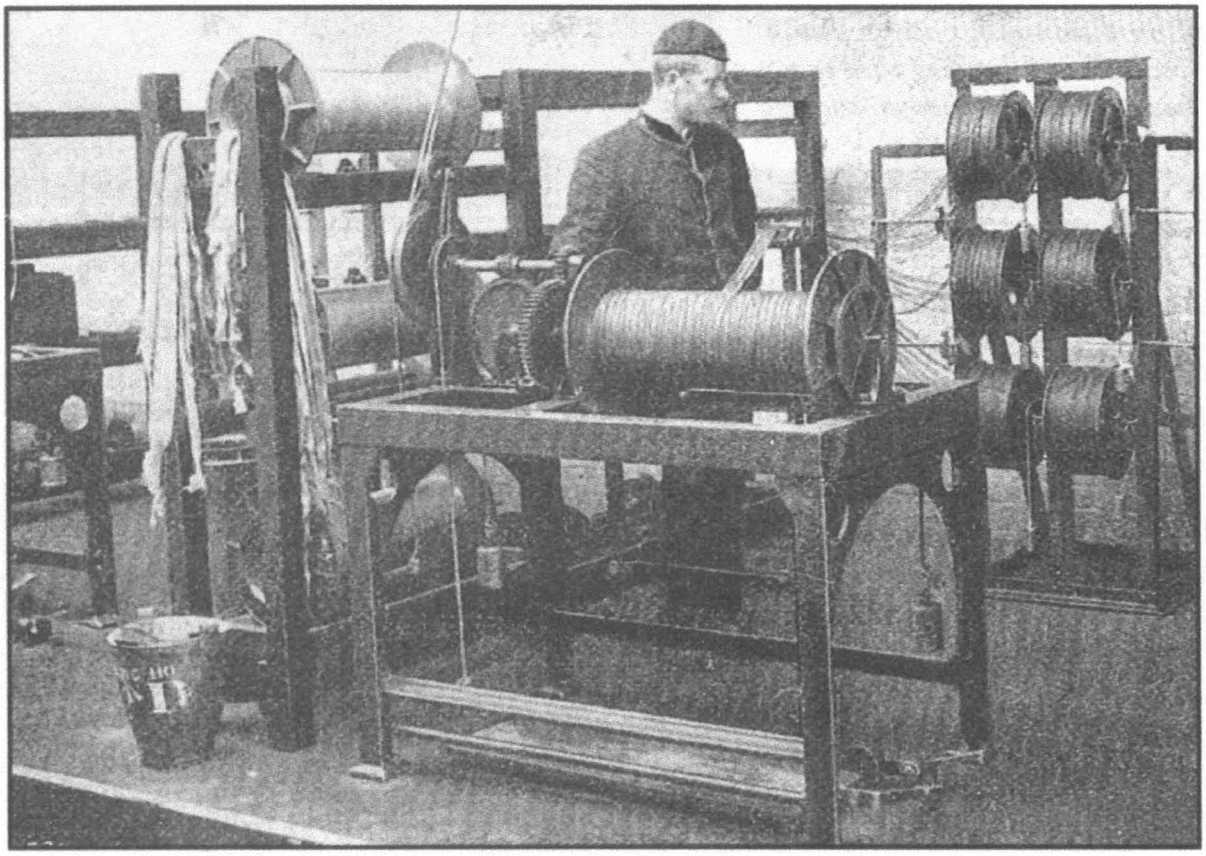
Note lengths of cordite on the tray. Probably for artillery cartridges.



ROYAL GUNPOWDER FACTORY.

CORDITE REELING.

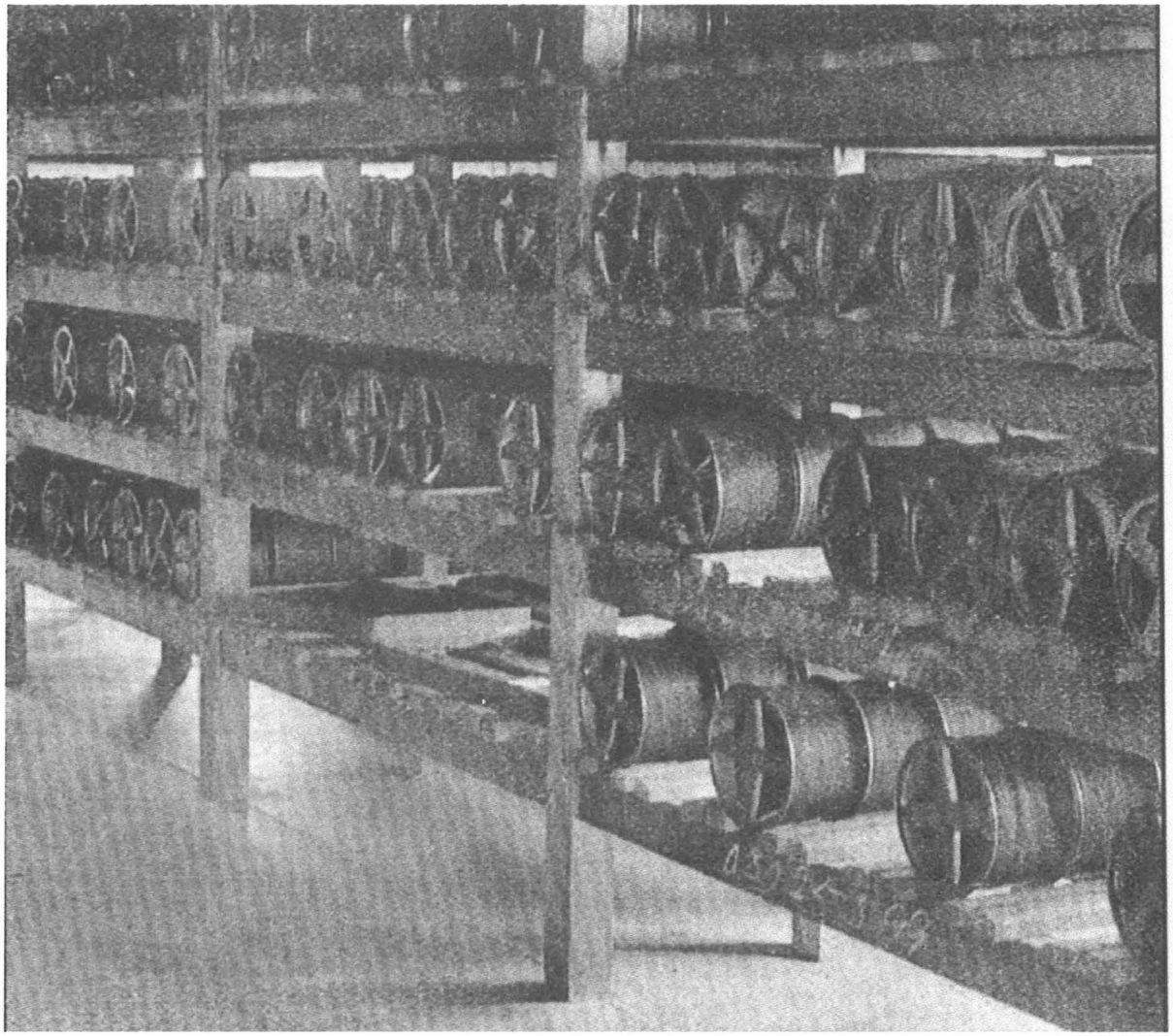
Ten reels of the dried cordite were placed on a machine and 10 strands, one from each reel, were twisted and blended onto one new reel. 6 of the new reels were again blended into one rope, consisting of 60 separate filaments. When cut to one and quarter inch lengths, these charges formed the 30 grains of propellant needed for the .303-inch ball cartridge. No cutting was carried out at Waltham Abbey, this was carried out at the cartridge factories.



ROYAL GUNPOWDER FACTORY.

DRYING ROOM.

Inorder to remove excess acetone, the cordite was removed to a drying room and exposed to a heat of up to 100 degrees. Half inch cordite required drying for 15 days, pistol and rifle cordite for 2 days.



ROYAL GUNPOWDER FACTORY.

SOUTH SITE.

QUINTON HILL.

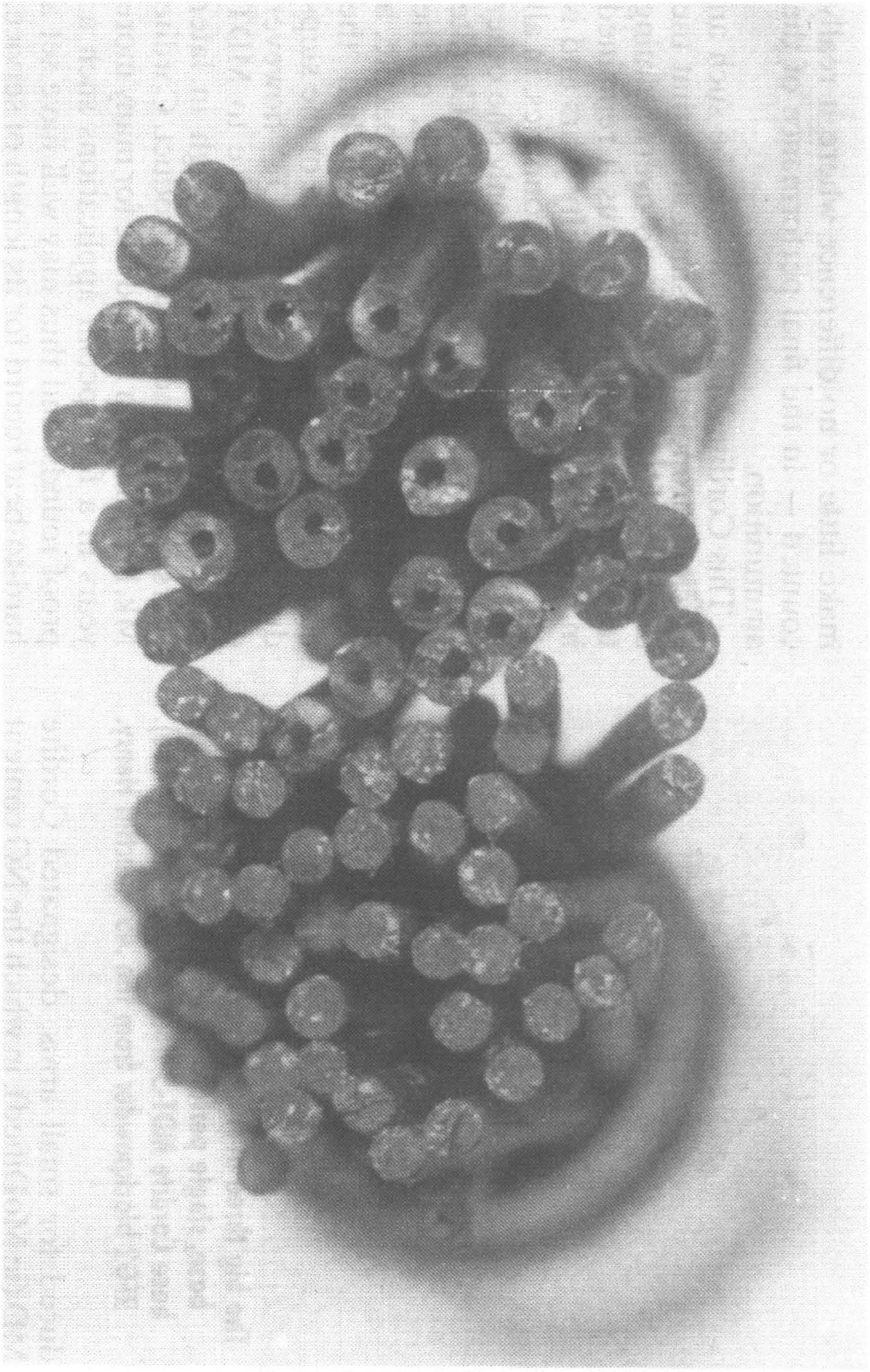
Interior of cordite reeling house after the explosion in 1894, with machinery in situ. Note the toe-boards defining the dirty area with tramway rails and clean areas.

ROYAL GUNPOWDER FACTORY.

Recovered artifacts- waste nitroglycerine acid bucket, nitroglycerine acid container and acetone bottle from the incorporating section.

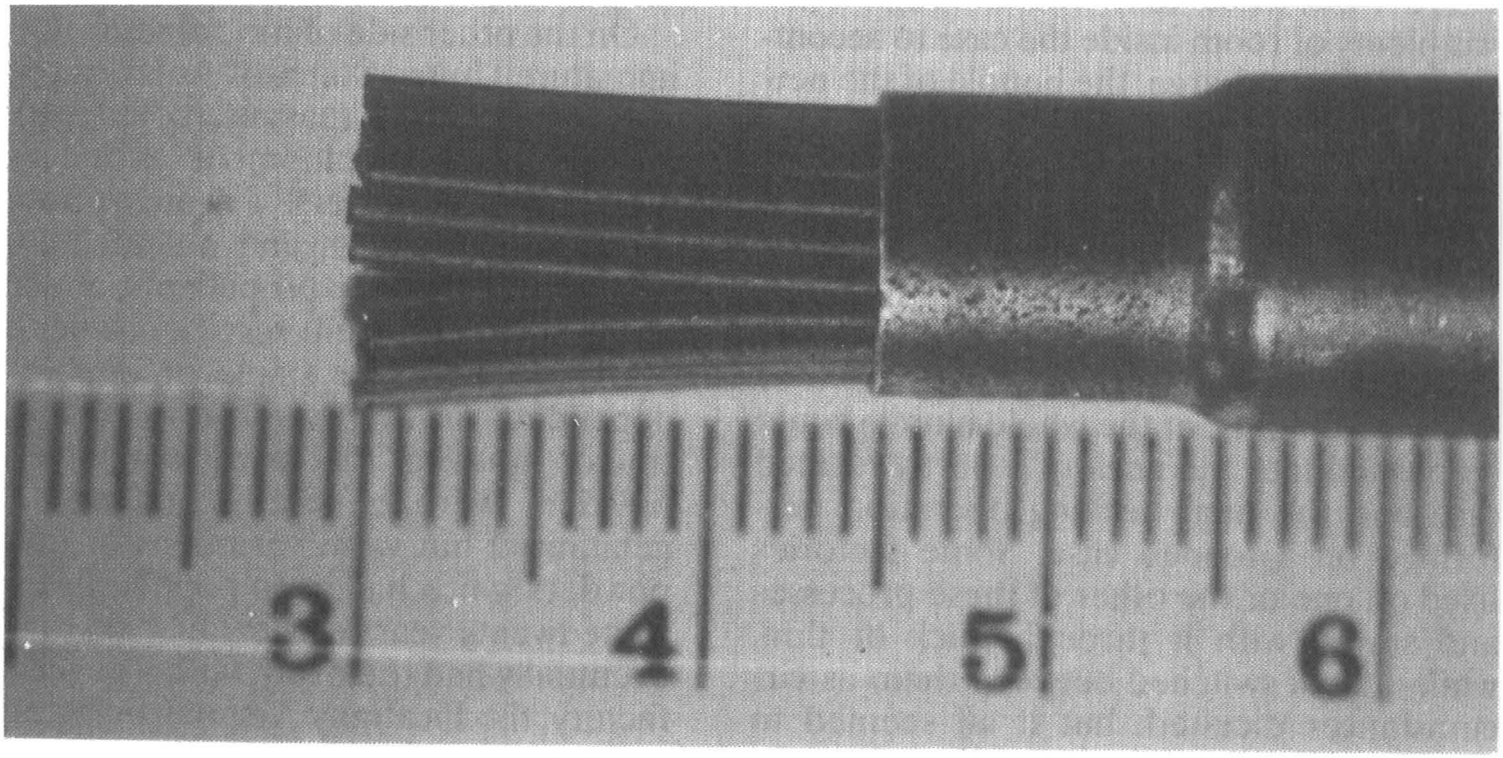
CORDITE.

Two main types of Cordite for the .303-inch cartridge.
Right- the original Cordite Mk 1 solid rods of O.O375-inch diameter.
Left.- The later type, Cordite MDT5-2, single perforate rods of outside diameter O.O5O-inch and inside diameter O.O2O-inch.

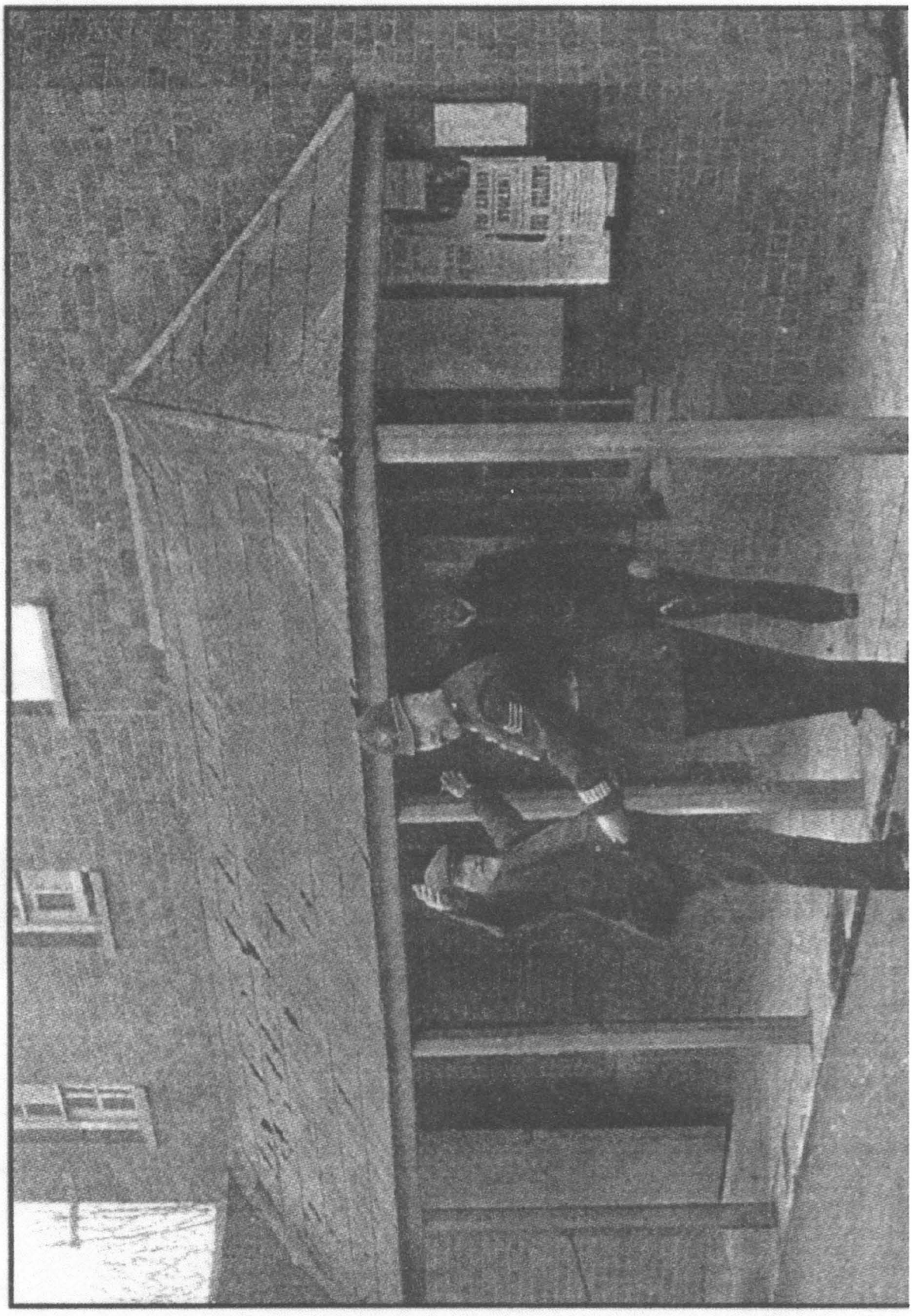


CORDITE.

A bundle of Cordite Mk1 size 3.75, 31 grains in weight and consisting of 60 sticks, which make up the full charge for a .303-inch Mk2 cartridge.



THE WORKERS.



ROYAL GUNPOWDER FACTORY.

FACTORY GATE SEARCH.

All workers at the factory were subject to the most stringent conditions which required daily physical searches for metal items or matches which might have caused a spark to ignite the contents of the workplace.

Note.

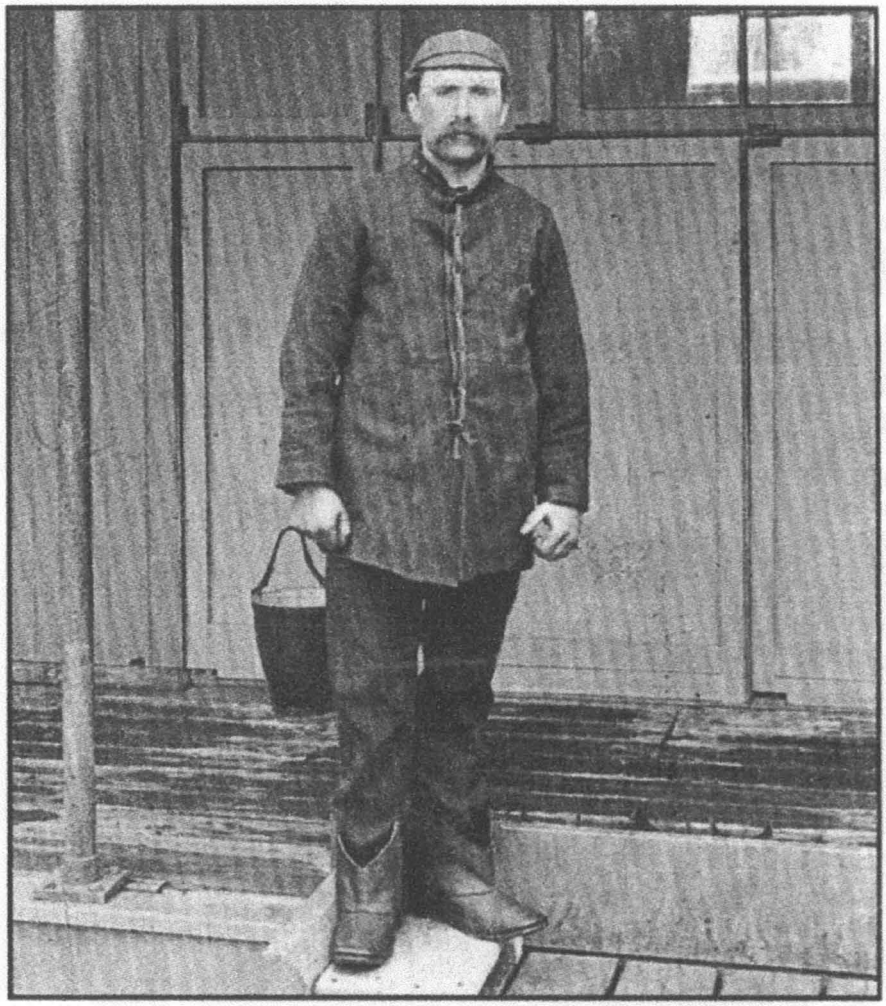
I was told by an elderly gentleman that as a boy he and his friends used to watch the workers on their way to the Quinton Hill factory. Some of the workers walked along a small lane alonside a cemetery. Some of the bricks of a wall that lined the cemetry were loose and the workers used to place their fags in the cavity left by the brick. The brick was replaced and they went on their way, the fags ready for when they finished work. The boys used to remove the bricks and take only one fag out of each packet no more, so as not to be missed.

THE ROYAL GUNPOWDER FACTORY.

By 1914 there were approved uniforms and safety dress provided for each activity.

From left to right.

1. Trucker, 2 Stoker, 3 Saltpetre Refiner, 4 Incorporation of Cordite, 5 and 8 Cordite Workers, 6 and 9 Guncotton Workers, 10 Nurse, 11 Police.



ROYAL GUNPOWDER FACTORY.

After an explosion at the RGPF in Wiston Churchill's constituency in January 1940, sabotage was rumoured and Chief Inspector William Salisbury, later of the Murder Squad, launched an investigation. His conclusion, with which the M15 counter-sabotage unit and Detective Chief inspector Williams of the Special Branch agreed, was that none of the three explosions which occurred on 18 January and killed five workers were caused by sabotage. The announcement of their findings received very little coverage compared to the headlines that the incidend provoked at first.

M15.

ROYAL GUNPOWDER FACTORY.

NITROGLYCERINE.

Nitroglycerine, made from chemically pure ingredients and at a temperature between 60 and 80 degrees F., is a water-white oily liquid, without odour at ordinary temperatures. Commercial nitroglycerine has a yellow colour, more or less deep. When free from water it is transparent; the presence of water makes it milky and translucent.

It has a slightly sweet taste, and gives a burning sensation. It is very poisonous and a very small quantity absorbed through the mouth, nostrils, or skin gives a characteristic symptoms of giddiness, faintness, and severe headache ; if the quantity he increased, these systoms became more aggravated, producing rigor and unconsciousness. Robust and highly nervous persons appear to be specially susceptible to the effects described.

Sometimes one never becomes immune to these effects, but, as a rule, the human system little by little adjusts itself so that workmen experience no unpleasant effects. The headache effect is most often experienced by those not accustomed to handling nitroglycerine.

Workers who handled it continually were always liable to suffer from what they called 'NG head'. Most workers became acclimatized to it after a few weeks, but if they were away from their work for a while, they had to go through the miserable period of acclimatization once again. To avoid this, many of them used to carry a small amount of the explosive around with them, despite all the rules and regulations against it.

THE ROYAL GUNPOWDER FACTORY

WALTHAM ABBEY.

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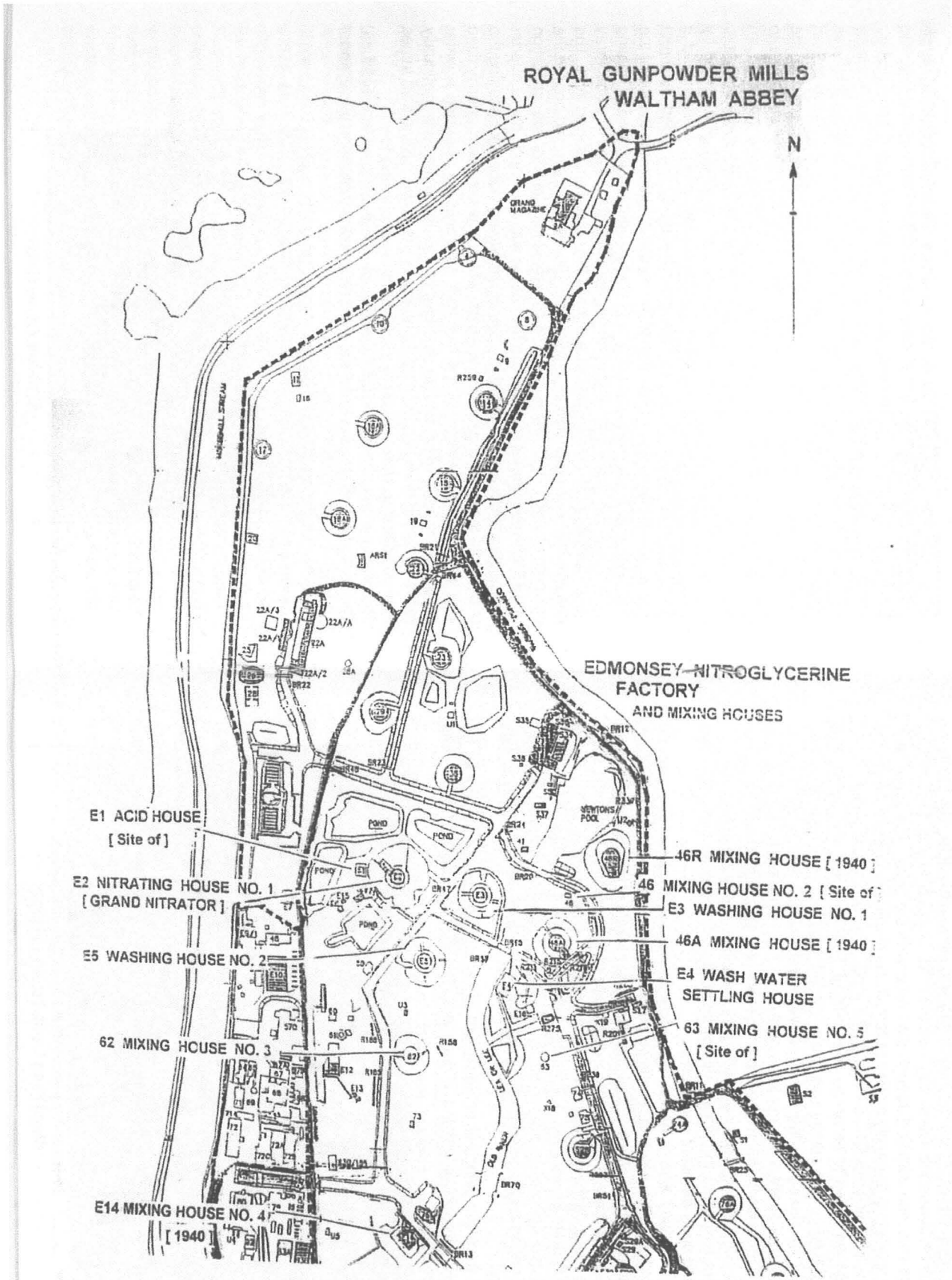
ROYAL GUNPOWDER MILLS
WALTHAM ABBEY.



ROYAL GUNPOWDER FACTORY

GROUP G MILLS

ERECTED 188-9

Photographed after explosion in 1902; in front is the raised platform of the tramway.

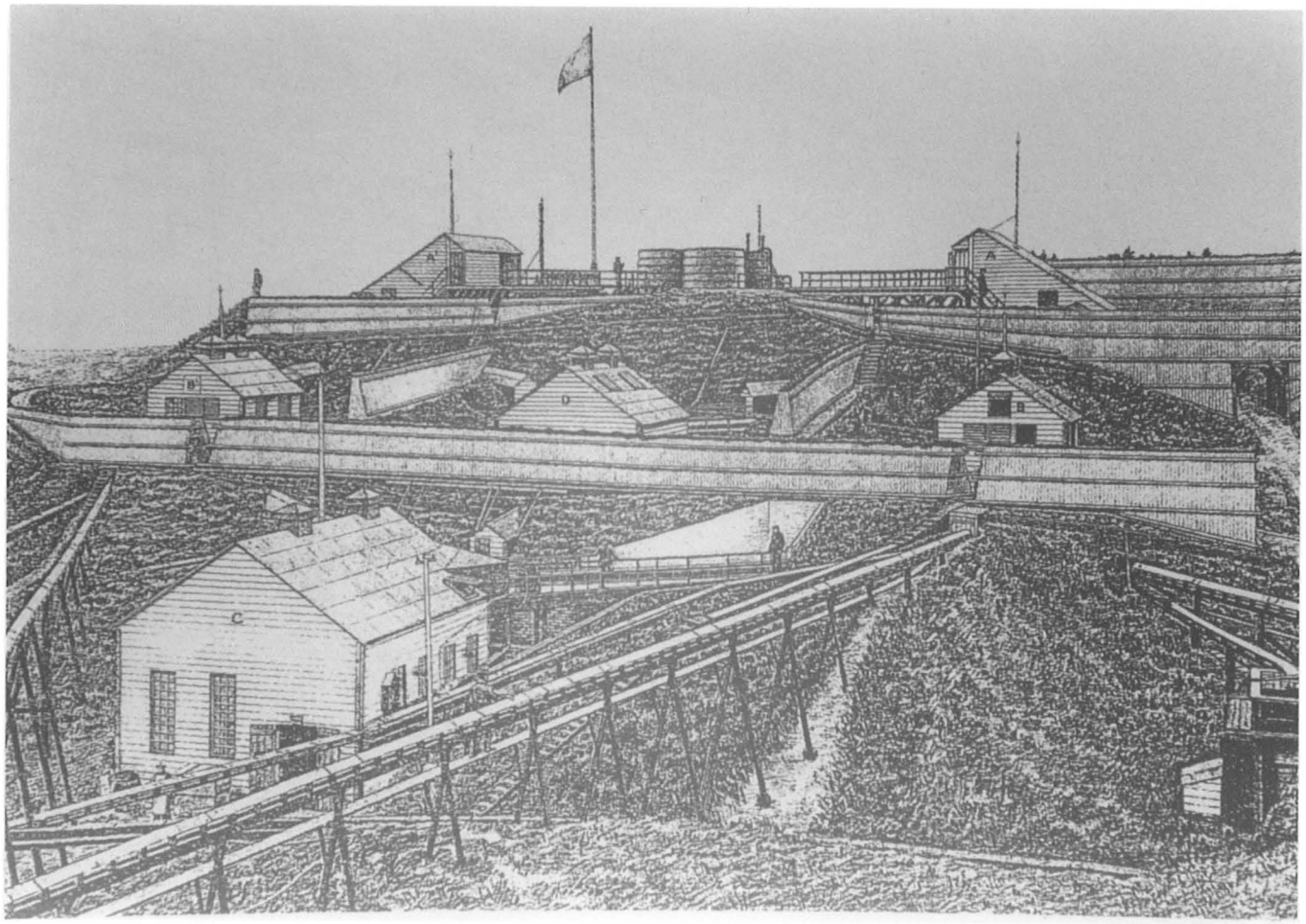
ROYAL GUNPOWDER FACTORY

SAFETY LAMP.

INCORPORATING MILLS.

ARDEER, AYRSHIRE.

This engraving captures the atmosphere of a late nineteenth-century nitroglycerine hill On the top of the hill are the tanks holding the acids and glycerine: below them is the nitrating house (A), protected by the red flag and lightning conductors. Below again are the separating and pre-washing houses(B) and below these the final washing and filtering house (C). The building (D) dug into the hillslope is protected by corrugated iron traverses filled with earth, so called 'Chilworth mounds'. Also clearly visible are the gutters that conveyed the liquids by gravity from building to building.



ROYAL GUNPOWDER FACTORY

SOUTH SITE.

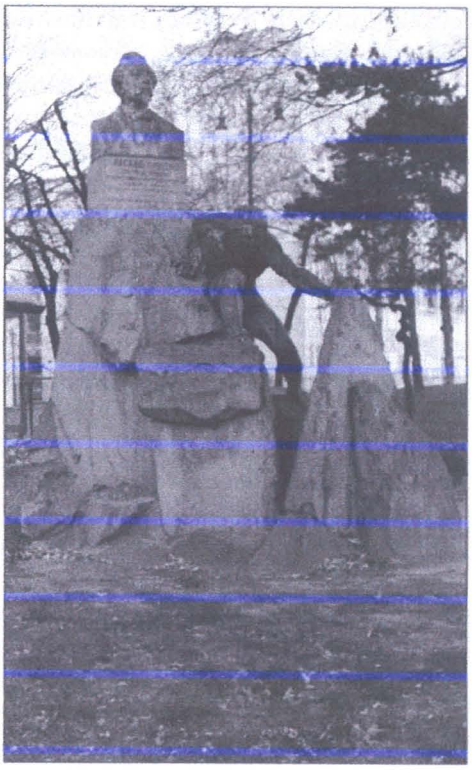
PULPING AND MOULDING ROOMS, 1888.

NITROGLYCERINE.

Nitroglycerine (NG) was first made by an Italian Ascanio Sobrero who graduated from the University of Turin in 1832 with a degree in medicine.
He made nitroglycerine in 1847 by treating glycerine with a mixture of concentrated sulphic and nitric acids. He described it as a yellowish oil, discoverd when a small sample blew up and spattered glass fragments into his hands and face, that it was violently explosive; and found, by tasting, that it had unexpected physiological effects. He reported.

It has a sharp sweet aromatic taste. It is advisable to take great care in testing this property. A trace of nitroglycerine placed upon the tongue, but not swallowed, gives rise to a pulsating, violent headache, accompanied by a great weakness of the limbs

Sobrero realized that he had made a very unusal substance, but he did little or nothing to exploit its potential. It is used as a medical treatment today.



The statue of Ascanio Sobrero in Turin. The inscription reads:

Illustrious Chemist
Discovered explosives of extraordinary power
Professor Emeritus
He stimulated the progress of industry
Under the auspices
of the Turin Association
of Industrial Chemistry

(Giuseppe Antonioli: Italesplosivi, Milan)

GUNCOTTON.

Cellulose, which is the main constituent of all plant cells, is the most abundant naturally occurring organic chemical. It is found in particularly large quantities in fibrous materials such as flax, hemp, bamboo, gras and coconut fibre, but the main commercial source for many years was cotton, which was replaced to some extent by wood and straw when it became too expensive. Although cellulose is so commonplace, it has a complex arrangement of atoms in its molecule; this was elucidated in 1937 by Sir William Hawworth, Professor of Chemistry at Birmingham University, whose pioneering research won him the Nobel Prize for Chemistry.

A year before Sobrero had first made nitroglycerin (NG), a German chemist, Schonbein, had treated cellulose with a mixture of hot concentrated nitric and sulphuric acids to make nitrocellulose (NC). He used cotton wool as his source of cellulose, and as he found that the nitrocellulose he made was explosive he called it guncotton. It is, however, unfair to give him all the credit for the discovery because a number of other chemists, all have claims.

It was at the University of Basle that Schonbein discovered guncotton, and he remained as professor there until he died on 19 August 1868.

The guncotton that he made looked very much like the cotton wool he had started with, but it felt harsher. When ignited in the open it burnt with a flash but in a confined space, it exploded. It was, then, very much like gunpowder, but it was noticeably more powerful

C.F. Schönbein. (Anne Ronan Picture Library)

GUNCOTTON.

The early attempts to make a smokeless powder from nitrocellulose were failures and consequently guncotton was used only as a blasting explosive, especially for military demolitions. It is still used to some extent for this purpose.

The moist guncotton is moulded into blocks in a hydraulic press and is then placed in a much more powerful press, where it is subjected to a pressure of four to seven tons per square inch. It is thus converted into a substance of the consistency of wood containg about 15 per cent. of water, which is decidedly insensitive and therefore safe.

To detonate it, use is made of a small primer of dried compressed guncotton, wich in turn is detonated by means od a detonator containing fulminate of mercury. These primers are made in a similar manner to the slabs of wet compressed guncotton but are afterwards dried in a stove.

Service Use.
1-oz primers and 15-oz slabs.
Size of wet slab of G.C., 6x3x1½-in.
Wet guncotton will not explode if hit by a bullet.
Wet guncotton can be sawn by a wet saw.
Requires dry primer, and detonator and fuse to explode.
Dry guncotton will explode if hit by a bullet
Dry primer of guncotton 1.35-in. diam., 1.15-in diameter at ends 1.25-in high.
Strength. 2½ times stronger than gunpowder, unconfined.
Strength, 7 to 8 times stronger than gunpowder, confined.

ROYAL GUNPOWDER FACTORY WALTHAM ABBEY.

Guncotton, a variety of nitrocellulose, was discovered in 1845-46 by Professor Schonbein of Basle by the action of a mixture of nitric and sulphuric acids on cotton. The importance of the invention was recognised immediately and attempts were made by the governments in various countries to develop it for military purposes, but a series of serious explosions in England, France and Austria caused the manufacture to be dropped again after a short time. In 1865, however, Sir Frederick Abel discovered that guncotton could be made satisfactory stable if it were reduced to pulp in a beating machine and thoroughly washed with water. Shortly afterwards the practice was adopted of boiling the guncotton with several changes of water. Sir Frederick Abel also introduced the use of cotton waste instead of raw cotton for the manufacture og guncotton. Formerly the nitration of cotton was carried out in small earthenware pots. The purified cotton waste after being picked over and passed through a teazing machine to open it up was dried and weighed out into uniform quantities of about 1.25-lbs. Each of these was then immersed in a strong mixture of sulphuric and nitric acids. After remaining in this for a few minutes it was lifted out by means of an iron or aluminium prong, placed on a grating over the back of the pan and pressed with the aid of a lever in order to remove the greater part of the excess of acid. Then the sodden mass, which consisted of partially nitrated cotton together with about eleven times its weight of mixed acid, was put into an earthenware pot, which was covered with an earthenware lid and olaced in a large trough of cold water together with numerous other similar pots. After remaining in this for 12 to 24 hours the pot was seized by a boy with a pair of tongs and tipped into a centrifugal machine together with the contents of several other pots. The centrifugal machine was then rotated rapidly to remove the greater part of the waste acid. The guncotton was taken out and immersed quickly in a large bulk of running water. After being washed for some time with cold water was transferred to large wooden vats where it was boilded for some days with several changes of water.

One of the objections to this process was the large amount of hand labour involved, during which the workers were exposed to acid fumes. The contents of the pots often fumed off, especially in hot weather, giving off large volumes of red fumes which obliged all the workers to leave the building until the fumes had cleared away again. The contents of the centrifugals also fumed off sometimes.

In Germany a method was adopted of nitrating in the centrifugal machine itself. This method, which is not much used in England, saves much labour but does not readily yield guncotton containing a high percentage of nitrogen, as it is not practicable to leave the cotton in the acid for more than about an hour. The process has been improved by providing for the agitation of the acid in the centrifugals and the transference of the wrung-out guncotton directly into running water which carries it away to washing tanks.

PRE-CORDITE - GUNPOWDER.

The 19th century was an era of accelerating economic, manufacturing and trade activity with increasing rivalry between the Great Powers. Demand for gunpowder similarly increased in both the civil and military fields. in the military application, advances in metallurgy applied to iron and the new steels had enabled the manufacture of larger guns requiring not only larger charges but more specialised powders with a controlled rate of burning. This led to major developments in powder technology in the form of pellet or shaped powders, moulded prismatic powders and 'brown' powders. These new requirements resulted in a significant expansion of production facilities at the Mills in the late 1870's, together with new canal links. At that time it would have appeared that the natural based gunpowder would be the world explosive and military propellant for the foreseeable future. However, the new science of applied chemistry had already laid the foundations for massive change at the end of the century. Pressure for improvements in quality, performance and explosive power was constant. in the military sphere there was also growing demand for a 'smokeless powder' which led scientists to explore the possdibily of replacing the natural based gunpowder with new chemically based materials.

GUNCOTTON- from 1864.

The foundation of chemically based explosive manufacture is the process of nitration - the replacing of hydrogen in a molecule with nitro groups. Around 1845 a Swiss chemist, Professor Schonbein of Basle, discovered a variety of nitrocellulose (NC) by the action of nitric and sulphuric acids on cotton and this was called Guncotton. Its explosive power was soon recognised but a series of explosions in many countries caused its manufacture to be dropped. Then, in 1865, Frederick Abel at Woolwich developed vital improvements making its manufacture and use practicable. He discovered that previos accidents were due to the imperfect washing of the material after nitration leading to severe instability and introduced a washing process which was put in place at the Mills. the civil explosives industry quickly 'cottoned on' to the commercial possibilities and many of the Waltham Abbey Mills processing improvements were widely disseminated throughout the industry. In the military the new material became widely used in torpedoes, mines, demolition charges and for shell filling. Guncotton continued as an important military explosive into WW11 and in 1940 the Mills were producing 120 tons per week. At the same time it was hoped that guncotton could be granulated to provide a superior replacement for gunpowder but these hopes were not fulfilled. Guncotton was found to be too explosive in force and gunpowder continued its dominance. However, demand for a 'smokeless powder' continued.

NITROGLYCERINE (NG) - from 1863.

Prepared by the action of nitric and sulphuric acids on glycerine this was first made by the Italian Sobrero in 1846. Although of much greater power than any other explosive it

was a sensitive and unpredictable liquid and in early manufacture many devastating accidents occurred. It was the Swedish chemist, Alfred Nobel, who 'tamed' NG by absorbing it into an inert clay (Kieselguhr) which reduced its sensitivity. This he termed 'Dynamite' and the material came into widespread use.

BLASTING GELATINE _ from 1886.
In 1875 Nobel introduced 'blasting gelatine' in which soluble NC was gelatinised by NG.

SMOKELESS POWDERS_ from 1886.
Poudre B 1886.
In 1886 the French developed 'Poudre B' made by gelatinising guncotton with ether_alcohol and working the paste into a dry horn like material. Although not perfect it could be regarded as the first practicable smokeless powder.

BALLISTITE 1887.
Nobel's blasting gelatine was too powerful for use as a military propellant bu in 1887 he patented Ballistite as a propellant, it being a mixture of soluble NC, NG and camphor as plasticiser.

CORDITE 1889.
The French achievement had caused considerable interest, if not anxiety, in the British military and in 1888 an Explosives Committee was set up under Sir Frederick Abel to investigate the potential of NG based material as a service propellant. Within a year, in 1889, they had patented 'Cordite) with insoluble NC, NG and mineral jelly using acetone as solvent. This was termed Cordite Mark 1 and had a composition of NG 58%, NC 37%, Mineral Jelly 5%. The process involved forcing the material through a die while in a plastic state to produce strands or cords - hence the name Cordite. The patent process had passed through murky waters, including an action fro infringement by Nobel - The Times termed it 'The Cordite Scandal'. In 1901 Cordite MD (Modified) became the standard service propellant, practically reversing the previous composition to NG 30%, NC 65%, Mineral Jelly 5%, the purpose being to reduce barrel erosion.

The development of and introduction of cordite into service was meteoric. it removed entirely the need for the brown and moulded powders which a short time before had seemed so advanced. By 1890 land south of the town had been purchased to allow for the necessary expansion with the Mark 1 cordite becoming the standard rifle propellant in 1891. By 1898 the North Site in conjunction with the new South Site were producing guncotton and nitroglycerine and was predominantly a cordite factory.
During WW1 Cordite RD (Research Department) B was developed using ether-alcohol solvent in place of the scarce acetone. Prior to WW1 the Mills cordite output was 26 tons a week. Within a year of the start of the war this had risen to 140 tons and by 1916 to 200 tons.

Important development work continued at the Mills after WW1. In 1933 Cordite W (Waltham) was developed with replacement of mineral jelly by 'carbamite', a more efficient stabiliser. Although earlier grades had been termed 'smokeless powders', pressure from the military for enhanced smokeless and flashness qualities has intensified. Following research at Woolwich, from 1928 the Mills had been evaluating compositions containing picrite (nitroguanidine) and by WW11 a formulation including 55% picrite had almost completely eliminated flash and smoke.

NOBELS FACTORY.

From 1910 to 1936 there was employment in Farm Hill, in a Factory (Nobels) dedicated to the production of small-arms ammunition.

In the years after 1945 the site was turned to the production of synthetic-resin mouldings and fabrications for household goods such as radios and hair-dryers. The company later diversified into plastic laminiates for low cost furniture, before closure in 1990.

THE ROYAL GUNPOWDER FACTORY

WALTHAM ABBEY.

THE MAKING OF THE PROPELLANT CORDITE.

WALTHAM ABBEY GUNPOWDER FACTORY.
DEVELOPMENT OF CHEMICAL EXPLOSIVES.
20th CENTURY

THE EDMONSEY ACID AND NITROGLYCERINE FACTORIES.

NITRATION.

Figure 5.23 RGPF Waltham Abbey, North Site. Edmonsey Mead Nitroglycerine Factory (section redrawn from HMSO 1900, Treatise on Service Explosives, plate XX opposite p75): 1 Glycerine bogie; 2 Glycerine store tank; 3 Acid store tanks; 4 Acid bogies; 5 Fume shaft; 6 Condensing towers; 7 Nitric acid receivers; 8 Acid towers; 9 Syphon tank and coil; 10 To concentration plant; 11 Sulphuric acid egg; 12 Acid egg; 13 Drain to river; 14 Separating bottles; 15 Acid tank; 16 Bogie lift; 17 Glycerine tank; 18 Nitrating apparatus; 19 Prewash tank; 20 Drowning tank; 21 Washing tank; 22 Filter tank; 23 Scales; 24 Drowning tank; 25 Wash-water settling tank; 26 Labyrinth; Red shows the path of the nitroglycerine.

THE EDMONSEY NITROGLYCERINE FACTORY.

NITROGLYCERINE MANUFACTURE AT WALTHAM ABBEY.

Nitroglycerine plant following the Nobel pattern, but with some modification, was erected on the new Quinton Hill site in 1890. After a serious explosion in 1894 following the recommendation of the subsequent Committee of Enquiry a second plant was erected in 1897, this time back on the original north site on Edmonsey Mead to the north. In 1904 the Quinton Hill plant was put into reserve and Edmonset became the Waltham Abbey nitroglycerine producer.

Figure 5.21 RGPF Waltham Abbey, North Site. Aerial photograph of Edmonsey Mead Nitroglycerine Factory. (NMR 1857/29)

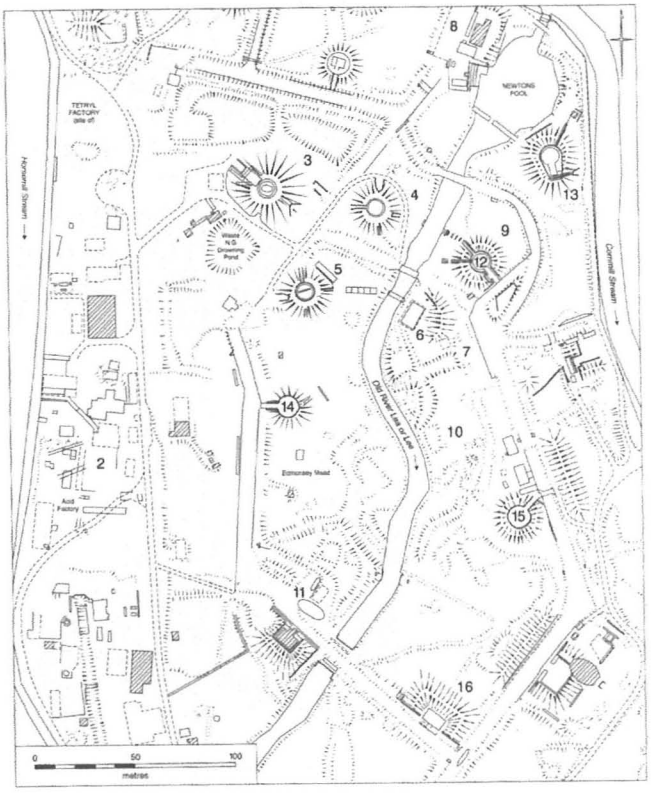


Figure 5.22 RGPF Waltham Abbey, North Site. Edmonsey Mead Nitroglycerine Factory, as surveyed in 1993: 1 Glycerine and acid shed; 2 Nitric acid factory; 3 Nitrating house (Fig 5.24); 4 Washing house; 5 Washing house; 6 Wash-water settling house; 7 Mud house; 8 Mixing house (former gunpowder granulating house); 9 Mixing house (built 1904 destroyed 1940); 10 Mixing house (built 1904 destroyed 1940); 11 Mixing house (former gunpowder Press House); 12 Mixing house (built 1940) (Fig 5.31); 13 Mixing house (built 1940); 14 Mixing house (built 1904) (Fig 5.32); 15 ?Mixing house (built 1940); 16 Mixing house (?1914–18).

ROYAL GUNPOWDER FACTORY. WALTHAM ABBEY.
South Site.
Quinton Hill Nitroglycerine Factory.

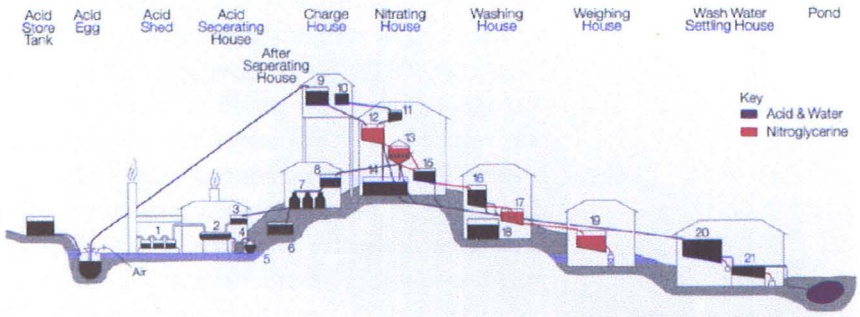
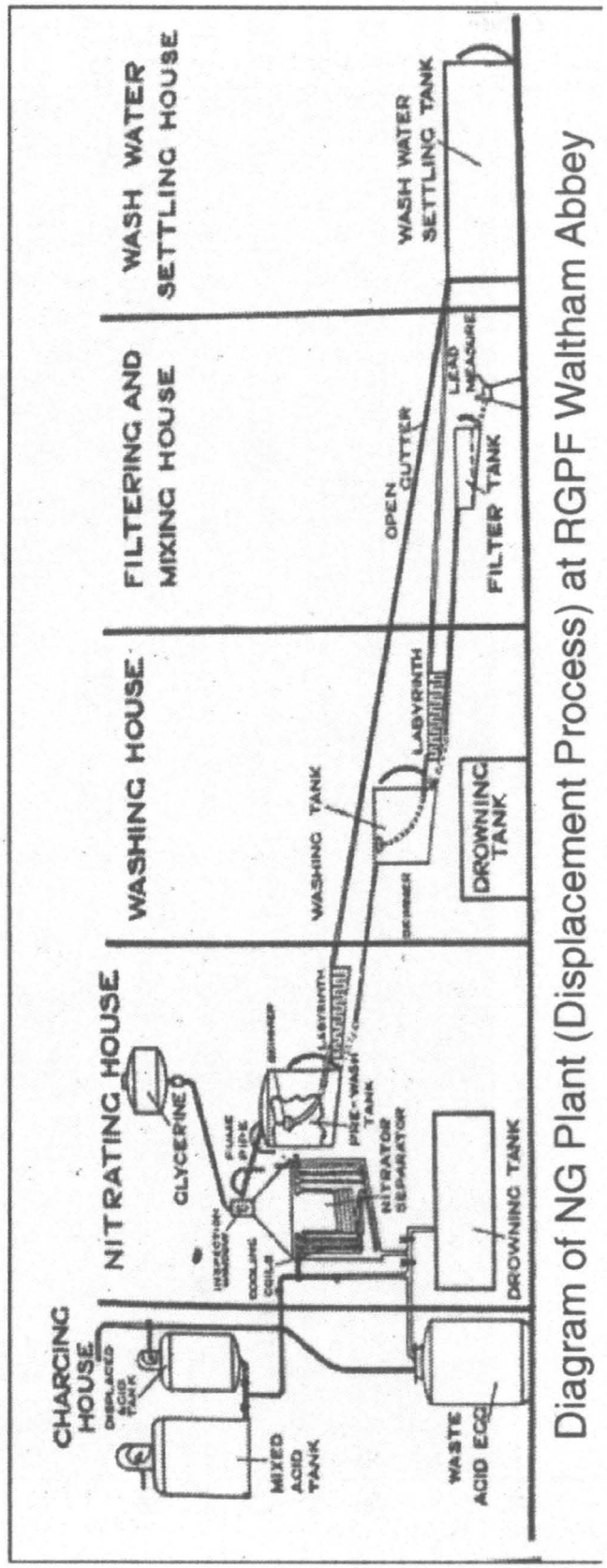


Figure 5.18 RGPF Waltham Abbey, South Site. Quinton Hill Nitroglycerine Factory (section redrawn from HMSO 1895 (Treatise on Service Explosives), *plate XIV opposite p81): 1 Nitric acid receivers; 2 Acid still; 3 Settling tank; 4 Syphon tank and coil; 5 Sulphuric acid carboy; 6 Drowning tank; 7 Separating bottles; 8 Acid tank; 9 Acid tank; 10 Glycerine tank; 11 Glycerine tank; 12 Nitrating apparatus; 13 Separating tank; 14 Drowning tank; 15 Prewash tank; 16 Washing tank; 17 Filter tank; 18 Drowning tank; 19 Store tank; 20 Wash-water settling tank; 21 Labyrinth; Red shows the path of the nitroglycerine.*

DIAGRAM OF NG (DISPLACEMENT PROCESS) AT RGPF WALTHAM ABBEY.



ROYAL GUNPOWDER FACTORY.

THE NATHAN-THOMSON DISPLACEMENT PROCESS.

Though the nitration process at Waltham Abbey was considered to make good guncotton, it was expensive. It was very labour-intensive; additionally a lot of power was required for the centrifuges and large quantities of water for cooling and immersing. Although none of the plant was individually expensive, items required frequent replacement. Spontaneous decomposition of treated cotton also led to losses. The commercial trade responded in different ways to similar factors. Nobel's factory at Ardeer, on the Firth of Clyde, introduced a direct dipping process, while Messrs Curtis's and Harvey at their Dartford guncotton works, built adjacent to their powder works, installed a nitrating centrifuge, a type of machine common in Germany. The system devised at Waltham Abbey by two of the factory's chemists, J M Thomson and W T Thomson, and implemented in 1905 was the displacement process. Displacement tanks replaced the stages of dipping, squeezing, digesting in pots, acid centrifuging, immersing, and water centrifuging. The new system was hailed as a great advance since it resulted in cost saving in labour and power, in greater acid recovery, and the less frequent need to replace plant; it also produced a more stable guncotton with an improved yield. It was widely adopted throughout the industry as the most efficient method of nitrocellulose production. Yet, though a major break-through in manufacturing technology,, it had relatively little effect on the outward form of the factory, despite considerable reorganisation internally. The dipping room was converted to the nitrating room, with little modification beyond replacing the shallow cooling tanks with a brick floor for the displacement tanks to stand on. Other plant such as immersing tanks and centrifuges was removed, with a resulting fall in power requirements. New plant concentrated on the manufacture and recovery of nitrating acids.

The new process also went some way to improving working conditions in the factory by reducing the amount of fumes in the building.

NITROCELLULOSE.

SECTION OF DISPLACEMENT APPARATUS.

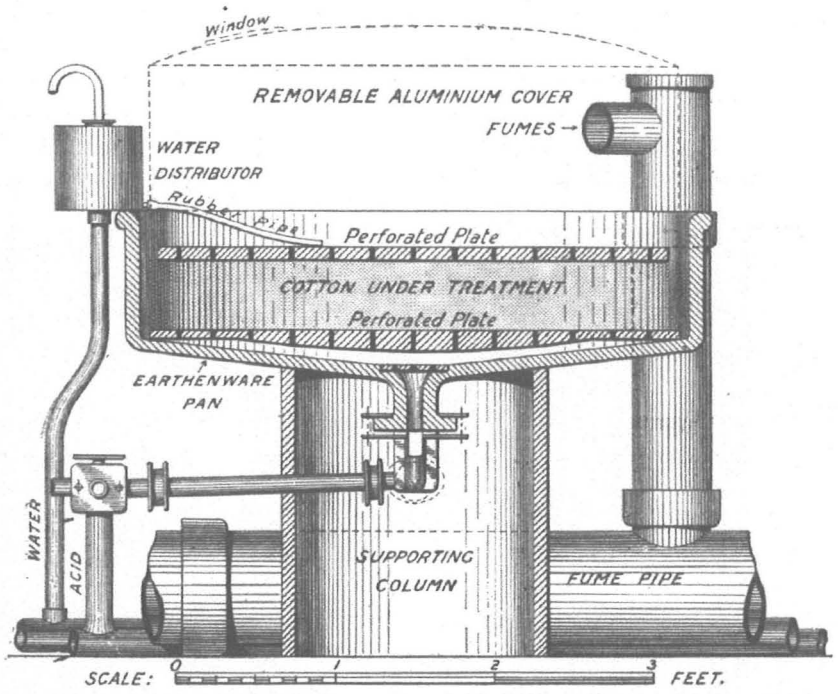
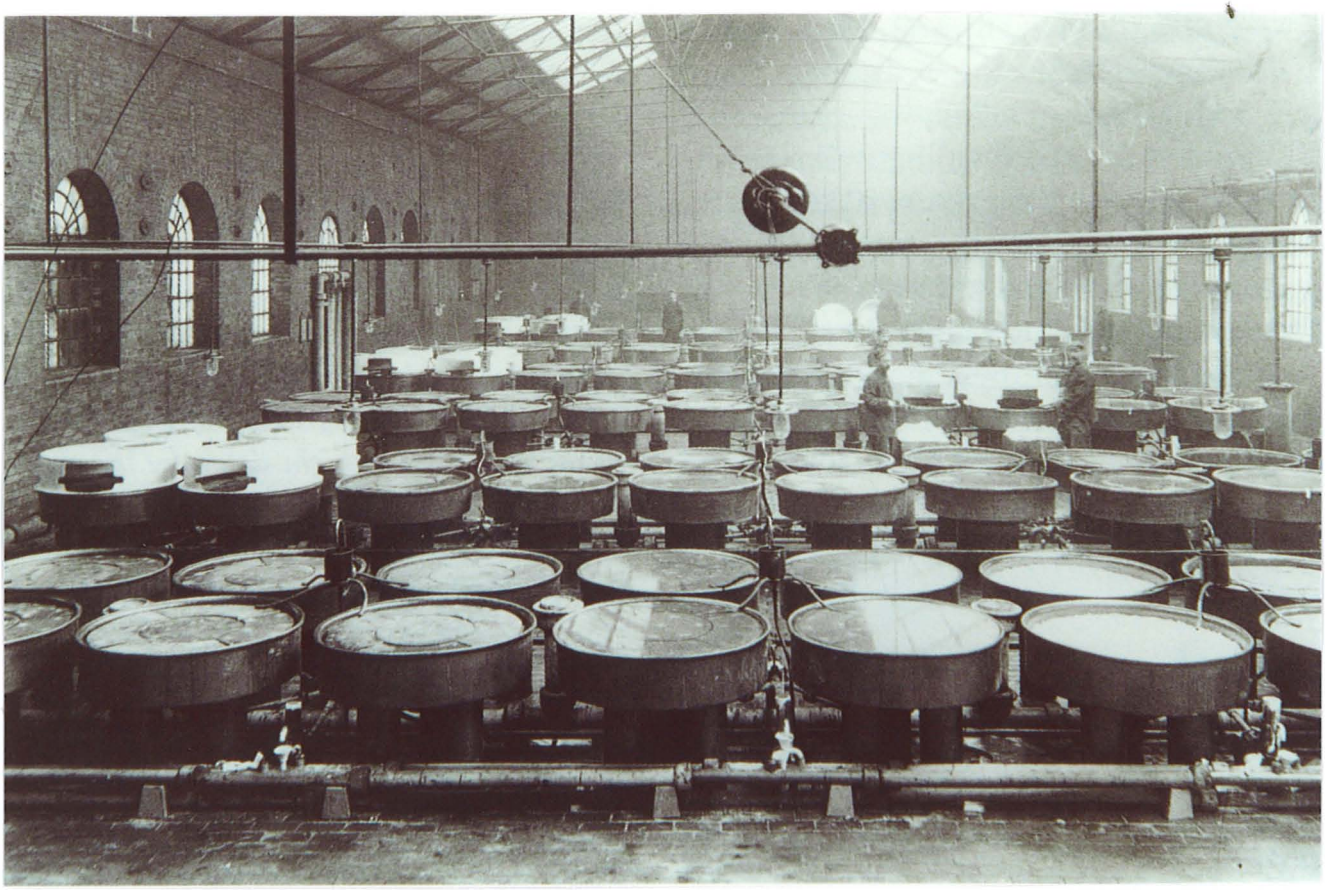


FIG. 3. Section of Displacement Apparatus (from *Arms and Explosives*)

RGPF WALTHAM ABBEY.
SOUTH SITE.

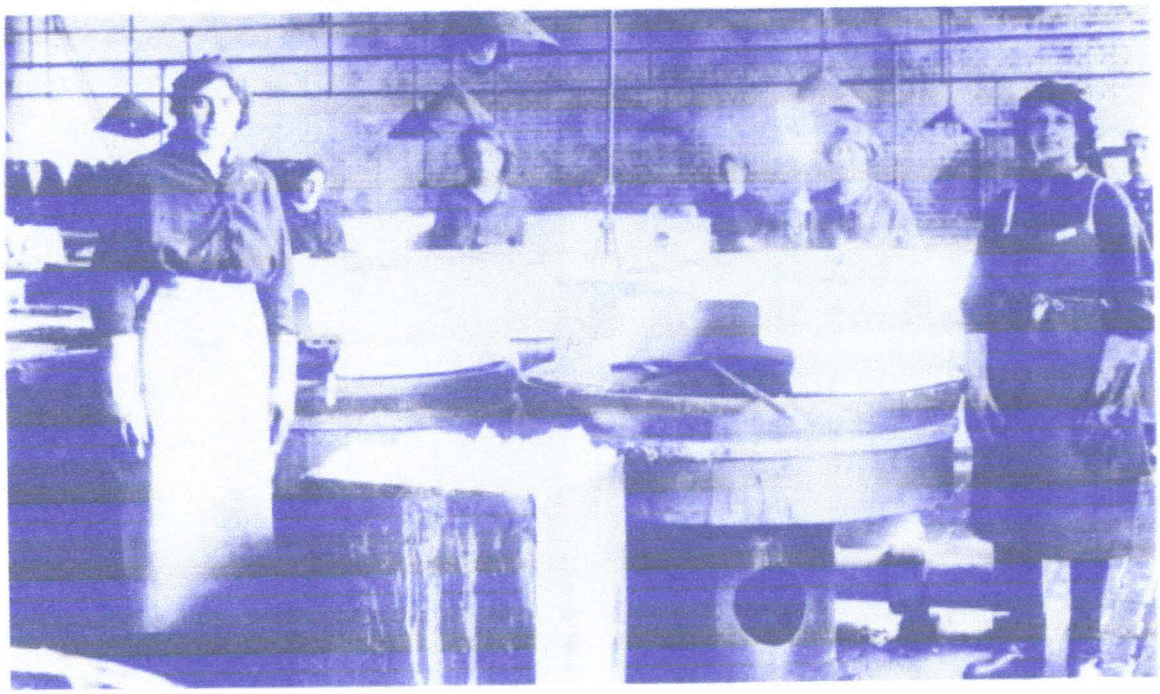
View of displacement tanks installed in 1905 in the former guncotton dipping room. The earthenware displacement tanks, 3ft 6in in diameter, were arranged in groups of four. Note also the fume hoods and perforated plates in the tanks, and the acid-resistant brick floor.



ROYAL GUNPOWDER FACTORY.

DISPLACEMENT PLANT.

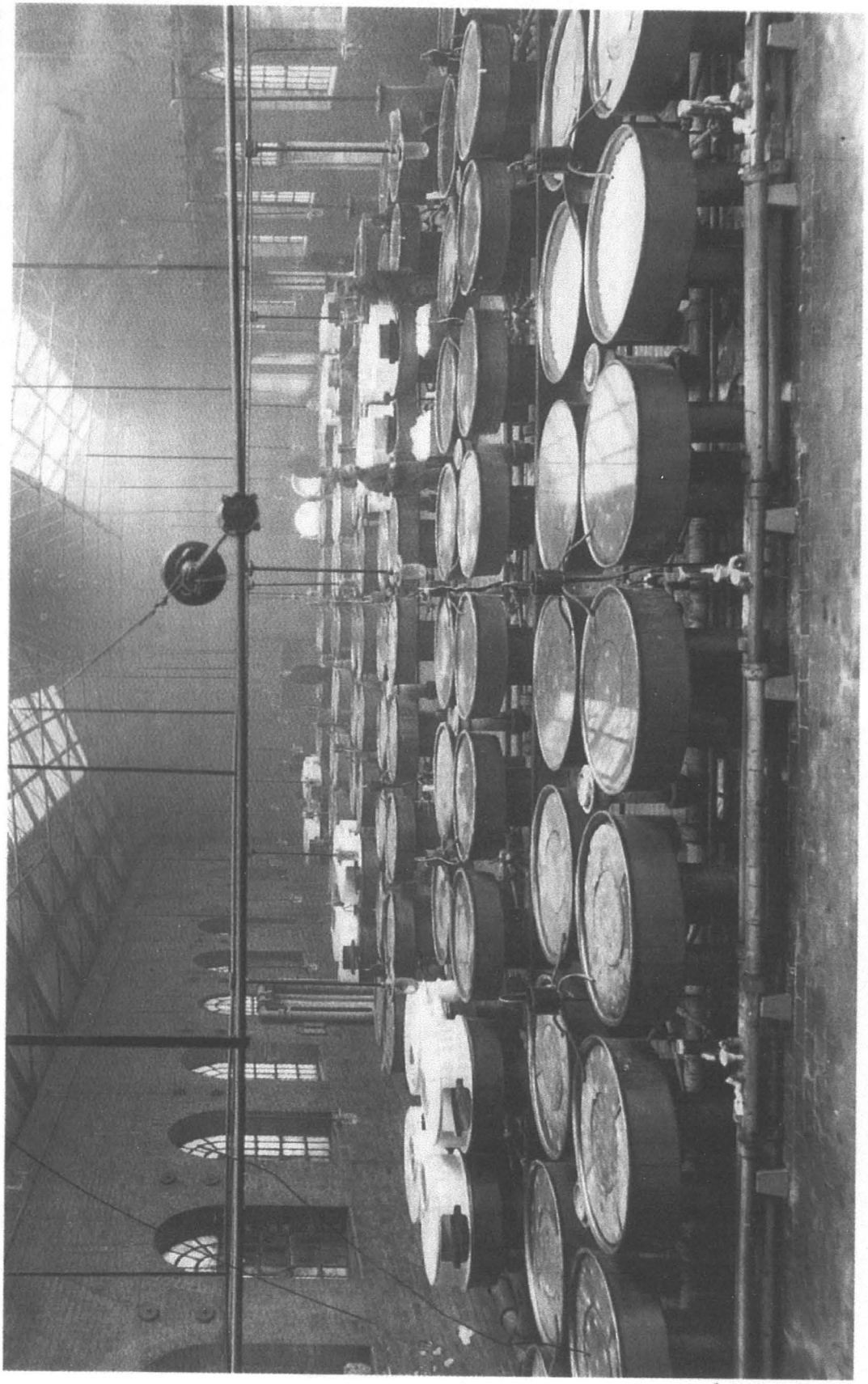
the Nathan-Thomson displacement process. In this method, the mixed acids were run into the earthenware displacement pans. A 20lb charge of cotton was immersed in each, with the pans covered by the aluminium fume hoods. Perforated earthenware plates were then fitted over the charge and a film of water was run over the plates to prevent the escape of acid fumes. Since the water was lighter than the acid it remained as a discrete layer on top. After about 3 hours, cocks at the base of the pans were opened allowing the waste acid to drain off for recovery, while at the same time water was run into the top of the pan. As displacement proceeded, the acid became weaker to a point where it was no longer viable to recover it and it was run to waste.
Following displacement, the guncotton was taken directly to be boiled.



ROYAL GUNPOWDER FACTORY WALTHAM ABBEY.

SOUTH SIDE.

View of displacement tanks installed in 1905 in the former guncotton dipping room. The earthenware displacement tanks, 3ft 6in in diameter, were arranged in groups of four. Note also the fume hoods and perforated plates in the tanks, and the acid-resistant brick floor.



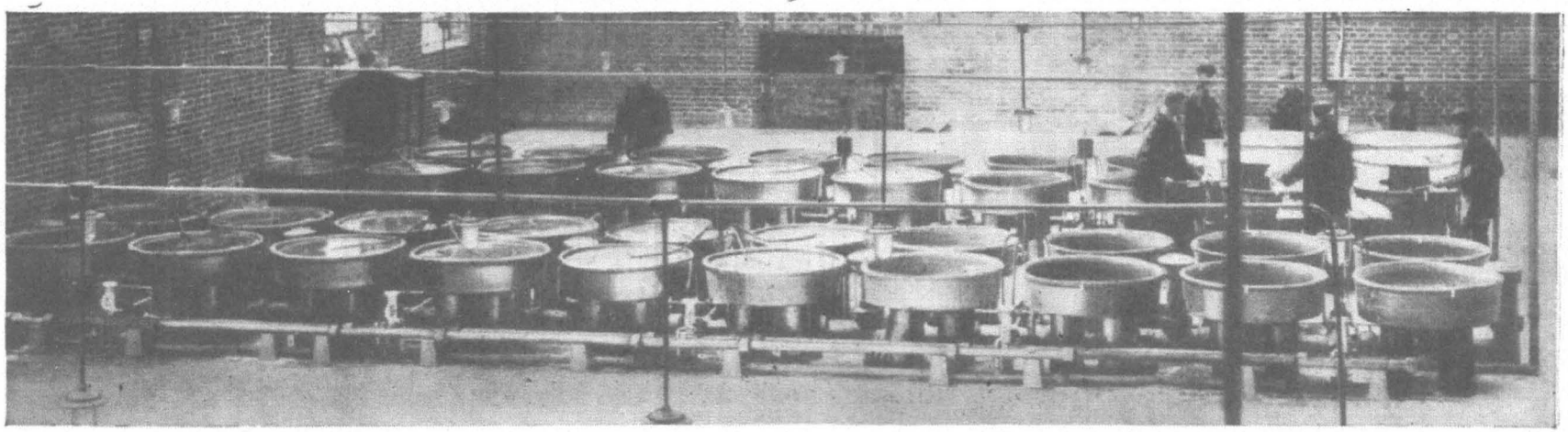


FIG. 4. View showing Arrangement of Units in Rows (from *Arms and Explosives*)

ROYAL GUNPOWDER FACTORY.

CORDITE MANUFACTURE WW2.

The RGPF was not a factory dedicated to the production of one final product, involving a common production process.

Nitro-glycerine was produced in large lead vessels called nitrators by the action of sulphuric acid and nitric acid upon glycerine.

The process was a very delicate one and very critical. Following the production of the nitro-glycerine itself, two further processes were undertake. The first was pouring the liquid onto dry guncotton in rubber bags, and, secondly, the mixing of the dry guncotton and the nitro-glycerine by working it through a half-inch mesh sieve by hand into calico bags. Some of the Mixing House buildings incorporated both these operations in the same structure and others took in 'poured-on' supplies from other parts of the factory. In any case, the two stages of production were never carried out simultaneously and only three operatives were allowed to work in the building at the time.

Guncotton, was produced in the Gunpowder factory section of the RGPF and, as 'wet guncotton', was transported in aluminium boxes in compressed cylindrical form by lorry to the nitro site for drying. The 55-60-hour drying process ended with the material being placed in bags and sent, via a Weighing House, to the Mixing Houses for the addition of the nitro and the subsequent mixing.

An initial portion, about 1,200-lbs (enough for 65 bags) was run into a holding tank along the gutter from the previous building in the process, the Washing House, where the product was purified. As soon as the portion arrived the process building, a special rubber hose shut off further supply to the nitro-glycerine tank. During its passage, the fluid would contiminate the lead-lined gutter so, to retain the integrity of the fail safe system, one of the process workers, called a 'hill-man', then cleaned the gutter out starting from the Washing House.

As soon as the nitro-glycerine arrived in the Mixing House, 20z samples were put in lead bottles and placed out of harm's way under the tank. the bottles were some 3-inches high and weighed 10½ ozs when empty. dry guncotton, contained in rubber bags, was then brought in from a Weighing House and a measured amount of nitro added. it was generally the duty of the chargeman to pour this on from one of the number of measuring vessels called burettes.

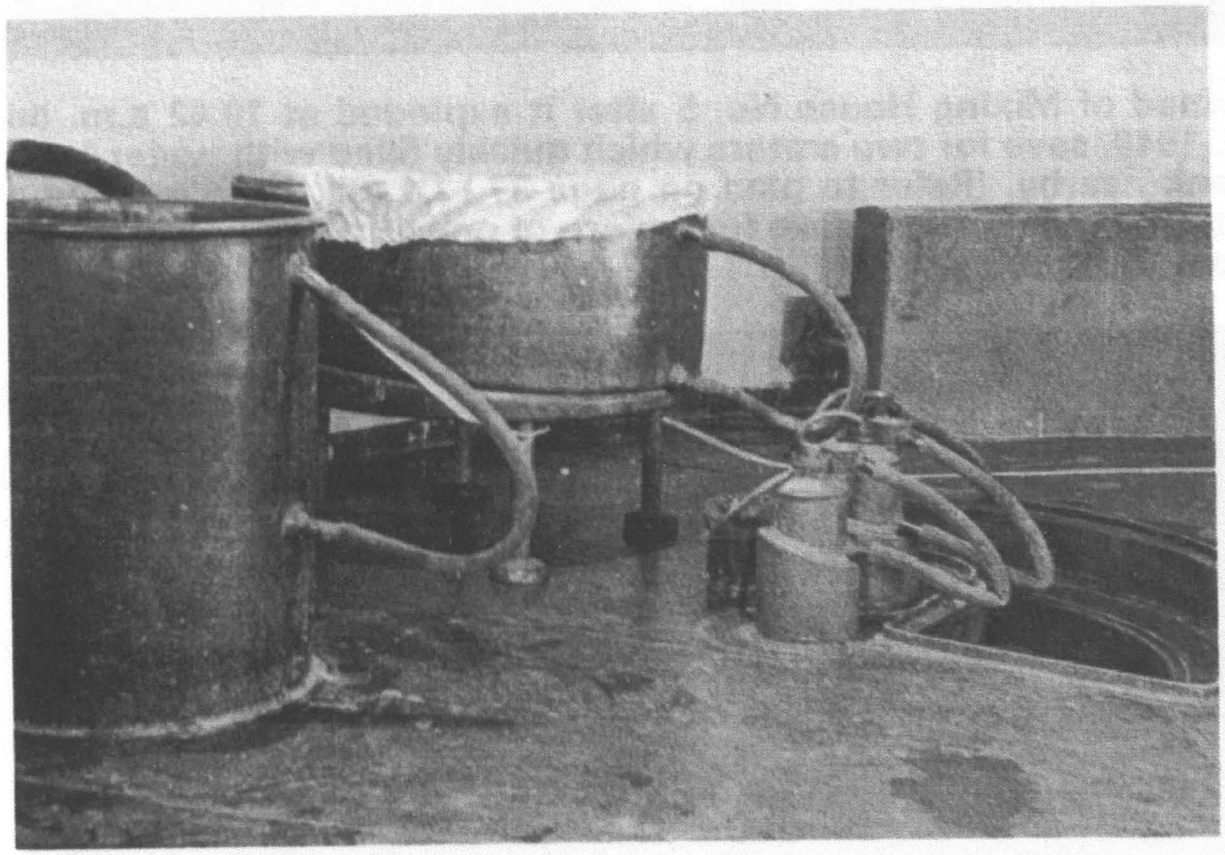
the bags were then either sent away in a barge to another building or put to one side until the initial operation was completed. The seperate mixing operatiom consisted of empting the contents of the rubber bags onto paste- mixing tables made of lead supported by steel framework welded to the floor and then taking the material to the phosphor-bronze sieve and hand working it throug to mix it thoroughly and deposit it into the hopper-mounted bag below. The operators wore leather gloves for this operation. When this process was completed, a barge would call at the canal side entrance and take the material, now called mixed paste, away for further processing into the final product such as cordite.

At irregular intervals during the day, one of the hillmen would call at the process building to collect the sample bottles, place them in a special carrying box, and take them to the laboratory for quality control testing. The handover of the bottles, between the hillman and the chargeman, took place in the porch of the building. This procedure allowed each to retain his respective level of cleanliness. After the hillman had taken samples to the laboratory, he returned with other tested samples for their respective process buildings. This operation was not undertaken at night, lest the hillman trip and fall in the dark.

ROYAL GUNPOWDER FACTORY.

MIXING HOUSE.

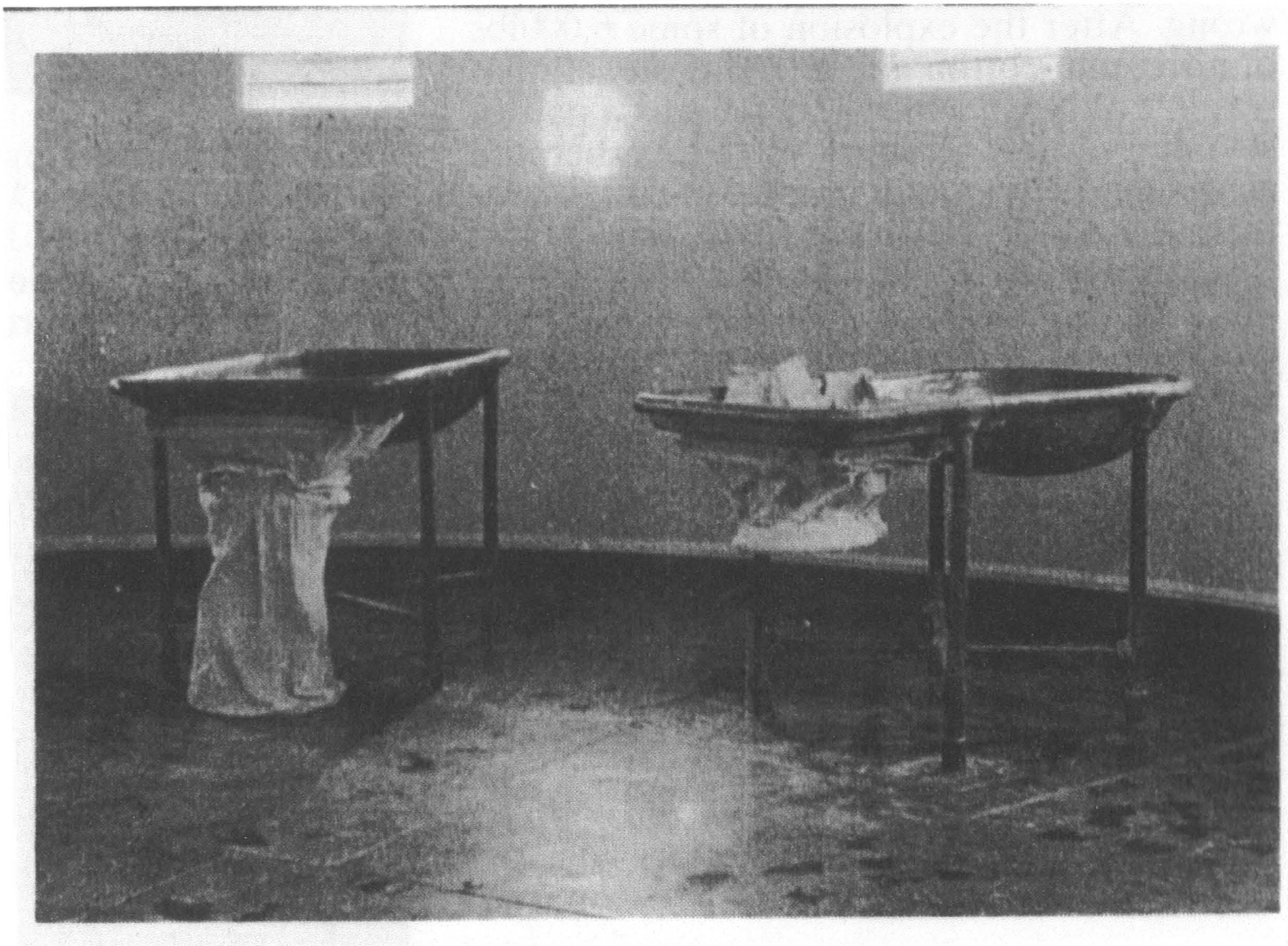
Close up of the burettes and the arrangement of rubber safety overflow pipes from them to the rubber bag on the stand. The 'well' was lead lined.



ROYAL GUNPOWDER FACTORY.

MIXING HOUSE.

Paste mixing tables made of lead were fixed to the floor and fitted with a phosphor-bronze sleeve onto which the contents of the bags of guncotton were emptied. The material then had to be worked by hand through the mesh by the operatives wearing long leather gloves. The resultant mix falling into bags which were then taken away for additional processing.



ROYAL GUNPOWDER FACTORY.

NITROGLYCERINE BURETTE.

Used to deliver a measured charge of nitroglycerine to mix with guncotton. A rubber tube was attached to the lower pipe; when not in use it was connected to the upper pipe.

THE ROYAL GUNPOWDER FACTORY.

NITROGLYCERINE BURETTE.

NITRATING HOUSE No.1- THE 'GRAND NITRATOR'.

INCORPORATING THE NITRATOR-SEPARATOR.

After much development work a patent was issued in 1905 under the names of Nathan-Thomson-Rintoul for nitrating apparatus in the Nitrating House which eliminated the use of earthenware stopcocks for removal of nitroglycerine (for the sake of brevity this will be referred to as NTR). Bt. Col. Sir F.L.Nathan was Superintendent of Waltham Abbey, J.M.Thomson was Superintendent of the nitroglycerine facility and W.Rintoul was a senior scientist. This combined the functions of the nitrator and the separator and was termed the nitrator-separator. It was concluded that as the problem lay in stopcocks controlling drawing off nitroglycerine from the base of the tank it could be solved by turning the system on its head, pushing the liquid from the top of the tank, and that the pushing force could be provided by another liquid already in the system - inert spent acid remaining from the previous batch.

The nitrator-separator was a cylindrical lead vessel with a sloping base and conical cover, containing cooling coils containing water and brine and air pipes. A glass observation panel and thermometer were set into the cover. The nitrating acid was led in through a pipe at the base. The pipe had two branches - one controlled by a rod to the operating platform leading to a drowning tank into which the charge could be discharged in an emergency and the other to the spent acid egg. The nitrating acid was stirred and cooled by the water in the cooling coils, refrigerated if necessary and nitration commenced by direct injection of the cooled acid through the top of the apparatus. Glycerine normally thinned by heating was gradually admitted in the form of a fine spray on the surface of the cooled and stirred acid. The rate of inflow was controlled to keep the temperature of the liquid near to the optimum of 10 degrees C. 15 degreesC was regarded as the maximum limit for safe operation and if the temperature exceeded this the charge was 'drowned', only a quarter turn of the control being needed to open the drowning stopcock releasing the charge into the drowning tank underneath, which was kept permanently filled with water. The operating of the stopcock automatically operated a water supply to the tank, which had an overflow, so that the water was continually renewed during drowning, keeping the temperature down. Nitric acid fumes from volatilisation were carried to the Guttman condensing tower.

The glycerine charge for a batch of nitroglycerine at Edmonsey was 1,400-lbs This took about 45 minutes to nitrate, with subsequent separation taking about an hour.

When nitration was complete the mixture was allowed to settle, with the lower density nitroglycerine separating from the acid. Spent acid from the previous charge was then admitted through the inlet pipes in the base. The upper layer of nitroglycerine gradually moved to its exit, the demarcation line between the two liquids being monitored constantly through the observation panel. When the line was seen to be at the correct level, 1.e. before any acid could pass over, the spent acid was closed off with the nitroglycerine flowing over and out via short guttering to the pre-wash tank. Until it was required for the next charge spent acid was left in the nitrator. The purpose of this was to avoid damage to the interior by exposure to spent acid fumes. The effectiveness of this practise was demonstrated by an inspection of the apparatus after 21/4 years use when the whole interior including cooling coils and pipes was found to be in excellent condition.

The Edmonsey nitrator had a fine safety record and as far as is known no charge had to be drowned. However the human element could not be left out. Glycerine injection was a critical opeation and the rate of injection was subject within some bounds to be the individual attitude of the operator. Inevitably some had a more dashing temperament than others. One operator at the Royal Naval Cordite Factory, Mr.Webster, achieved fame if not notoriety when he was cited somewhat sourly by Dr.Ramsay, the Government Inspector commenting on irregularities in nitroglycerine factories, as 'a notoriously fast nitrator'.

NITRATING HOUSE No.1.
THE ' GRAND NITRATOR'.

Apart from the principle achievement of removal of use of stopcocks for nitroglycerine movement, the advantages of the NTR process over earlier plant were manifold.

1. Reduced total elevation from top of nitrator to bottom of wash water settling tank of 16ft. against 331/2ft.
2. Less total ground area.
3. Elimination of separating house removed undesirable operation of guttering carrying mixture of acids and nitroglycerine.
4. Elimination of after-separating house.
5. Nitroglycerine is removed from the acid as quickly as it separates reducing possibility of contamination.
6. Introduction of cooling coils sustantially lessened risk of overheating.
7. Fewer pieces of apparatus.
8. Measurement of acids, glycerine and nitroglycerine instead of weighing.
9. Fewer personnel required, giving more economic operation and less total risk.
10. Better working conditions - fume removal.
11. Yield increase. Theoretically 100 parts of glycerine should produce 246.74 parts of nitroglycerine. This is the optimum and plant limitations mean that something less will actually be achieved. However the NTR process did produce a significant yield increase over earlier systems. The earliest plant produced around 200%. Later improvements led to around 210% (based on weight of glycerine). At Waltham Abbey NTR the average yield over 8 years was 214.25%. Post NTR the average over 2 years was 220.18%.

ROYAL GUNPOWDER FACTORY.

Remains of an old nitroglycerine 'gutter' by which the explosive ran by gravity between buildings. Long since deprived of its lead lining, this particular one had a felt-covered wooden lid rather than the usual canvas cover.

PRE-WASHING (WITHIN NITRATING HOUSE.)

The nitroglycerine was pre-washed of acid with water by agitation with compressed air injection into the tank. There were several pre-washes, the last being of soda solution to render the nitroglycerine alkaline before settling to the bottom of the tank and run down by guttering to the Washing House. By means of a rubber 'skimmer' the wash waters were run into a 'labyrinth' where any remaining nitroglycerine separated out. There were no stopcocks on the pre-wash tank. Runoff was by disconnection of a rubber runoff pipe and connection to a fixed nozzle on the end of the guttering to the Washing House. No clamp was employed on the pipe, regulation being entirely with 'kinking' by hand prseeure..

Water Quality and Wash Water preparation.
The water at Waltham Abbey was hard and could have precented serious limescale problems. To prevent this all wash waters were filtered and softened and the heating of wash waters and preparation of soda solutions was carried out centrally in the Charge House to avoid operating inefficiencies and dis-econmony which would arise if this were done individually in each process house.

E3 and E5 Nitroglycerine Washing Houses.
Prior to running down the nitroglycerine from the pe-wash warm soda solution was run down the gutter to the Washing Houses, then the nitroglycerine was sent down then another run of soda solution.
Procedure was similar to the pre-wash. The nitroglycerine was washed in wam soda solution agitated by compressed air. To remove the sodium carbonate the last two washing were with warm water. A rubber skimmer removed wash waters to a labyrinth to recover remaining nitroglycerine. Again nitroglycerine runoff, to filtering, was by hand kinked rubber tube, eliminating the stopcock.

(5) Filtering (in Mixing House).
The final stage in manufacture of nitroglycerine before it passed into the cordite manufacturing chain was filtering. The filter tanks were situated in the Mixing Houses. The filter tank was of lead with a false bottom of perforated lead. The filter comprised a layer of sponges sewn in flannel laid on the false base. Drawing off of filtered nitroglycerine was again by kinked rubber tube into a lead burette, allowing accurate measurement of the charge, eliminating the weighing scales previously used. The nitroglycerine was then 'poured on' to guncotton in the first stage of cordite production.

(6) E4 Wash Water Settling House..
Spent washing water from the washing Houses run in guttering to a tank in the Wash Water Settling House, agitated by compressed air. At the end of each day the air was shut off and any nitroglycerine allowed to settle out, again removed by rubber tube and taken back to the pre-wash tank. A mud comprising mainly lead sulphates and some nitroglycerine remained. At the end of each week the mud was taken to the Mud Washing Shed for final washing.

7Mud Washing Shed.

The mud was passed through flannel filters suspended over a lead washing tank. Washing to remove nitroglycerine and to render the mud alkaline by converting to lead carbonate was again by warm soda solution. Finally the mud was wrung in flannel to remove any vestiges of nitroglycerine, mixed with paraffin and burnt.

8 Wash Water Settling Ponds.

The above is the conclusion of the Edmonsey nitroglycerine process except for one final stage. Contaminated wash waters were drained into settling ponds, which surrounded the Nitrator. To finally remove any nitroglycerine, rather startingly in view of the surroundings, was for the foreman, each Saturday morning in what must have been regarded as a pleasant weekend diversion, to blow up each pond with a dynamite charge.

The Final Chapter.

The NTR plant operated until 1951. After this nitroglycerine for Waltham Abbey was obtained by leaching out of dynamite. In the early 1960's for a time there was some restoration of production, on a small scale, to supply research laboratory requirements.

ROYAL GUNPOWDER FACTORY.

WOMEN WORKERS WW1.

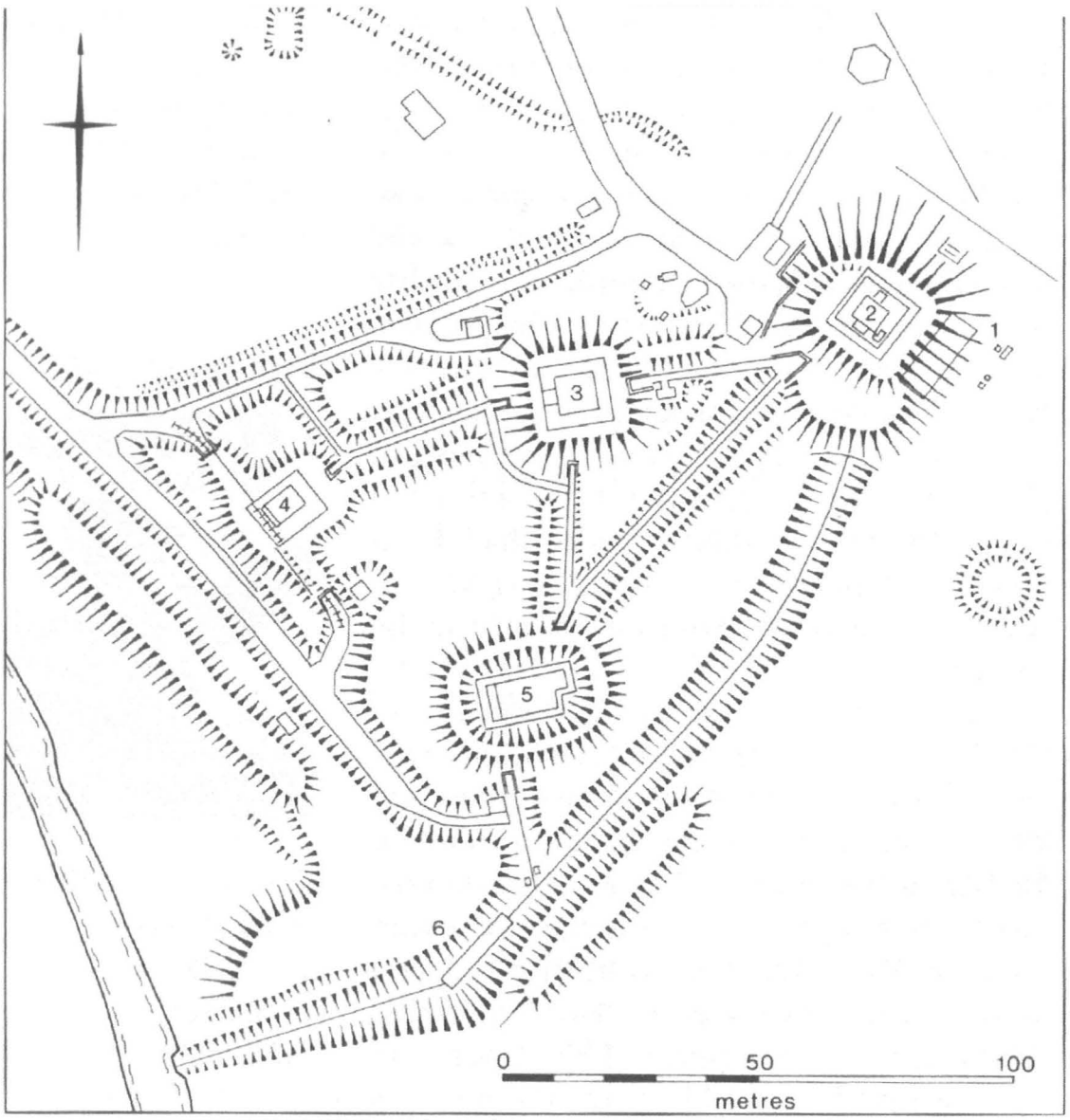
Women workers in factory clothing. Trousers and tunics were another novelty for women by the war.

ROYAL GUNPOWDER FACTORY.
NORTH SITE.

Surveyed plan of the New Hill nitroglycerine factory.

1. Charge house.
2. Nitrator.
3. Wash house.
4. Mixing house.
5. Wash-water settling house.
6. Flume house.

The plant was never put into production. It might be that events overtook its commissioning as new plants became operational elsewhere and brought and end to nitroglycerine production at Waltham Abbey in September 1943.

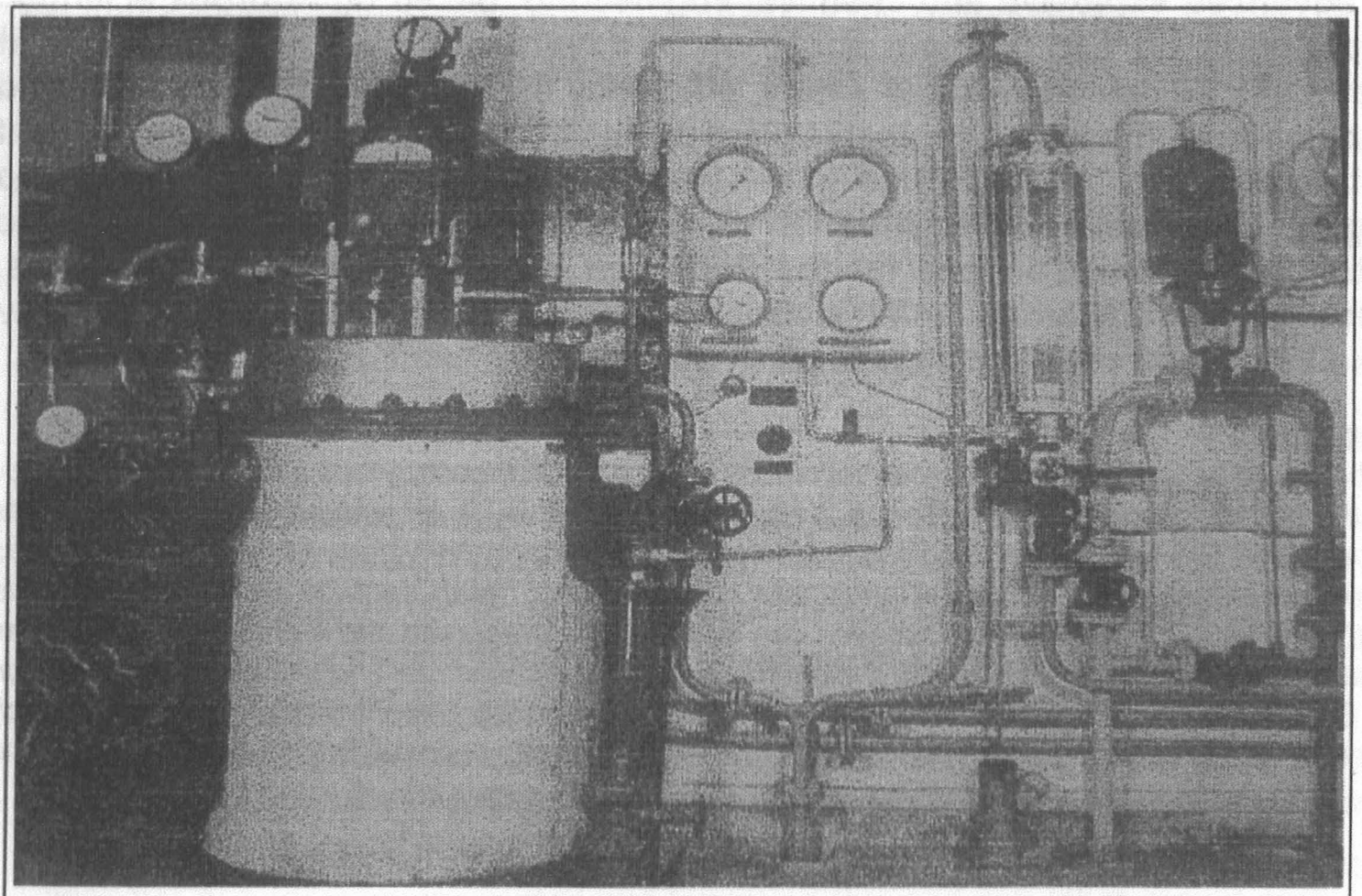


Settling Pond.

A pool adjoining the cordite works is for draining all the water from the various nitro-glycerine houses as this water contains a certain quantity of nitro-glycerine.
Every Saturday this pond is blown up by means of a dynamite cartridge,in order to get rid of the explosive matter it contains. After the terrible explosion in the nitro-glycerine house on the 7th of May,1894,when four men were blown to pieces,such a large quantity of nitro-glycerine accumulated in the pool that when it came to be blown up,the result was really startling. The explosion blew holes 20-feet around the pond.

THE SCHMID CONTINUOUS PROCESS.

Whilst it was a major success in the context of its day the NTR system had one fundamental drawback - it was a batch process, with the resultant bulk quanties of material present at each stage presenting a safety hazard. In the 1930's the Schmid process was developed in Germany. This reflected the same basic elements of nitration but differed fundamentally from NTR, being a continuous production process, thus eliminating the disadvantage of batch production. In the early 1960's at Waltham Abbey building E5, previously Washing House No.2, was converted to conduct experiments on a Schmid plant.



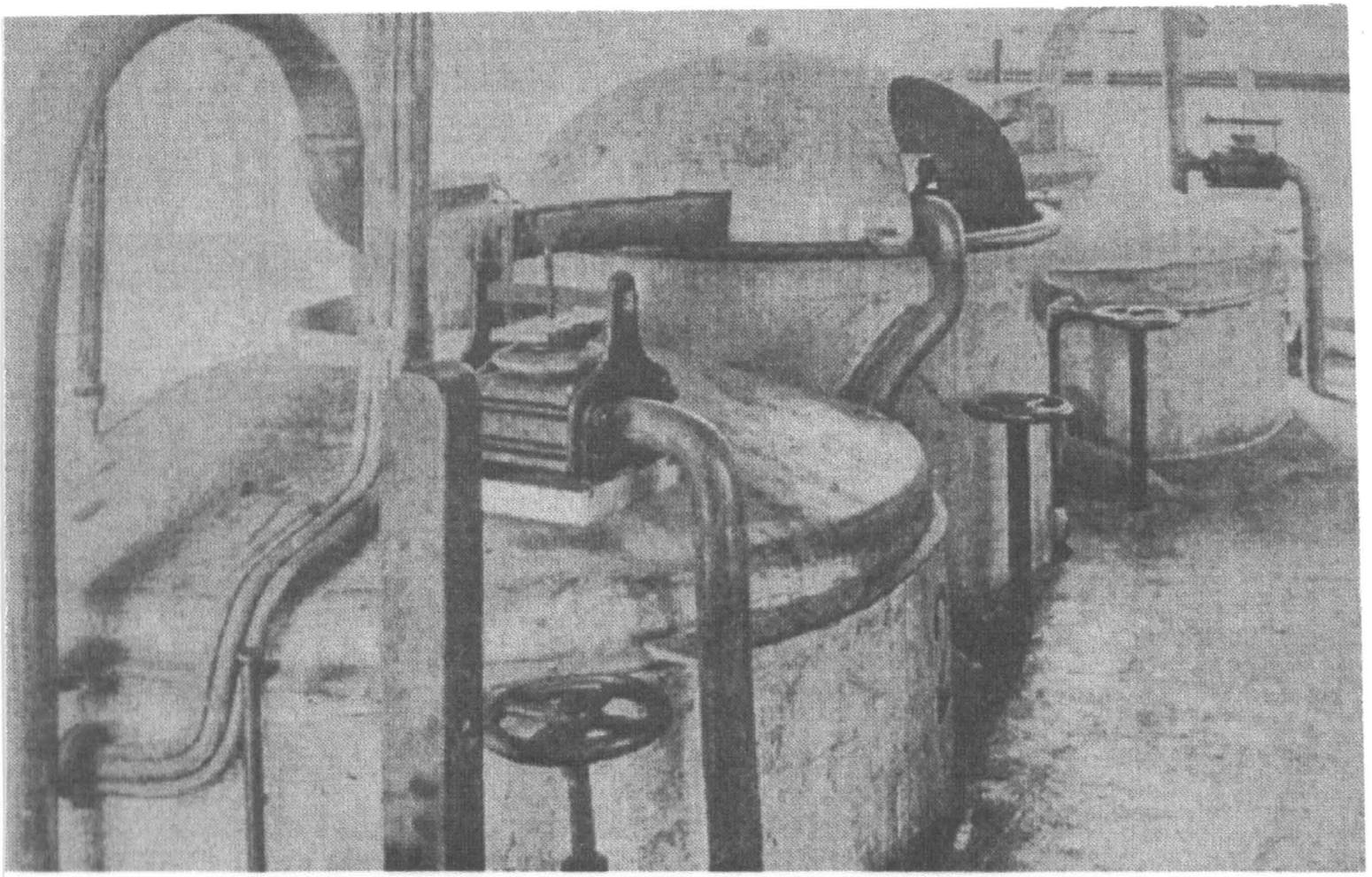
Schmid Nitrator (Royal Naval Cordite Factory 1930's)

WALTHAM ABBEY GUNPOWDER FACTORY.

NITROGLYCERINE.

The following are examples of a "Use Lists" for various houses and are the only authorised articles permitted:
Lists were posted on a board outside each house and also showed the quantity of explosives and the number of men allowed in accordance with the usual practice in explosive factories as required by HM Inspectors of Explosives.

2 NITRATOR-SEPARATORS
WITH PRE-WASH TANK IN BETWEEN.
(ROYAL NAVAL FACTORY-1930's)



2 Nitrator-Separators with Pre-Wash Tank in between
(Royal Naval Cordite Factory - 1930's)

ROYAL GUNPOWDER FACTORY.

North Site.

Quinan Stove.

Experiments took place in the designs of structures to militate against the effects of accidental explosions. Work on a Quinan type guncotton drying Stove began in 1934 and construction was under way by July 1935.

It presents a contradiction between its contemporary design and the outmoded technology it housed, together with its continuing dependence on barge transport. It was built on the Hyrib construction principle, employing rail pattern girders firmly anchored in theground. Its roof members were lightly secured, so that in the event of an explosion the walls would offer considerable resistance and the pressure would be relieved through the roof. To reduce danger from flying debris the wall panels were infilled with wire mesh, rendered in pumice concrete. Other features were standard in explosives industry buildings, including external lighting, lightly wired glass windows, a gritless asphalt floor, and doors which opened outwards. Internally it was lined in painted calico. It was divided internally into 15 bays.

Danger Precautions.

Precautions included a police force dedicated to rooting out all items of smoking. In peacetime,workers found with a few flakes of tobacco,a paper,match ot pipe on their person,would have a criminal prosecution followed by instant dismissal. In time of war they might just escape with a £5 fine-a week's wages.

On site,the workers wore special protective clothing to reduce the chance of a stray spark,and be protected from the chemicals involved in the processes. The hob-nailed boot was banned and stitched leather clogs and slippers were worn. In the most dangerous areas,primarily the nitro-glycering works,the railway was reduced to a hand-worked tramway with leather-lined carriages running on a spark-free wooden track.

To reduce the dangers of explosion from the tools used in the process,all metals were phosphor bronze or lead,and rooms were lined with wood,leather or lead. In some cases virtually the whole floor of some buildings were lined with interlocking sections of elephant hide and one such building survived into the 1990s. Thick leather buckets fashioned from hide were used.

By 1940,for newer items,there was a general move towards the substitution of rubber for the leather but with the superior longevity of the leather item,both materials were to be employed side by side for a further 50-years. With a general resistance against the mechanical,all jobs employed tools long out-dated. Wooden knives and gunmetal chisels were never to match their steel counterparts.

The temperature of the rooms in which the work was carried out was a critical factor. An extensive network of lagged steam pipes snaked through the site carrying a means of heating the individual process buildings from a central boiler room. Inside the building,the heat was by means of a radiator. As most processes required a temperature of 70-degrees F (21c),the network of pipes was an important feature in winter. Standing instructions were that all work would cease if building temperatures fell below 50-degrees F (10 degrees C).

Lyddite.

Another product was the explosive substance known as Lyddite, of which picric acid was the chief constituent. The acid stained everthing with which it came into contact a bright yellow and those men working in that particular part of the factory were easily recognisable by their yellow tinged skin and hair. A formidable explosive. Lyddite was also found to be of great value in the treatment of burns.

SCHMID NITRATOR
(ROYAL NAVAL CORDITE FACTORY 1930's).

E2 NITRATING HOUSE EXIT TUNNEL for GUTTERING (1981).

QUINAN GUNCOTTON DRYING STOVE.

Experiments took place in the design of structures to militate against the effects of accidental explosions. Work on a Quinan type guncotton drying stove began in 1934 and construction was under way by July 1935. it presents a contradiction between its contemporary design and the outmoded technology it housed, together with its continuing dependence on barge transport. it was built on the Hyrib construction principle, employing rail-pattern girders firmly anchored in the ground. Its roof members were lightly secured, so that in the event of an explosion the walls would offer considerable resistance and the pressure would be relieved through the roof. To reduce danger from flying debris the wall panels were infilled with wire mesh, rendered in pumice concrete. other features were standard in explosives industry buildings, including external lighting, lightly wired glass windows, a gritless asphalt floor, and doors which opened outwards. Internally it was lined in painted calico. It was divided internally into 15 bays.

Their principle was rapid drying of guncotton in small quantities. the advantage of this new system was that it greatly reduced the amount of guncotton in a stove at any one time, while maintaining an efficient through-put by a speedier drying time.

QUINAN GUNCOTTON DRYING STOVE.

BAYS INSIDE THE STOVE.