THE ROYAL GUNPOWDER FACTORY

WALTHAM ABBEY.

THE MAKING OF THE PROPELLANT CORDITE.

Cordite.

Abel and Dewar patented their invention of Cordite,,British Patents 5,614 and 11,664 of 1889. This is not the place to go into the involved story of the repercussions,but there were several patents which claimed to anticipate them; Nobel,s Ballistite patent,one by Engel,one by Maxim and lastly one (B.P. 13,308/1888) by Mr.A.Anderson of the Royal Laboratory,Woolwich,and Mr.I.M.T. Anderson of the New Explosives Co.,Ltd.,Stowmarket. The last seems to have been particularly annoying to Abel and Dewar. To quote from their report....."This patent was taken out in November 1888 by special permission of the War Office,upon the recommendation of the late Director General of Ordnance Factories (Dr.W.Anderson) and without any conditions being imposed,for the production of a smokeless powder from gun-cotton gelatinized by means of a solvent. The complete specification of this patent was lodged some time after the Committee had been engaged in experiments in the Arsenal on the production of Cordite,the nature of which could not but become known to Mr.Anderson in his official capacity in the Department where part of the Committee's work was carried on and it included a claim which was not indicated in the provisional specification,namely that of employing explosives generally in the form of threads,strips,cylinders and tubes produced by squirting materials through holes or slits in metal or other plates". Such a serious view of the possibilities of this specification was taken that the Cordite Patent was kept secret lest possible proceeding by the Anersons might have led to the disclosure of details of manufacture not enlarged upon in the specification

Opposition came,however,not from any of the surprisingly numerous Andersons,but from Alfred Nobel,who claimed that the Cordite Patents infringed his Ballistite patent (B.P.1471/1888) and that,in evidence he had given Abel's Committee,he had revealed manufacturing details of Ballistite that had been of great service to the Committee in evolving the manufacture of Cordite,but there seems to be no evidence that what he told them was of any real value to them. Although the War Office offered Nobel a joint interest in the discoveries of both sides,negotiations came to an end and the case eventually came before the Courts in the form of a friendly action. Nobel lost the case and Mr.Justice Romer said in his judgement that Abel and Dewar had solved the problem Nobel had left unsolved,that of making a good powder of insoluble nitrocellulose and nitroglycerine. It would be an unwarrantable extension of Nobel' patent to hold that it covered the use of guncotton when the patentee had expressly limited himself to the use of soluble nitrocellulose.

At this period of his life Nobel was involved in a series of misfortunes. Both his mother and his elder brother died,his own health,was bad,political and economic difficulties had assailed his French company and his neglected mistress was having a child by an Austrian Officer. Schuck and Sohlmann quote the judgement in the case in full and there seems no doubt that it was a just one,but Nobel bitterly resented it and carried the case to the Appeal Court and the House of Lords,thereby incurring costs to the tune of £28,000. Still indignant,he started to write a satirical play called "The Patent Baxillus",but he seems to have had little grounds for complaint as his company received orders from the Government for making cordite and were also allowed to make it for various foreign governments including the Japanese.

CORDITE.

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By 11th May,1891 complaints were already being received of irregular performance of Waltham Abbey Cordite and the Superintendent wrote in reply to an Ordnance Committee minute that he was really not surprised at irregular results as arrangements were far from satisfactory. "It is incorporated here,pressed at Woolwich mixed here-for you cannot call it blending-and,so far as I am aware,never tested before it is issued,"

By 20th May,however,a considerable degree of success had been achieved for we find Thomson,the manager asking Skerman (the foreman imported from Woolwich) how many men and boys he would require to press,reel and cut two tons of cordite a week,if he had enough presses,etc. Pressing started at Waltham on 17th June,and on the 7th July the Explosives Committee paid their last visit of inspection to Waltham. Cordite had been well and truly launched by this band of pioneers.

A day or two later (10th July) D.G.O.F. wrote to the Superintendent saying that it was absolutely necessary that energetic steps should be taken at once to ensure a considerable and regular output.

The Superintendent,not without reason,seems to have been more than a little annoyed. He wrote a long and somewhat heated reply showing how much he had done and continuing "I must,however,impress upon you the absolute necessity of having my demands met with a greater degree of promptitude than has hitherto been the case". He showed how his demands were held up at Woolwich whatever their nature,quoting examples of steam pipes,an enlarged porch for the dry guncotton stove,trucks for transport of cordite and additional presses for the manufacture of rifle material,and said that these instances showed how no amount of energy on his part could avail so long as such a state of things was allowed to exist. The minute received an unpromising reply,but ten days later the Derector-General visited the factory and settled all outstanding matters to the satisfaction of the Superintendent. On the 5th August,however,we find the Superintendent writing to Superintendent of Building Works to point out that he could not proceed with the manufacture of Cordite at night until the new electric lamps were put into the press house.

In spite of all these difficulties progress seems to have been good and a fair amount of experimental work was done,for by the middle of August it had been decided that the spirit drying process for guncotton was not a success and authority was being sought for the purchase of more land at Quinton Hill as no suitable site for more drying stoves could be found "owing to the dangerous nature of this process and the proximity of adjacent buildings."

CORDITE.

On July,10th,1888 the Secretary of State appointed a committee to consider questions relating to new explosive agents and to new applications of,or improvements in,the production and application of,known explosive agents. This committee,known as the Explosives Committee, had Sir Frederick Abel as its President with Professor J. Dewar and Dr.A.Dupre as its Members,the Secretary being Capt.J.H.Thomson,R.A. It was a committee which acted with remarkable speed and efficiency and interpreted its duties more widely than might have been expected.

Their first meeting was held within a week of appointment and on 20th August,1888 they wrote to the Director of Artillery,stating that their entry upon work necessitated early consideration of the following functions not specifically dealt with in the Circular of Instructions issued to them.

1. To examine into and report on the novelty and merits of explosive inventions.
2. To afford advice and assistance in connection with new applications or modifications of known explosives.
3. To watch the progress of invention and keep the authorities informed and advised with regard to recommended course of action in regard to fresh advances here or abroad.
4. To pursue experimental investigations having for their object the advancement of knowledge of explosives and the originating of improvements and inventions in their manufacture and use.

The Committee were of the opinion that No.4 represented their most important duty,but pointed out that any success they had would not be regarded with favour by the explosives makers,and that they would inevitably come under the stigma of not being impartial judges and of profiting by information imparted in confidence. They pointed out that no facilities or resources were being given them and that there was not even any possibility of secrecy,and that therefore they could only secure to the Government the practical results of their official investigations by taking out patents.

They stated that it was essential that regulations should be laid down under which all officials producing inventions bearing on service requirements would have the right to take out patents with the approval of the Government,securing them in the public interest,but giving the inventor the option of taking out foreign patents at his own expense in all cases in which the Government does not consider it necessary in the interests of the Service to secure secrecy.

To this very reasonable suggestion no reply was received,but there can be no doubt that the present procedure with regard to such patents is based on it.

There can be little doubt that one of the reasons for the appointment of this committee was the fact that in 1886 the French had brought out the first successful smokeless propellant,the famous "Poudre B". This was made by gelatinizing a mixture of guncotton and collodion cotton with alcohol and working up the paste to small squares of a dry horn-like material.
For some 30 years Abel and others had been trying to moderate the force of nitro-cellulose so as to apply it to ballistic purposes,but the French material was the first which gave good results. There can be little doubt that the Service Authorities in this country were seriously disturbed by this spectacular advance.

CORDITE.

The Committee examined all the many powders which were being hawked about and for which startling and totally unsubstantiated claims were being made. They turned down one after another after fair but rigorous trial. In December 1888,however,Nobel submitted two samples of an entirely new type which gave very promising results. These had been manufactured at Nobel's factory at Honfleur. They were,in fact,the first samples of "Ballistite" and consisted of a mixture of nitro-glycerine and soluble nitro-cellulose with camphor as a plasticizer. The material was not affected by damp,but evaporation of the volatile camphor on exposure to the air rapidly affected the ballistic results. In every other way the powder gave the sort of results the Committee was looking for. On receipt of a report to this effect on 25th April,1889 Nobel promised to submit samples in which camphor had been replaced by some substance not liable to evaporation. He did not do so,and,according to the Committee,did not appear to realize sufficiently the importance of what they had told him.

The Committee thereupon took steps to investigate experimently the production of a substitute containing no volatile ingredients. They used guncotton instead of soluble nitrocellulose and adopted a method of manufacture slightly different from Nobel's in that the ingredients were kneaded together with a solvent such as acetone,afterwards removed by stoving,instead of being worked between steam heated rollers without a solvent. They quickly obtained promising results and also hit on the idea of making up the charge in the form of a bundle of wires or rods of a length to occupy the whole of the powder space of the cartridge. The material was produced in this form by forcing the preparation while in a suitable plastic state through a die of the requisite diameter.

The mixture,numbered 128 in the original series,became "Cordite,Mark 1". It's composition was:-

Nitroglycerine	58
Trinitrocellulose	37.
Vaseline	5.

The name "Cordite" appears to have been first used in the Proceedings of the Committee for 5th June,1889. Before that the material had been referred to as "Cord Powder" or "The Committee's modification of Ballistite". On 27th March a meeting between the Director-General of Ordnance Factories,the Superintendent,R.G.P.F. and the President of the Explosives Committee had taken place to consider the manufacture at Waltham Abbey,and it may well be that the more convenient name had been suggested at that meeting.

Exactly how the work of the Committee was being financed is a matter of conjecture. The Director of Artillery on 4th April,1889 approved the further expenditure of £100 to cover expenses of manufacture at Waltham Abbey. When that was exhausted he would require a progress report and a statement of further requirements. The committee replied that progress was such that they anticipated the amount would be considerably exceeded in the current year,but they would report in due course. In June the President forwarded to D.of A. a letter from Messrs. Easton and Anderson (Engineers) describing in general terms the machinery they had designed for the manufacture of Cordite. The cost was to be about £100. This modest expenditure was forthwith approved and work proceeded.

Sir Frederick Able

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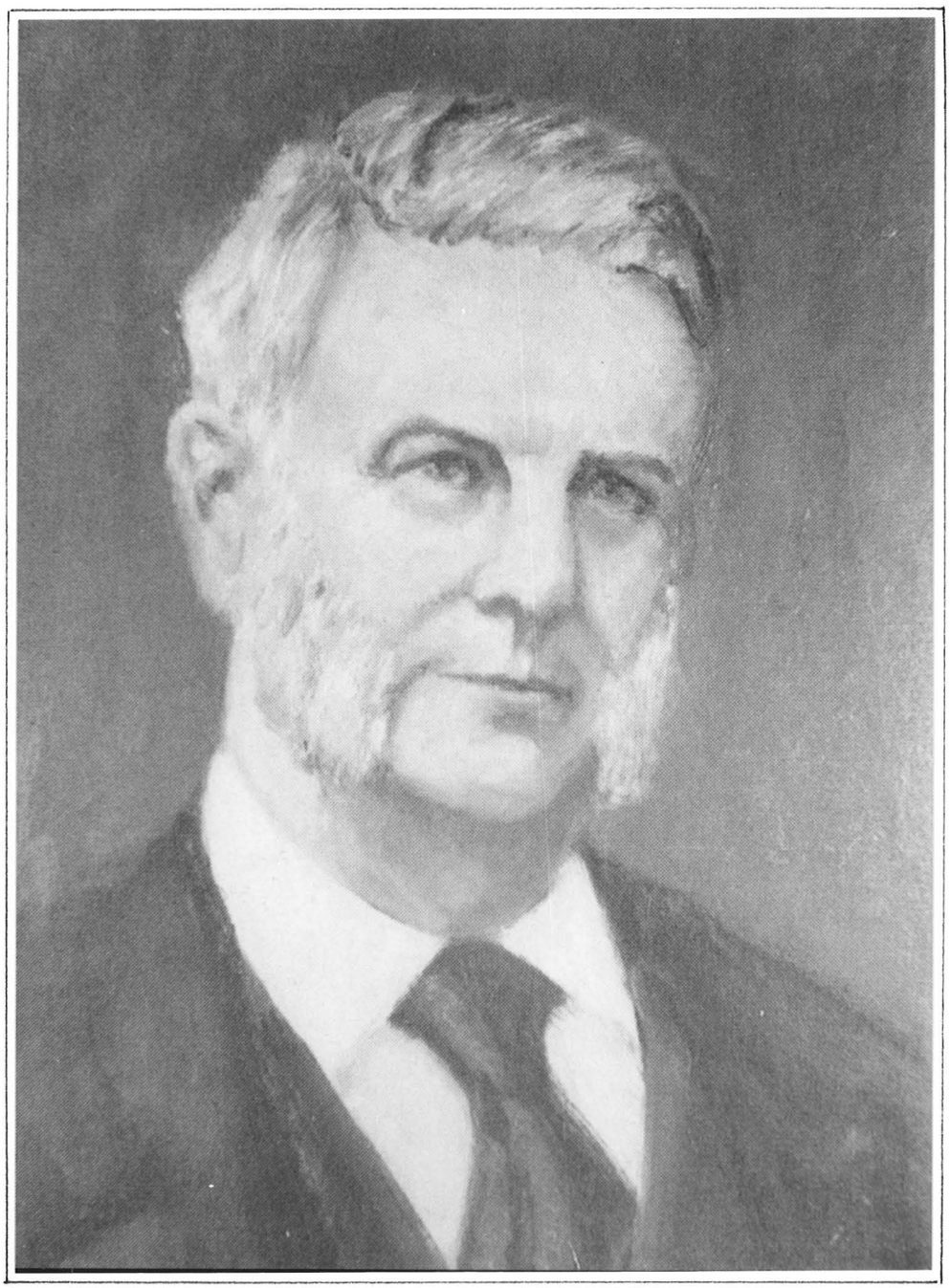

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In September Capt. Thomson,R.A. who had been Secretary of the Explosives Committee,was appointed Experimental Officer for Cordite,his duties being to carry out and record all experiments with Cordite required by D.G.O.F.,reporting the results to him. This appears to have been a further blow to the authority of the Superintendent as apparently he was not even to be informed of the results of experiments.

In spite of all difficulties and opposition the triumphant march of Cordite continued and on 6th October,1891 the Superintendent wrote a long minute to D.G.O.F. setting out his requirements to make 2 million pounds of cordire a year,only to be informed that "there is no doubt that half the supply of Cordite will be obtained from the trade." The equivalent of the make of black powder at Waltham would be half the quantity mentioned,and the Superintent was to supply details of modifications required to bring output up to that figure. The acquistion of additional land for this purpose (Cob Mead) was approved by the middle of October and by the end of the month the Superintendent was able to detail his requirements without,however,assigning positions to buildings until he knew just how much land it was proposed to acquire and until the results of a proposal to deliberately fire a cordite stove were known. It is clear that,although operations had been so bar carried through without accident,the dangerous nature of the manufacture was becoming clearly recognised and more detailed information on the risks involved demanded.

The general manufacture of Cordite by private firms,apparently imminent in 1891,did not commence until 1894,when the National Explosive Company and Kynoch Ltd. were each given a contract for 600 tons to be delivered over three years at a price of 2/10½d. a pound,although in 1891 Superintendent Waltham had reported his cost to be 2/- to 2/6 a pound and inprovements to reduce that figure considerably could be foreseen. The highest tender sent in was 4/3 and 2/10½ was the lowest so the bargain was perhaps not an unreasonable one.

The firms were also apparently allowed to sell Cordite elsewhere if they could and Kynochs were soon to supply the Japanese Navy with it. But when the contract was placed they had not as much as a hut or a fiels,let alone the plant for manufacture. The commenced by placing a contract with Nobels to supply the Cordite paste and only did extrusion,drying,and blending themselves,though apparently they soon started making nitroglycerine and guncotton for some part of their output. In 1900 they admitted at the enquiry of the Select Committee on War Office contracts that they were importing guncotton from Germany,and by that time the price was down to 1/10½.

Nobels had built a Cordite factory at Ardeer in 1893/4 and the loss of the sole contract must have been somthing of a blow to them,but they appear to have started exporting at an early date and,after the nitroglycerine explosion at Waltham in May 1894,Nobels and the others came to the assistance of the Government to produce between that date and June 1898,1000 more tons of Cordite than they would otherwise have done,but it was not until January 1899 that Nobels received another order for Cordite from the British Government,and it is hardly surprising to see that in 1900 they were not very enthusiastic when the Government started to press for greatly increased output and in their reply stated that they would want earl notice of requirements as they had to accept orders from Foreign Governments who were willing to pay higher prices. They would,however,if it were made worthwhile,decline such business and restrict their manufacture largely to the requirements of the British Navy and Army.

CORDITE.

Although one of the factors that had decided the Explosive Committee to standardize on the use of Mineral Jelly in cordite,was the lessening erosion and corrosion in guns,it was found in the Boer War that this was still serious and in 1901 Cordite M.D. was introduced to effect a further improvement. In this the proportions of guncotton and cordite were practically reversed,thus making the composition:-

Guncotton	65
Nitroglycerine	30
Mineral Jelly	5

This considerably reduced the temerature of explosion with greatly improved results as far as the expectation of life of guns was concerned,and M.D. remained the standard cordite until 1915 when circumstances compelled a further change.

When M.D. was introduced the output of the factory was considerably increased by increasing the guncotton plant and acquiring fresh land for the erection of cordite stoves to the south of Quinton Hill. These extensions were completed by 1906.

It was not very long after the introduction of Cordite M.D. that the first serious accident in cordite manufacture at R.G.P.F. took place. On 15th December,1902 an incorporating machine blew up,killing three men. No entirely satisfactory explanation was forthcoming,but the occurrence led to a further tightening up of regulations particularly as regards inspection and mixing of the paste and ingredients,and nothing of the sort ever took place again.

In 1901-2,two of the very remarkable team of Chemists then employed at the Factory under the inspiring leadership of Sir Frederick Nathan,Dr.R.Robertson and Mr.W.Rintoul,commenced experimenting on the recovery of acetone from the cordite stoves by the bisulphite process. It was not until 1906 that a plant on these lines was completed and put into operation. It proved very successful,saving about 50% of the acetone used and was in operation until 1918.

At the outbreak of the 1914-1918 War the output of cordite was 26 tons a week. This was stepped up immediately to 57 tons and by March 1915 had reached 64 tons. This was all done without any new plant,but in the Autumn of 1914 orders had been received to increase production of rifle cordite to 20 tons a week and cannon cordite to 120. This was completed within a year of the outbreak of the War. At this point,in August 1915,the factory was transferred to the Ministry of Munitions and by various extensions the capacity was incresed to 200 tons of Cordite M.D. About the end of 1916 the shortage of acetone compelled the new Cordite R.D.B. to be used for all large sizes. R.D.B. was a wartime development and consisted of 52% Collodion Cotton,42% Nitroglycerine and 6% Mineral Jelly,ether-alcohol being used as a solvent.

The years between the wars were years of depression at the R.G.P.F. but the small staff remaining there did a great deal of valuable work with the very limited means at their disposal. Not only was the plant maintained in good order but much investigational work was carried out. Solventless cordite and flashless cordite owe much to the early plant work that was carried out by the staff in those critical years,but perhaps the most outstanding feature was the development of "Cordite W". Between 1928 and 1932 guncotton was made with a mixture of 50% linters and 50% cotton waste. In 1932 it was found that cordite made from it gave corrosion spots on climatic trial which definitely shortened the life of the cordite. It was decided to revert to the use of cotton waste only but possible dangers had been shown up. The corrosion usually centred round foreign bodies and a new type of straining arrangement was designed which led to greater freedom from foreign matter in the cordite. It was also felt that a more efficient stabilizer than mineral jelly was required and as a result of experiments carried out by H.A.Phillips and P.G.Kmapman it was decided to use 6% of "carbamite" (diphenyl diethyl urea). This cordite was first produced in 1933,and proved very much superior to its predecessors as regards stability.

At the same time other qualities were being called for in cordite. Freedom from flash and smoke became of increasing importance as also did more rapid methods of manufacture which did not demand extended periods of stoving.

The first of these problems was solved by the use of "picrite" (nitroguanidine) which was suggested by the Research Department at Woolwich. A cordite containing 55% of this material was made at Waltham in 1928. Various compositions of this type were tried and eventually wartime manufacture settled down to compositions containing approximately:

55% Picrite
20% Guncotton.
20% Nitroglycerine
4.7% Carbamite.
0.3% Cryolite.

Such compositions are stable enough to allow the use of wood and straw cellulose in place of cotton and give almost complete freedom from flash and smoke.

The "solventless" process,by eliminating the use of volatile solvents such as acetone,does away with the necessity of stoving and the large ground area and many buildings required for it. The time occupied in drying cordite,particularly the large sizes,is very considerable and when production is urgent this can be a serious drawback. Compositions made in this way normally contain nitrocellulose (12.2% N2) and its gelatinization by nitroglycerine is enhanced by the presence of carbamite. A further advantage of the solventless process is the much greater safety resulting from the fact that a wet slurry of guncotton is mixed with nitroglycerine and thus the drying of guncotton and dry mixing are completely avoided.

In addition to its duties as a producing factory Waltham continued to do a great deal of experimental and pioneering work on various types of cordite right up to the time it closed in 1943.

Manufacture of Cordite Mk1 and Cordite MD.

These propellants contain nitroglycerine which is manufactured by nitrating glycerine,in approximately 1,500-lb batches,in a special nitrator which contains no pipes with cocks,and which is provided with cooling coils (brine) and air under pressure for agitation.

The mixture of concentrated sulphuric acid and nitric acid is run into the nitrator,and the glycerine charge introduced beneath the surface of the acid. The temperature of nitration is kept at 10-degrees Centigrade by adjusting the speed of addition of the glycerine and the brine flow through the coils. The time of nitration is about 1-hour.

The nitroglycerine which separates on the surface of the waste acid is displaced into a preliminary washing tank and then subjected to a thorough washing treatment and finally dried by a filtration method.

The nitrocellulose used in cordite is known as guncotton,and contains 13% of nitrogen,almost the maximum quantity which can be introduced from the point of view of chemical stability. Although it is blended intimately with the nitroglycerine in the finished explosive,guncotton will not dissolve in nitroglycerine under ordinary conditions.

In the manufacture of cordite,the guncotton is first dried in a current of warm air in stoves,this operation having to be done with extreme care on account of the tendency of dry guncotton to fly about as dust and of its highly sensitive character. The correct quantities of dry guncotton and nitroglycerine are first blended to some extent together by hand,and are then introduced into an incorporating machine,this consisting of a covered metal box,in which a double worm revolves,giving a kneading motion to the material in the mixer,together with the requisite quantity of acetone. For the manufacture of Mark 1 about 23%,and for M.D. about 40%,of solvent is required. After working for about 3½-hours,when most of the guncotton has been gelatinized and blended with the nitroglycerine,the mineral jelly is added,and the working continued for an equal time. The resulting mass,which has a dough-like consistency,is pressed through a die and formed into cords. These are dried in stoves at 110-degrees F.,until practically the whole of the solvent has been evaporated.

Manufacture of N.C.Z.

The propellent is made from two nitrocelluloses of different nitrogen contents,one of which alone is gelatinized in the final powder. In the first instance,the nitrocelluloses are carefully blended in a pulped condition by stirring under water. The mixture is wrung so as to leave about 30% of water in it and then dehydrated by placing it in a cylinder in which it is first squeezed and then treated with alcohol,which is run into the top of the cylinder,gradually displacing the water and finally completely dehydrating the nitrocellulose. The block of nitrocellulose containing a definite proportion of alcohol is then broken up in a rotating drum and placed in an incorporating machine. This consists of a covered metal box,in which a double worm revolves,giving a kneading motion to the material in the mixture. At this stage a proportion of ether,together with a small quantity of graphite and diphenylamine is added. After mixing for one hour,the nitracellulose mixture,which has been partly gelatinized by the solvents,is transferred to a press in which it is subjected to a pressure of 1,800 lb. per square inch.

The block so formed is then extruded as cords through a die containing many holes,the motion helping to effect further gelatinization.

The cords are reformed into a block by pressure and finally extruded through a multi-holed die which forms this into a number of tubular cords. Each cord is collected separately and is subsequently run through a cutting machine,by which it is cut into short lengths.

The chopped grain is partly dried in a slow current of warm air from which the solvent is recovered,then immersed in water which displaces most of the residual alcohol.

The grains are then placed in a tumbling machine under warm water,together with the requisite quantity of dinitrotoluene,and worked until the whole of this substance has been absorbed into the surface layers.

The propellent is finally dried in air,until it contains the correct amount of moisture,and blended in large batches.

It is noteworthy that the gelatinizing solvent used for nitrocellulose powders is ether-alchol and not acetone,the product from the latter solvent being much too brittle.

THE YEARS BETWEEN THE WARS.

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DEVELOPMENT OF CHEMICAL EXPLOSIVES.

19th CENTURY

THE QUINTON HILL NITROGLYCERINE FACTORY.

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 nitrocellulose 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.

DEVELOPMENT OF CHEMICAL EXPLOSIVES.

The following is a historical synopis of main developments in chemical explosives.
These developments reflected the constant quest for more explosive power, more economy, more controllability- in the civil field particularly for blasting in mines, quarries, tunnelling, construction etc. and in the military area for propellant and high explosive.
Organic chemistry provided the way forward. An explosion is a very rapid chemical reaction, normally oxidation - conbination with oxygen. It was discovered that the introduction of the molecular nitro group N02) served as an internal source of oxygen for the oxidation of the carbon and hydrogen 'fuel' atoms in carbohydrates such as cellulose or the fats such as glycerine, created the conditions for a more powerful explosion. This arose from the relatively unstable attachment of the constituent oxygen and nitron atoms of the nitro groups. On firing, the less stable oxygen-nitrogen linkages undergo sudden disruption and the simultaneous union of the atoms of carbon and hydrogen with those of oxygen accompanied by liberation of an enormous amount of heat energy leads to instant production of a very large volume of gaseous product, with explosive effect.

NITRATION.

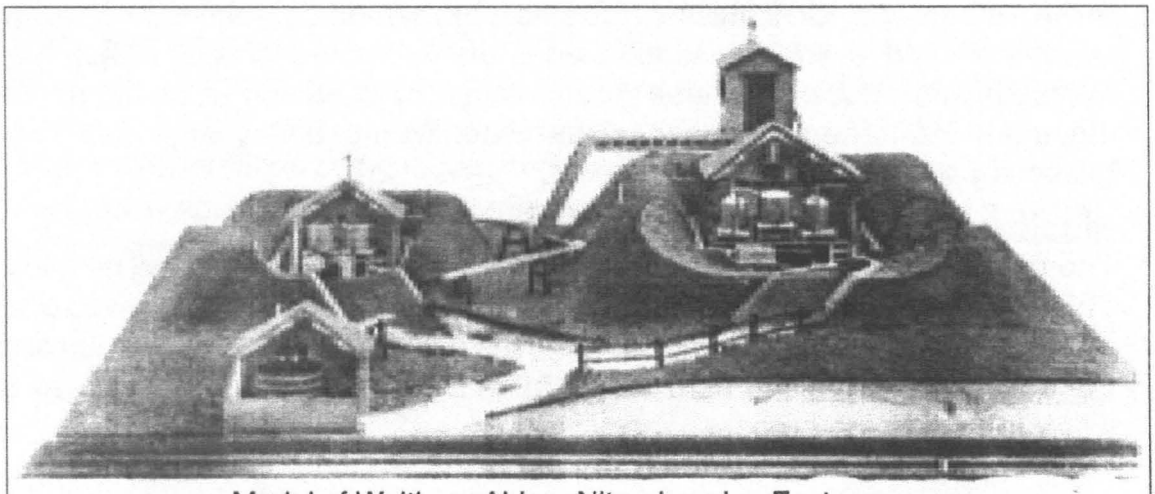
The mode of introduction of the nitro groups is the process termed nitration. This involves treating the parent organic compound with a mixture of concentrated and sulphuric acids, the nitric acid bearing the nitro group and the sulphuric acid acting as a dehydrating agent facilitaing the removal of water formed in the process.
1833 - Braconnot nitrated starch.
1838- Pelouze treated paper and cotton and various other materials with strong nitric acid, producing highly flammable materials.

NITROCELLULOSE.

1846- Schonbein and Bottger developed the process by using a mixture of nitric and sulphuric acid to nitrate the carbohydrate fibrous cotton cellulose producing the nitric ester cellulose trinitrate or nitrocellulose as it became known, or guncotton reflecting its military application. Schonbein patented guncotton and it did not take long for private industry to become aware of the potential for commercial blasting purposes of this new more powerful material. In the same year John Hall & Son of Faversham obtaining manufacturing rights, built a factory and were offering guncottn with a claim that 4 ounces of guncotton equalled 24 ounces of gunpowder an impressive demonstration of the turn of speed which the Victorian entrepreneur could raise when introducing a new product into the competitive market place. However, regrettably, the Halls also demonstrated the validity of the saying 'more haste, less speed' for in the following year their guncotton factory was destroyed by explosion and civil development went into abeyance.

MILITARY EXPLOSIVES NITROCELLULOSE (CELLULOSE TRINITRATE) GUNCOTTON.
In development of nitrocellulose the emphasis was on the military application, hence the generalised term guncotton.
Guncotton was an unstable material prone to spontaneous decomposition and there were further accidents, in France, almost to the extent of stopping further development. However the Austrians in particular persevered and in 1862 permitted the War Office chemical advisor, later Sir, Frederick Abel to visit Baron von Lenk's experimental facility at Hirtenberg to gather information. Abel correctly deduced that purification to remove residual nitric acid was the key to safer manufacture. Abel and his team at Woolwich and Waltham Abbey developed a system whereby after acid dipping firstly the bulk of the acid was removed by centrifugal action then vigorous agitation in water followed by boiling then beating into a pulp followed by poaching 1.e. stirring in water - the latter two operations being introduced by Abel, finally alkali being added as a precaution against any residual acid before pressing into finished material.
By 1865 Abel had sufficient confidence in the efficacy of his methods to take out a patent. This year could therefore be taken as the commencement of guncotton as a practicable manufactured material. One problem remained - dry guncotton was still a very sensitive material, making storage transportation and use difficult. The problem was eliminated by the discovery in 1868 by a member of Abel's team E.).Brown that guncotton in its safer wet state could be stored for long periods and detonated by a small quantity of dry nitrocellulose fired by fulminate of mercury.
At a rapidly increasing pace guncotton was then adopted for use in military mines, torpedoes and blasting charges.
In 1872 a full scale production unit producing 250 t.p.a. was erected at Waltham Abbey. However, Abel's goal of developing guncotton in granular form as a military 'smokeless powder', i.e. propellant and shell filling, eluded him. Its rate of burning was too speedy.

THE FIRST SMOKELESS POWDER.
Poudre B- Guncotton based - Vielle 1886.
It fell to the Frenchman Vielle to produce the first chemically based propellant- smokeless powder- guncotton based, 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 cotton gelatinised, working 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%.



Model of Waltham Abbey Nitroglycerine Factory
Exhibited at Brussels Exhibition 1910

CIVIL EXPLOSIVES.

NITROGLYCERINE (GLYCERYL TRINITRATE)

An alternative material to cellulose for nitration was glycerol, more popularly known as glycerine, derived from fatty acid (discovered by the Awede Scheele in 1779 and popular as a remedy for skin chapping) and in 1846, the same year as Schonbein and Bottger's work on nitrocellulose had been publicised, Sobrero discovered the explosive properties of an oily compound made by nitrating glycerol which he termed piroglycerine and which later came to be known not entirely accurate as nitroglycering. The discovery trmained of academic interest as, unlike gunpowder or guncotton, no method of detonation by fuze could be discovered. However the attractions of the material in chemical and operational terms were noted - in gunpowder the fuel and oxidant elements were separate and had to be incorporated whereas in nitroglycerine they were present in intimate association in the one molecule.

When the Crimean War started in 1854 the need arose to protect the sea approaches of the Russian fortresses and Russian academics approached the Nobels, who at the time had an engineering business in St.Petersburg, seeking their aid in endeavouring to incorporate nitroglycerine in naval mines. It is possible that this was attempted in one fortress, Cronstadt, but no record exists of actual detonation.

The Nobels were Swedes and doubtless their interest was aroused by the potential for profitable business in the extensive Swedish metal ore mining industry - they had calculated that the explosive power of nitroglycerine was about 13 times that of an equal volume of gunpowder. In 1862 Immanuel, father of Alfred Nobel, produced nitroglycerine on an experimental basis and experimented with adding it to gunpowder. This did improve substantially on the explosive performance of gunpowder but the material only preserved this property for a short time.

BLASTING OIL 1863.

However in the following year 1863 Alfred Nobel discovered a method of detonating nitroglycerine by a small charge fired by a fuze or percussion cap containing mercury fulminate and a small production plant was built near Stockholm offering a product which he termed nitroglycerine with the commercial name Blasting Oil. Success was immediate. The mining industry in Sweden and very shortly worldwide siezed on it as a huge improvement on gunpowder in performance and economy and Alfred was on the way to fabulous fortune which he later used to fund the famous 'Nobel Prizes'.

DYNAMITE. 1867.

The new material was by no means perfect. Its liquid nature meant that it was dangerous to transport and handle and Nobel sought a way of transporting nitroglycerine more safely. In 1867 he found that it could be absorbed successfully in a type of imert porous silica called diatomite or Kieselguhr which he had been using as a packing material for nitroglycerine tins. The new product was termed Dynamite. The idea was that at point of use the nitroglycerine would be leached out of the dynamite. However doubtless Nobel and the users were delighted when a secure method of detonating dynamite itself without the need for extration of raw nitroglycerine was discovered

NITROGLYCERINE AND NITROCELLULOSE COMBINATION.

CIVIL EXPLOSIVES BLASTING GELATINE 1875.

Nitroglycerine and Nitrocellulose Collodion Cotton.

Dynamite did however have disadvantages particularly its propensity to exude nitroglycerine when stored. In the course of experiments to produce a non exuding dynamite Nobel discovered in 1875 that the problem could be solved by blending collodion cotton, the type used by Vieille in Poudre B, with nitroglycerine, the nitroglycerine gelatinising the cotton, in the ratio 7% collodion 93% nitroglycerine. Probably apocryphal but the story is that Nobel was led to collodion cotton by a cut finger. In solution in ether alcohol it was sold as a protective film for cuts under the term "newskin".

The new material proved to be an explosive of very high power, unrivalled for blasting hard rock, and it enjoyed immediate success under the term Blasting Gelatine.

MILITARY EXPLOSIVES BALLISTITE 1887.
In parallel with the above developments in the civil field interest in a military chemical based propellant, smokeless powder, had continued unabated.
Vieille's Poudre B of 1886 took pride of place as the first but it had disadvantages - it was dangerous in storage in certain circumstances and efforts were spurred to better it both in this aspect and explosive power.
Inevitably the arch experimenter Alfred Nobel entered the scene. He would have been aware of the potential of his nitroglycerine/nitrocellulose blend. In blasting form it was too powerful for use as a propellant, however by 1887 he had succeeded in producing a material which had the stability and slower burning qualities required for mility use. This was achieved by employing a much higher proportion of collodion- 45% and introducing 10% of camphor as a moderant of the speed pf explosion. The new propellant was termed Ballistite.

EXPLOSIVES COMMITTEE 1888.
There can be little doubt that the British Government was shaken by these developments. Whilst the efforts of Abel and his team had produced a pre-eminent position for Britain in guncotton it had not resulted in a successful propellant and it now appeared that Britain, the greatest Imperial power, was totally deficient in an area rapidly being taken over by other countries. In some haste therefore and Explosives committee with Abel as President and Dewar and Dupre as members was formed with instructions to observe and report on developments. Almost immediately they proposed to the Director of Artillery that their brief be extented to 'pursue experimental investigations having for their object the advancement of knowledge of explosives and the originating of improvements and inventions in their manufacture and use'. The Committee asked for submission of samples of smokeless powders for examination, doubtless with the implication that success would bring with it substantial contracts. Nobel submitted Ballistite. This gave promising results but these were substantially affected by the evaporation of the volatile moderant camphor. Nobel was informed of this, but for some reason did not respond with any suggestion for a substance less subject to evaporation.

CORDITE 1889.
The Committee pursued investigation of removal of the volatile ingredient and in a prodigious turn of speed reminiscent of Hall & Son in guncotton came up with what was termed Cordite consisting of a mix of nitroglycerine and guncotton combined with a solvent acetone and incorporating a proportion of mineral jelly with the intention of reducing barrel fouling.
The composition was 58% Nitroglycerine, 37% Guncotton and 5% mineral jelly.
While in plastic state the material was extruded through dies to produce rods or cords of appropriate diameter which when bundled occupied the whole of the poder space in the cartridge,

In June 1889 the Director of Artillery approved the expenditure of the princely sum of £100 to set up manufacture of Cordite at Waltham Abbey.

In 1891 Cordite was officially adopted as the propellant for the British Army's service rifle and it progressively replaced gunpowder in heavier aemaments. The days of gunpowder were finally over.

The Explosives Committee had therefore over a very short time period achieved an excellent product which had overtaken its rivals and was to serve the British Forces through various modifications for many years. However the cordite story was not without its troubles. Doubts were raised as to how far access to Nobel's work from his submission and samples had enabled short circuiting of cordite development- in fact reports of the Committee's earlier proceedings referred to 'The Committee's modification of Ballistite', without recompense to Nobel. Nobel felt strongly enough to open an action against the British Government for infringement of patent. The action failed on the grounds that there were material differences in the patent specifications -Nobel's formulation employed collodion cotton, soluble in ether/alcohol, relying instead on solubility in acetone, and the patent therefore referred to 'insoluble' nitrocellulose.
However there was a degree of opinion that Nobel had not been treated entirely fairly overall. The troubles did not end there. Abel and Dewar had been permitted to take out foreign patents on cordite and derived considerable financial benefit from this. Not for the first or last time there was

controversy over how far scientists in Government employ using Government facilities and staff should be allowed to benefit financially, apart from any internal recognition, from discoveries made. The 'Times' was sufficiently disturbed by the cordite saga to term it the 'Cordite Scandal'.

1891-1894.
The nature of nitroglycering presented critical problems of movement. Pipelines were out of the question - they could not be opened for the frequent inspection and cleaning necessary and the only practicable methods was by gravity in open lead lined guttering, covered by detachable canvas to permit cleaning. The plant was therefore dominated by two adjacent Nitrating Houses Nos1 and 2 on the summit of Quinton Hill separated by a brick traverse with a Charge House on top of the traverse. At any one time one of the Nitrating Houses would be in operation with the other down for maintenance. After nitration of the glycerine the nitroglycerine was run down the gutters to the Washing House with the waste acid run off to an After_Separation House. The washed nitroglycerine was sent to store and the wash waters to a Washed nitroglycerine was sent to store and the wash waters to a Wash Water Settling House.
It should be emphasised that production was on a batch basis, flow nitration in the form of the Schmid process was introduced into the industry in the 1930's but Waltham Abbey did not reflect this until the last days of production in the 60's.
Production progressed without major incident until there was a serious explosion in the Washing House and Nitroglycerine Store in 1894, destroying buildings, and extensively damaging surrounding buildings including the No.2 Nitrating House.

1895-1908.
Production then progressed at a steady pace; during the Boer War producing around 18½ tons of nitroglycerine per week.

Then in 1901 an explosion occurred in an earthenware cock at the base of a nitrator after the charge had been run off. Since the 1894 explosion there had been a painstaking process of investigation of plant improvement to enhance productivity, economy and safety. Althoug the effects of the 1901 explosion were relatively minor it provided a further impetus to development and in 1903 the plant in No.1 Nitrating House was replaced by that bearing the names of the senior management who had led the development effort - Nathan- Thomson- Rintoul, termed the nitrator-separator, eliminating the use of earthenware cocks in the nitrating apparatus., see Edmonsey factory commentary below, No.2 continuing on the old Nobel basis.

In the meantime due note had been taken of the Court of Enquiry' recommendation for duplicate building in 1897 a nitroglycerine facility had been built on land to the north of the North Site at Edmonsey Mead, together with associated cordite production to the south of that.

In 1903 Cordite MD was introduced, with a significantly reduced nitroglycerine content - 30%, to reduce the barrel erosion problem which had been occurring with the original material. Reflecting this No.2 Nitrating house at Quinton Hill was put into reserve. At the same time the Edmonsey Mead House was renumbered Nos 1 and 2 taking the Numbers 2 and 3 respectively.
In 1904 the Edmonsey Mead installation was updated with Nathan -Thomson-Rintoul, larger capacity, plant, what was now the Quinton hill No.2 House being temporarily reactivated to permit this.

In 1908 what had become Nitrating House No.3 with the old Nobel plant was demolished.

1909-1922.
The Quinton Hill guncotton factory continued, supplying the North Site cordite factory via the internal canal system up to the Grand Magazine at the extreme north of the site for storage then moving back down the site for drying and processing to cordite. The cordite then travelled back to the extensive Water Stoves at Quinton Hill for frying.
Nitration House No.2 stayed in reserve and from 1992 after closure of what had become the Research Establishment it and all other South Site buildings were cleared, ultimately to make way for residential, recreational and industrial warehousing development.
The rebuilt Washing house of 1894 had survived in remarkably good condition and had become a

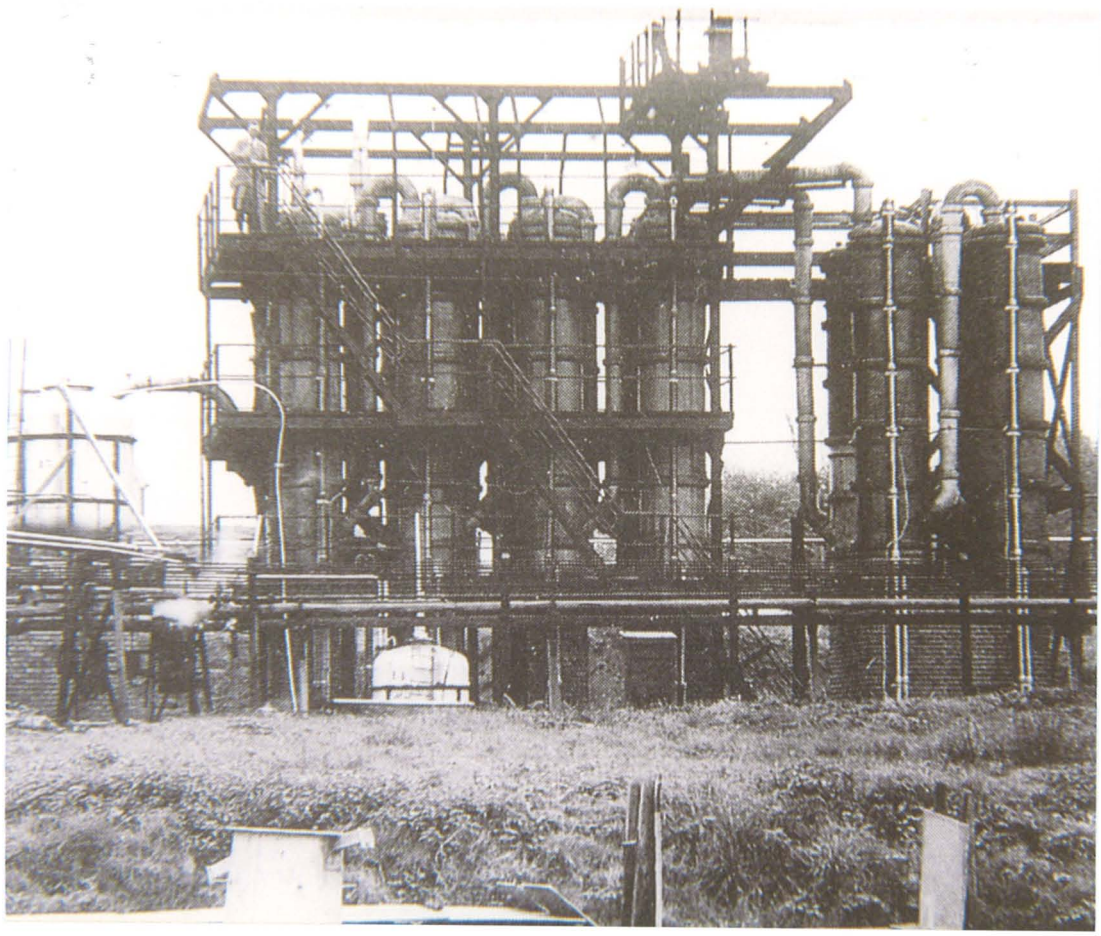
unique survivor in Britain of its type. Reflecting this it was dismantled and taken to store on the North Site, which opened as an interpretative centre in 2001, with the ultimate intention of re-erecting it.

From 1904 therefore Edmonsey Mead took on the position of prime nitroglycerine producer for the Factory.

1. The Acid Factory 1902-1943.

Quinton Hill had bought in its acids from the East London chemical industry. Edmonsey presented an opportunity to purpose build an acid factory on the site, ensuring higher concentration and purity and efficient recovery and reprocessing and in 1902 an acid factory was constructed between the Horsemill Stream on the west and the nitroglycerine factory to the east.
The plant reflected two main functions - production of nitric acid and concentrated sulphuric acid. Nitric acid production was a distillation process, based on the design of F.Valentiner whereby sodium nitrate, commonly termed nitre or Chile saltpetre reflecting its main origin and distinguishing it from the saltpetre employed in gunpowder manufacture, which was potassium nitrate, was distilled with sulphuric acid producing nitric acid and the by product 'nitre cake' - a mixture of two sulphates. Disposal of by products was and is a perennial problem in the chemical industry. On occasion as in the gas industry a profitable outlet is found. The destination of Waltham Abbey nitre cake is not known. However it is interesting to note that the Royal Naval Cordite Factory at Holton Heath, Dorset sent 50 tons per week of its nitre cake to Harpic Ltd., the makers of the well known domestic cleaner of the same name.

Acid recovery and reprocessing was an important part of the activity of the Edmonsey acid factory. Plant employed for this purpose included an after-separating house, denitrating towers to remove nitric acid from sulphuric acid, sulphuric acid concentrators. These followed the Kessler design. In the late 1830's this was replaced by the 'Evans-Bowden' design. The Kessler plant was built of acid proof Volvic lava bricks from France and the authorities became uneasy about cost and security of supply. Dr.R.C.Bowden, Superintendent at Waltham Abbey 1934-1939, devised a plant employing British made acid resistant bricks built in layers jointed with glass powder and pumice at a cost of £40 per fill compared with £600 for Volvic. This was very successful and the Evans-Bowden concentrator was built at Waltham Abbey and other governmental and private factories at home and overseas. Lt.Col. P.H.Evans was Dr. Bowden's predecessor as Superintendent, from 1917 to 1934, Dr.Bowden was the first civilian Superintendent.
The Acid Factory was a tough place to work. There was much physical handling of material in taxing conditions- constant possibility of leaking joints or burst pipes spurting acid, spills over the floor, working atmosphere heavily fume affected. In fact an eminent commentator on the chemical industry at the time evocatively termed the nitric acid process 'a laborious procedure of manslaughter'.
The Acid Factory was demolished after WW11. All that remains are floor slabs and one building - E10 Nitrate Soda Store.



THE EDMONSEY NITROGLYCERINE FACTORY
1897-1960's.

The Edmonsey Nitroglycerine Factory is now a place of mystery dominated by the nitrating 'hill' in the deserted north of the site, surrounded by the other long deserted processing buildings. The isolated nature of the surroundings and the knowledge of what was produced there evoke a strong sense of history if not foreboding in the observer.

The factory consisted of an Acid House, Charge House, the Nitrating House, Washing Houses, Filtering within the Mixing Houses, Wash Water Settling House, Mud Washing Shed and waste washing water settling ponds.

The sensitivity of nitroglycerine and the need to clean after each batch meant that it could not be transported between buildings by pipe. The flow of chemical was by gravity, in lead lined V shaped guttering supported on trestles, with canvas covers fixed on one edge and tied on the other, permittin untying for cleaning and inspection after each batch. As Edmonsey was a flat site the height necessary for gravity flow had to be created by raising the processing units on platforms within the buildings. The processing buildings were round timber structures with conical roofs set within circular brick revetments and over this earth blast traverses, giving the site the appearance of a series of grassy mounds - 'hills'. Each building had a curved brick arched entrance with red painted door indicating danger. Guttering for nitroglycerine and wash waters entered and left the buildingd through brick arched tunnels. Floors were covered in lead with the interior of the roofs lined with Willesden paper.

Processing tanks were of lead for acid resistance and also as a soft metal spark resisting.

Nitrating House Exit Tunnel for Guttering (1981)

THE EDMONSEY NITROGLYCERINE FACTORY

Acid mixing and delivery to the Charge House.

Concentrated nitric and sulphuric acids were pre-mixed and stored at the Acid Factory. The nitric acid was run into the mixing tank first then sulphuric acid was blown in by compressed air, agitation in the tank also being by compressed air. A fume pipe led from the cover of the tank to a battery of Guttmann ball towers, named after the leading explosive scientist O.Guttmann. One of his devices was the Guttmann ball, a hollow pottery sphere about the size of a cricket ball with six holes punched in the middle. These avoided the 'clogging' problems associated with the use of coke filling in condenser towers. The acid mix was then conveyed in a bogie on a tramway to a lift at the base of the nitrating hill, which raised the bogie to the Charge House. The lift was later replaced by the use of compressed air to push acid by pipeline from store tanks in the Acid House to the Charge House. The acid store tank was a cylindrical steel vessel standing vertically, termed an 'egg'. Glycerine was similarly conveyed from store tanks at the Acid Factory.

E2 Nitrating House No.1 *(circa 1900)*
showing Acid/Glycerine lift with 'Tramway' in foreground

THE EDMONSEY NITROGLYCERINE FACTORY.

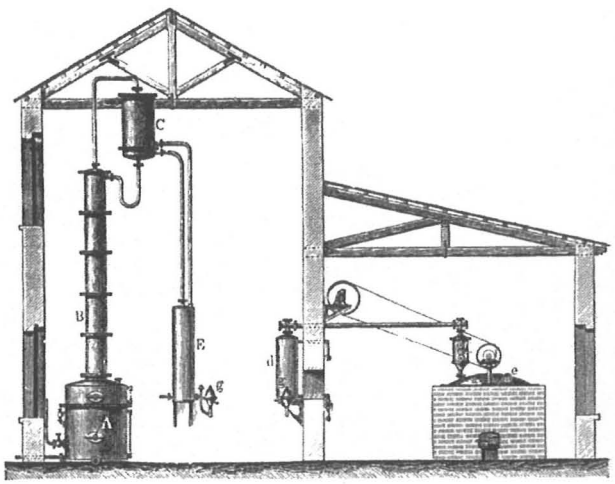
THE CHARGE HOUSE.

The Charge House was the highest point of the nitrating hill. The incoming acid level was obderved through a gauge glass and when it was slightly above the required charge level the compressed air was shut off, with any surplus above the level being drawn off in an overflow pipe, similarly with glycerine, which had been made fluid for blowing by heating. The glycerine tank in the Charge House had coils for cooling or heating as required. wash waters and soda solution were prepared in the Charge House.

EARTHENWARE STOPCOCKS.

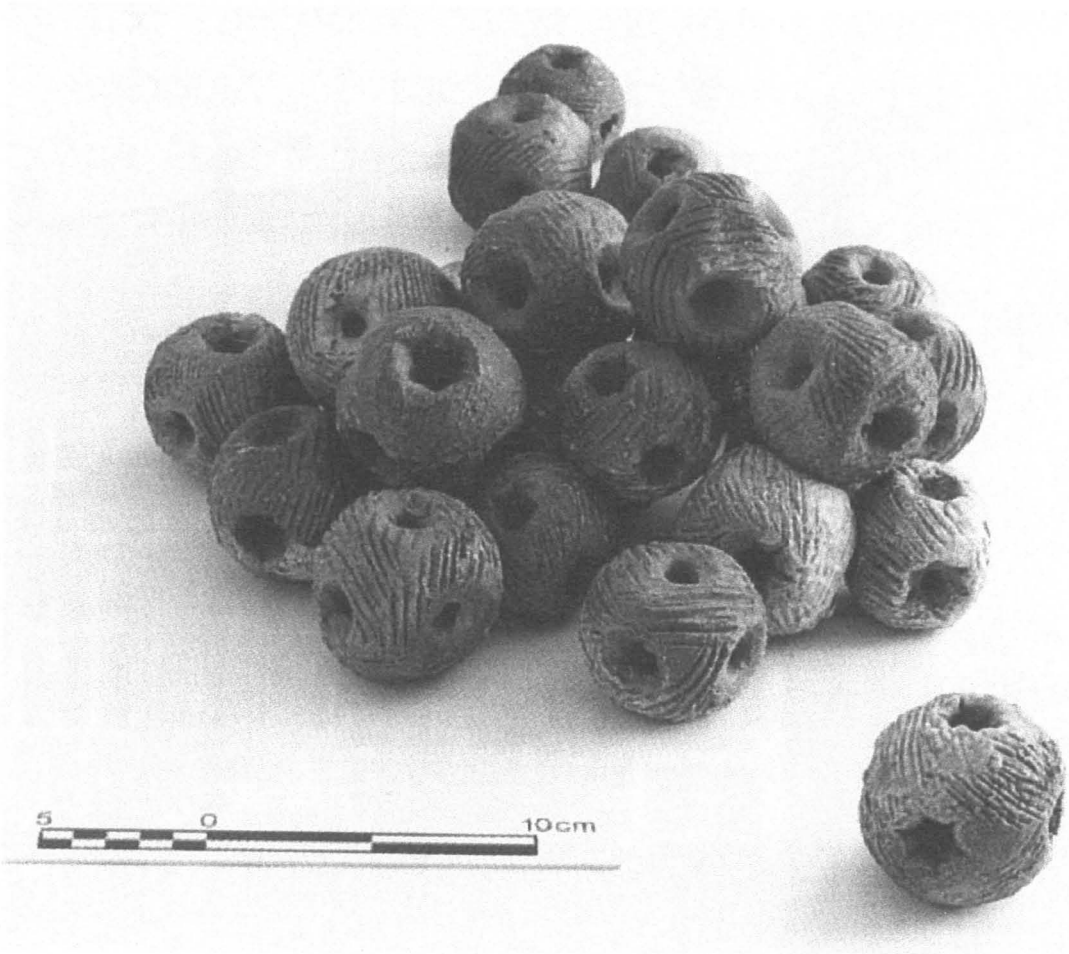
As with many chemical processes nitroglycerine manufacture involved the flow and taking off of separated liquids at various stages, involving the stopping and restart of the flow. The prevalent mode of control was by earthenware stopcock. In normal use these did not present any serious problems but their characteristics and performance became of prime importance when a product of an extremely sensitive nature such as nitroglycerine was involved. A spectrum of potentially dangerous situations was identified - friction and consequently heat could be generated between the body of the cock and key when turned if any grit had lodged in the cock, similarly if nitroglycerine had frozen in the cock and any force was used to free it, droplets of nitroglycerine could lodge in the cock after use.

By 1901 Waltham Abbey had succeded in eliminating stopcocks from all plant subsequent to the separator but they still remained in use controlling nitroglycerine transmission in the nitrator and separator.



GUTTMANN BALLS.

These were used to pack acid towers to produce a large internal service area.



NITROGLYCERINE.

The nitration of glycerine is carried out in large lead vessels provided with cooling coils through which cold water is circilated, and with perforated pipes through which air is blown to keep the contents in a state of violent agitation. The glycerine is introduced gradually in the form of a fine spray. When it has all been introduced the nitroglycerine is allowed to separate from the acids and is then run off and washed. Formerly the nitration and separation were carried out in separate vessels, but in most factories both operations are now performed in the nitrator-separator of Nathan, Thomson and Rintoul.

The mixed acids are introduced through the pipe d, and are agitated by means of air blown through the perforated pipe 9 and kept cool by water circulated through the coils h. The injector for glycerine is inserted through the top e and the flow is regulated so that the temperature never exceeds 22 degrees C. When the nitration is complete, the injector is removed, and the temperature, as shown by the large thermometer S, is reduced to 15 degrees. Some waste acid from a previous charge is run in through d until the surface of the liquid in the vessel rises to the level of the windows f. The nitroglycerine, being lighter than the acid, floats to the surface. When a sufficient quantity has collected, a little more waste acid is admitted through d, and this causes the nitroglycerine to run over down the pipe k into the pre-wash tank. This is continued until all the nitroglycerine has been displaced into the pre6wash tank. The waste acid is then run off through a branch pipe and the nitrator-separator is then ready to start a fresh charge. Another pipe leads to the drowning tank to which the charge is run in case of accident. the pipe m is to carry off the air and fumes.

the pre-wash tank is an open circular lead vessel. The bottom slopes down to one side, and at the lowest point there is an orifice to which is connected a large rubber tube for running off the nitroglycerine. There is another orifice which is connected inside the tank with a rubber tube which is used to skim off the washing waters which, being lighter than the nitroglycerine, separate out above it. To the bottom of the tank are burnt air pipes so that the contents can be agitated by means of compressed air.

In the pre-wash tank the nitroglycerine is washed with several changes of water and then with a dilute solution of sodium carbonate to remove the greater part of the acid which has been carried over by the nitroglycerine.

The nitroglycerine is then run through a lead gutter to the final washing house, where its purification is completed in a vessel similar to the pre-wash tank. It is here washed with several changes of dilute soda solution and then with water. It should then be slightly alkaline. It is passed through dry sponges to remove water and is then ready to be mixed with other substances for the manufacture of composite explosives.

ROYAL GUNPOWDER FACTORY.

NITRATOR-SEPARATOR FOR MAKING NITROGLYCERINE.

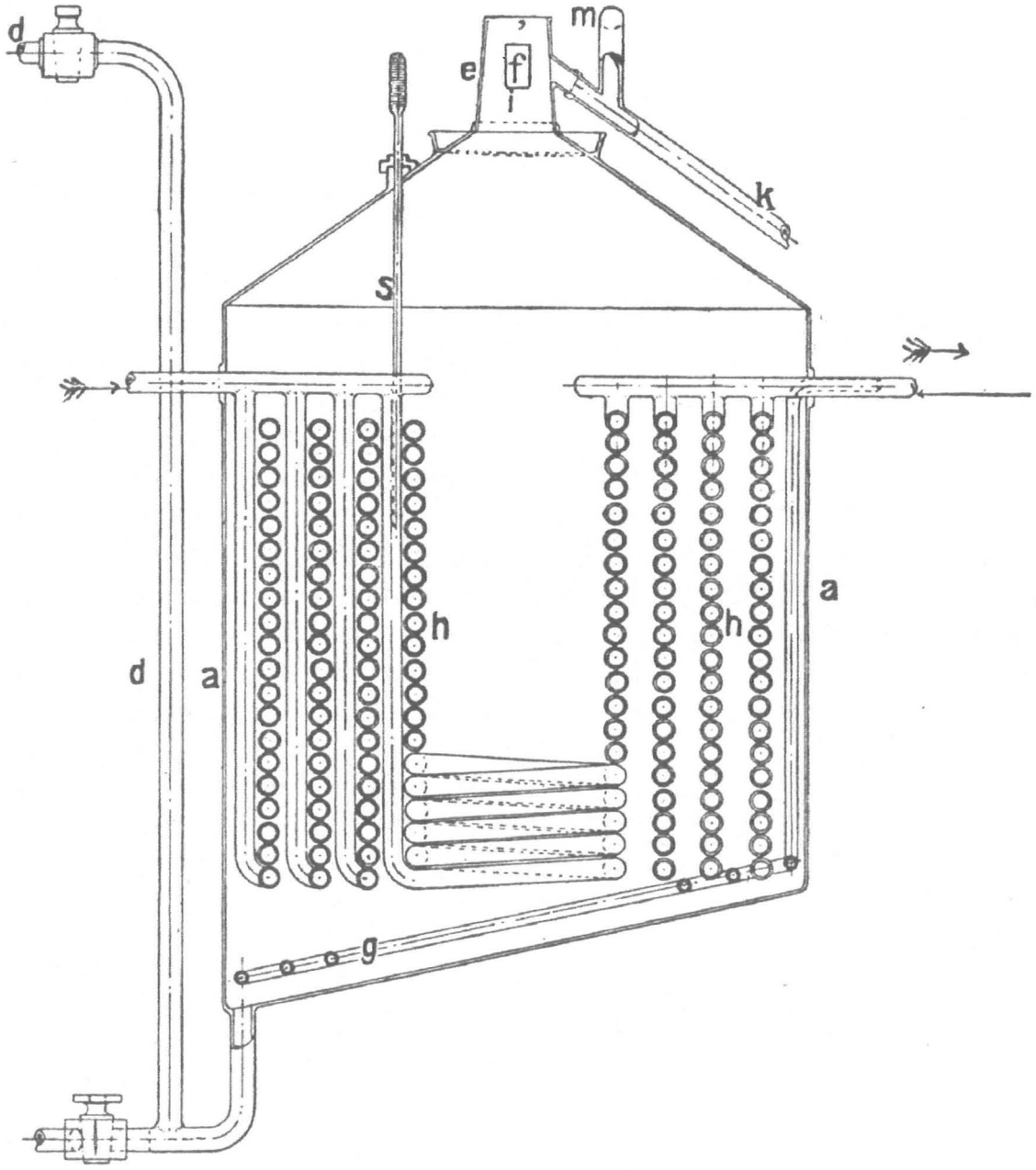
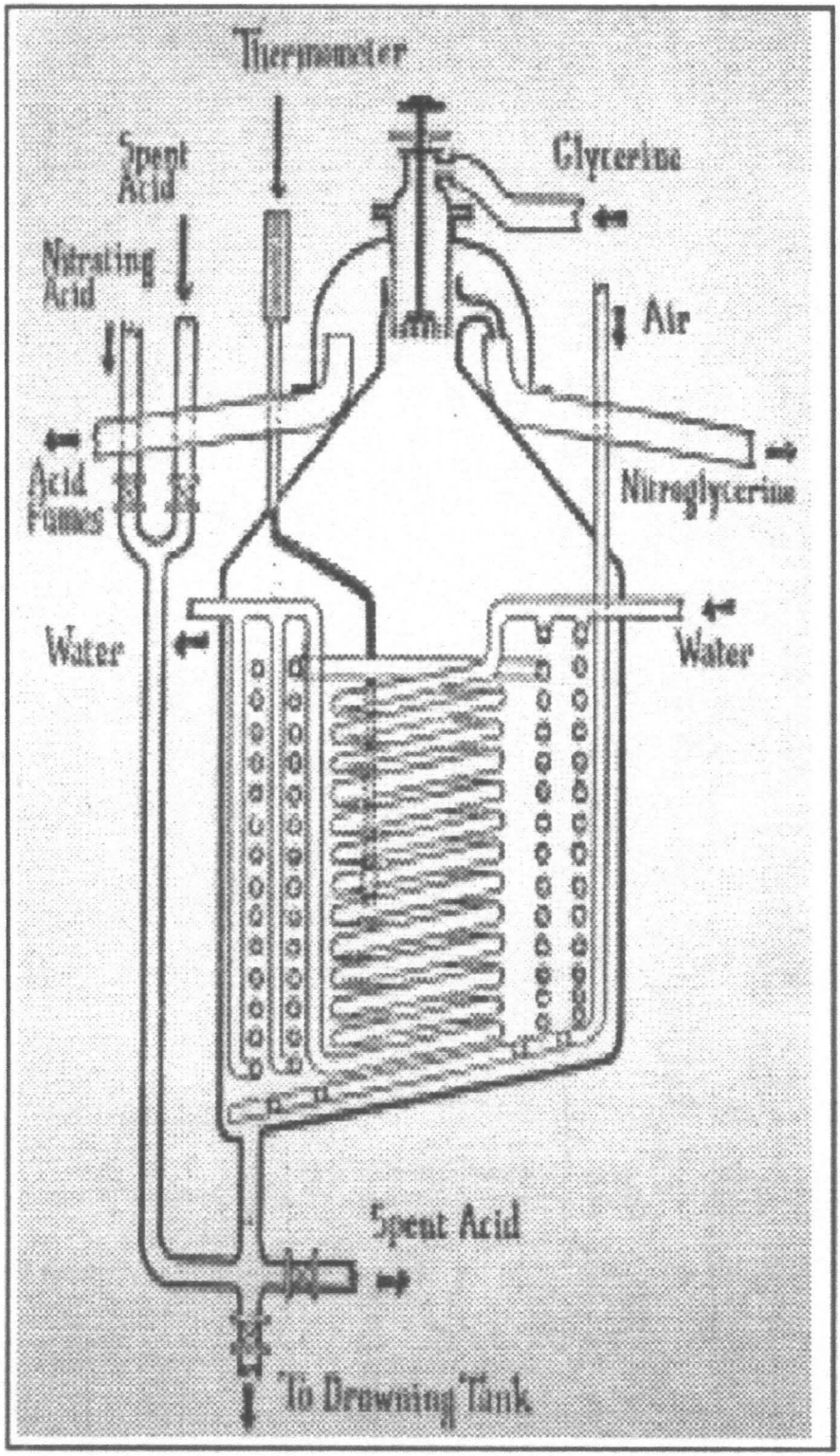
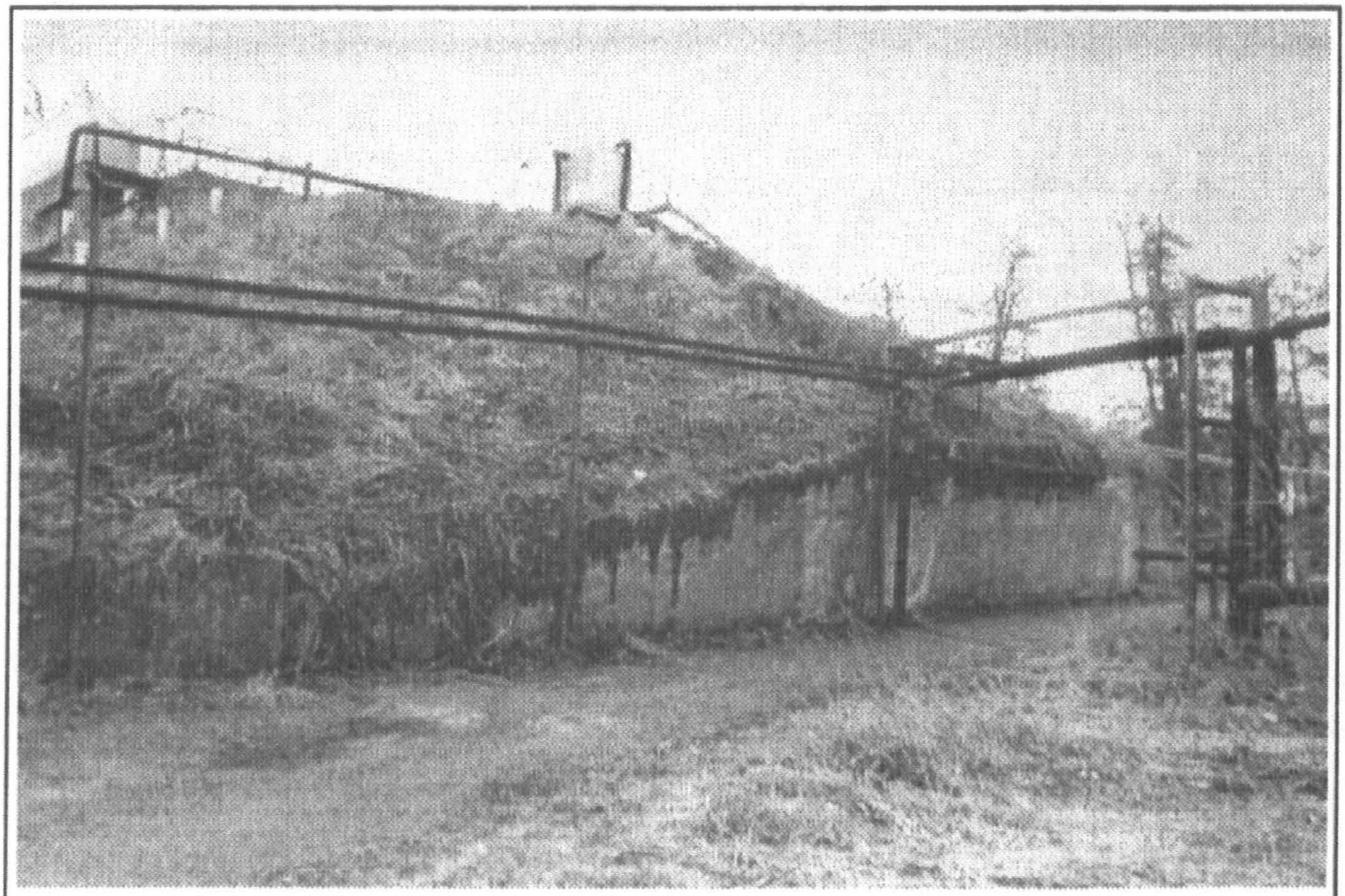


FIG. 6. Nitrator-Separator for making Nitroglycerine

NITRATING SYSTEM.



E2 NITRATING HOUSE (1981).



E2 Nitrating House (1981)

THE ROYAL GUNPOWDER FACTORY WALTHAM ABBEY.

1895-1908.

Production then progressed at a steady pace; during the Boer War producing around 181/2 tons of nitroglycerine per week.

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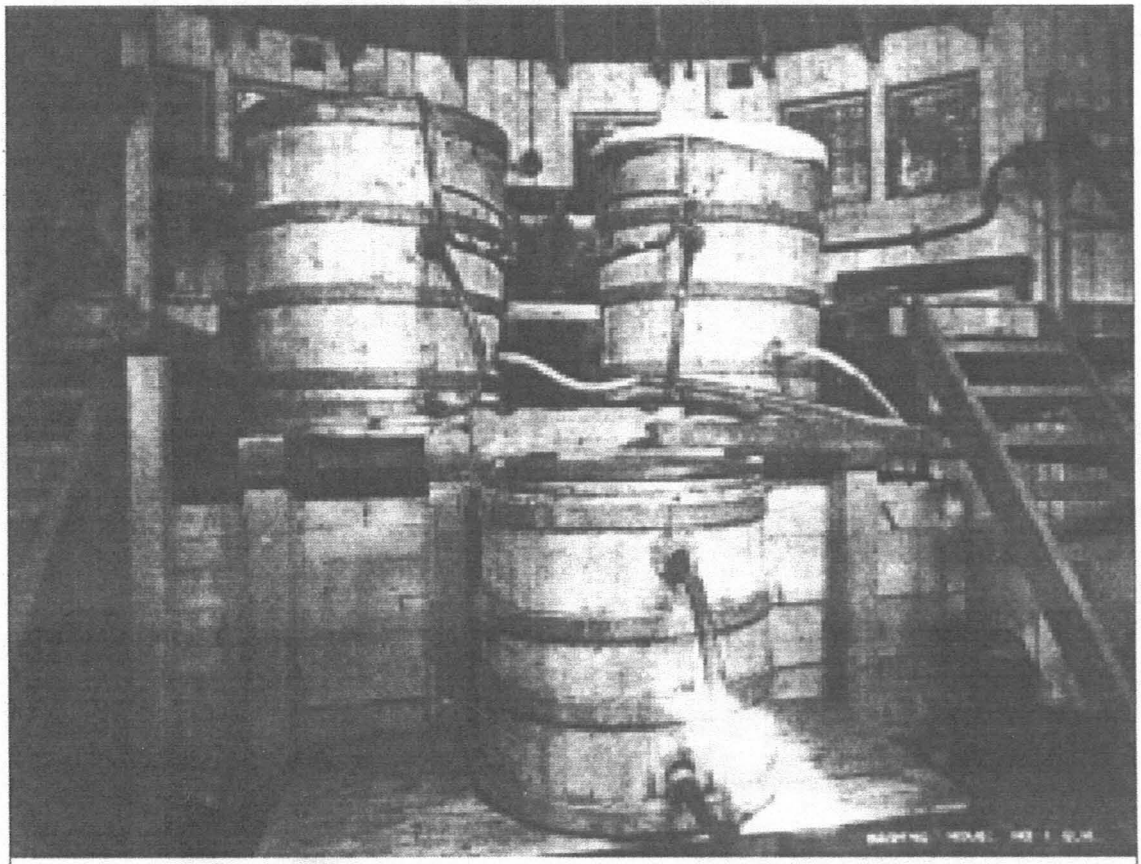
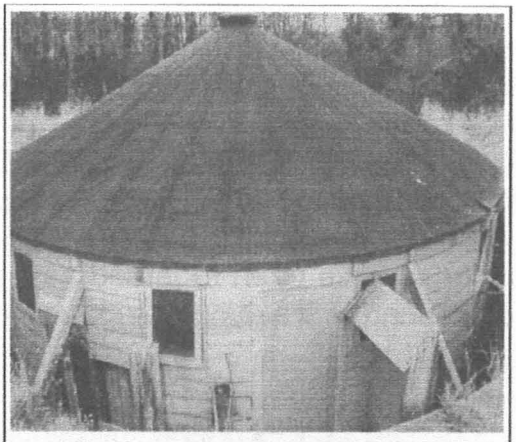
1903 QUINTON HILL
NITROGLYCERINE WASHING HOUSE.

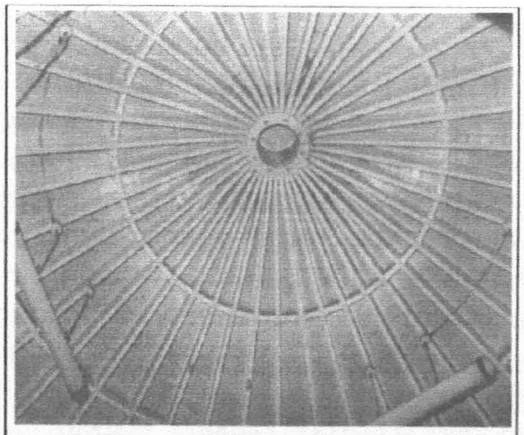


1903 Quinton Hill Nitroglycerine Washing House
Washing tanks on upper platform and Filtration tank
on lower with a Drowning tank below the Washing tank.

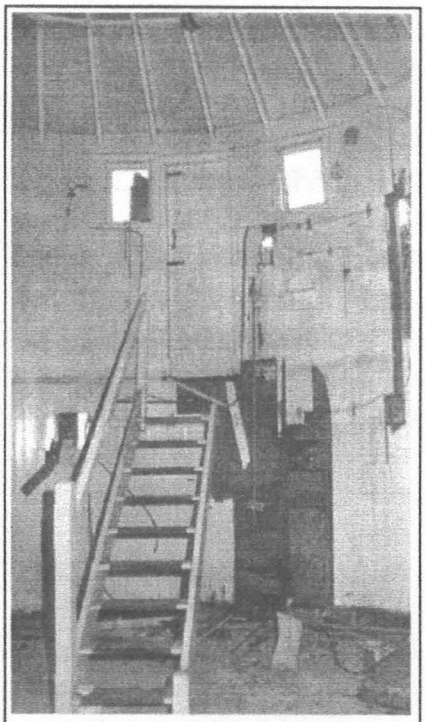
WASHING HOUSE No.1, and No.2.



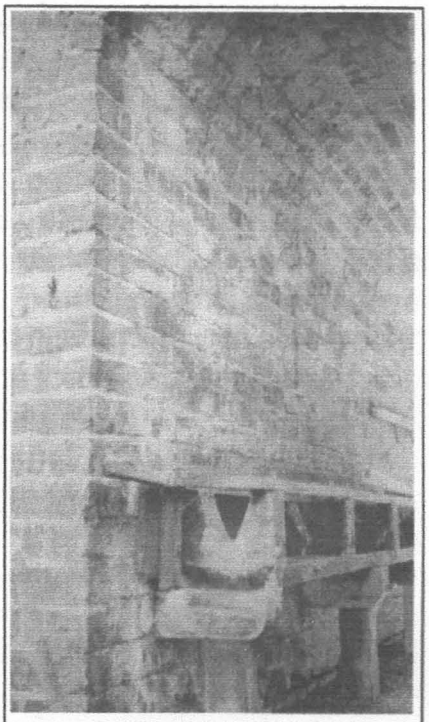
Washing House No.2 (1981)



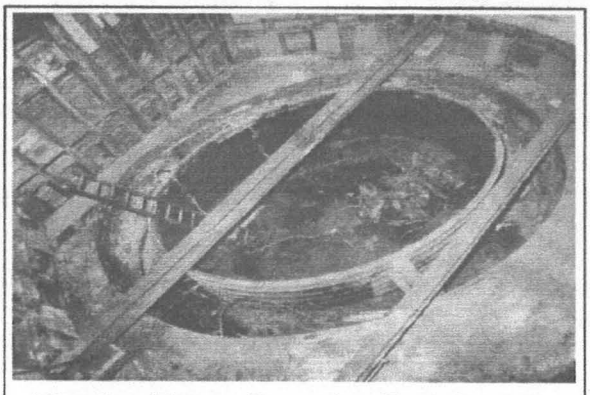
Roof Interior of Washing House



Washing House No.1 (1981)



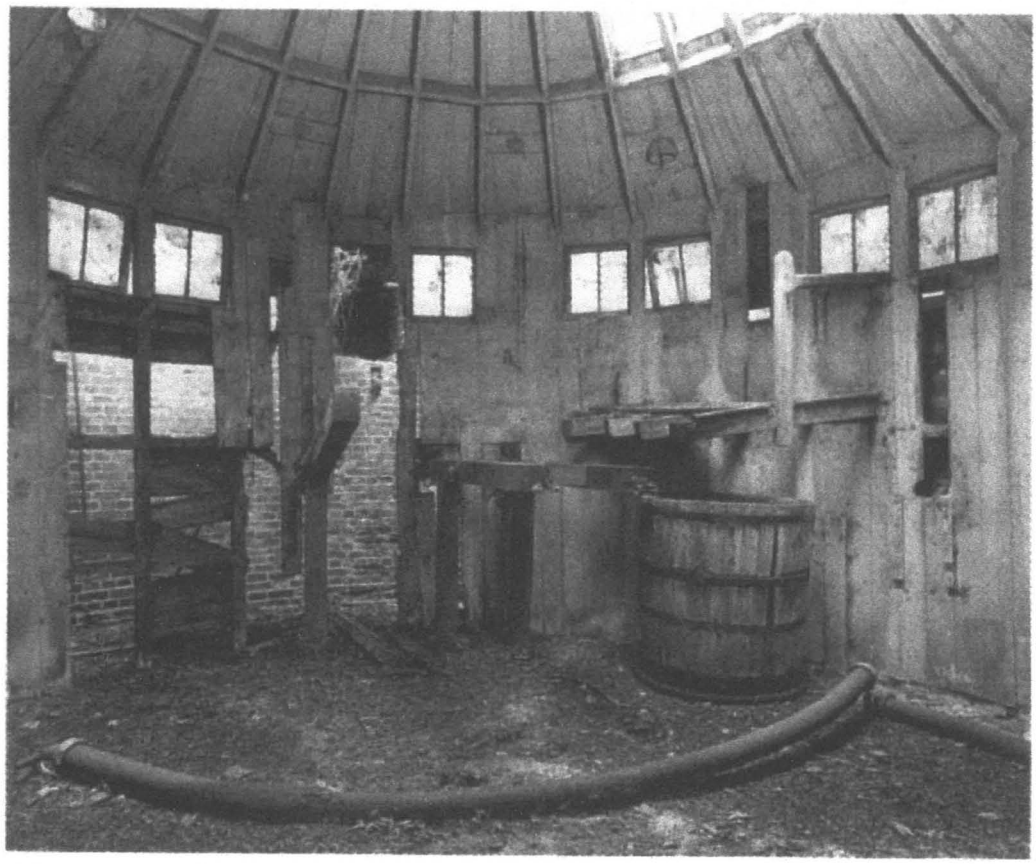
V shaped guttering on trestles

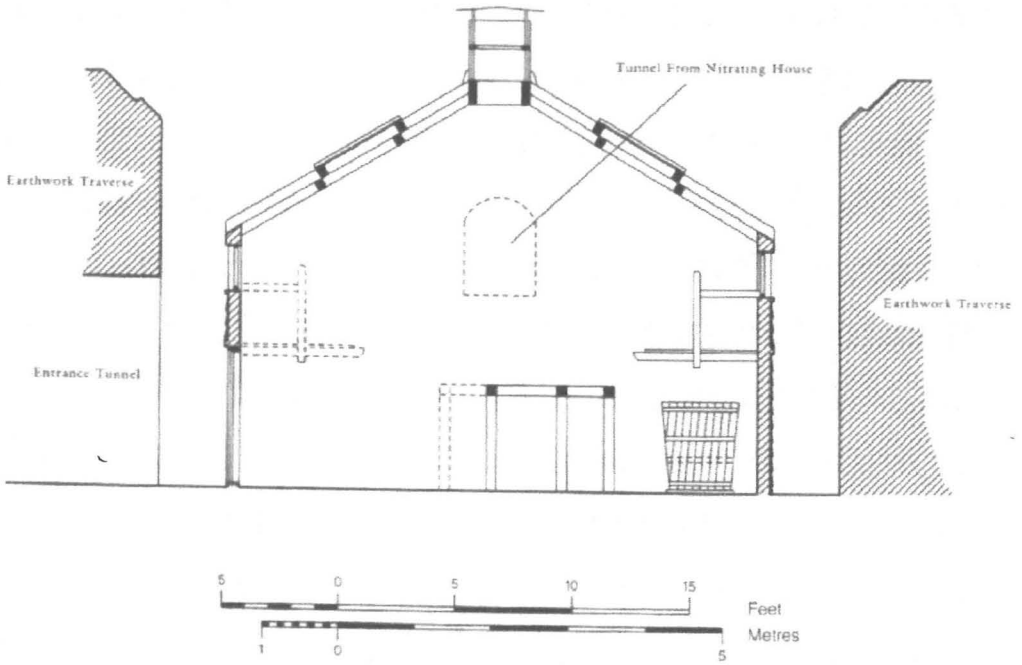


Nitrating House Drowning Tank (1981)

WALTHAM ABBEY GUNPOWDER FACTORY.

(South Side.
Quinton Hill Nitroglycerine Factory. Nitroglycerine Wash House. 1894.
Note the original washing barrel. In the foreground is a displaced steam heating pipe; to the rear the opening of the tunnel through which the nitroglycerine was run into the building is visible.





WALTHAM ABBEY GUNPOWDER FACTORY.

1903 QUINTON HILL.

1903 QUINTON HILL

Background:- Nitrating Houses and Charge House

Centre:- Washing House

Foreground:- Junction House with 'Covered Way' housing the gravity fed NG gutter, sunk in a gulley, and wash water gutters to Wash Water Settling House.

THE ROYAL GUNPOWDER FACTORY WALTHAM ABBEY.

1909-1992.

The Quinton Hill guncotton factory continued, supplying the North Site cordite factory via the internal canal system up to the Grand Magazine at the extreme north of the site for storage then moving back down the site for drying and processing to cordite. The cordite then travelled back to the extensive Water Stoves at Quinton Hill for drying.

Nitration House No.2 stayed in reserve and from 1992 after closure of what had become the Research Establishment it and all other South Site buildings were cleared, ultimately to make way for residential, recreational and industrial warehousing development.

The rebuilt Washing House of 1894 had survived in remarkably good condition and had become a unique survivor in Britain of its type. Reflecting this it was dismantled and taken to store on the North Site, which opened as an interpretative centre in 2001, with the ultimate intention of re-erecting it.

From 1904 therefore Edmonsey Mead took on the position of prime nitroglycerine producer for the factory.

EXPLOSION 1894.

Production progressed without major incident until there was a serious explosion in the Washing House and Nitroglycerine Store in 1894, destroying these buildings and extensively damaging surrounding buildings including the No.2 Nitrating House.

The subsequent Enquiry did not establish a precise cause of the explosion but did uncover a number of risks associated with operation which demanded attention.

Risk from:
Blow arising from fall of 'skimmer dish' in Washing House.

Use of earthenware cocks to draw off separated liquids from base of tanks e.g. if nitroglycerine froze in cold weather or cock stuck for any other reason any force applied could generate friction heat between body of cock and key causing explosion, similarly if a particle of grit lodged in cock.

Friction from vibrating lead air pipe.

Dropping of any object - the 'Use List' covered a large range of implements.

Other serious operational concerns:
Practice of accumulating successive batches of nitroglycerine in store.
Proximity of danger buildings to one another.
Ineffectiveness and danger from flying bricks of brick built traverses.
Hair raisingly, an adjacent puplic right of way opened at weekends along which smokers strolled, often dropping matches, which could be picked up on a worker's boot.

In addition a significant recommendation was made that consideration should be given to building a second facility totally separate from existing plant. This led to the Edmonsey factory on the North Site.

All of these matters were given due consideration as part of the ongoing effort for safety improvement which was part of explosive work

Nitroglycerine was no longer stored in quantity but 'poured on' to guncotton as soon as ready, producing the safer cordite paste.

Earth traverses revetted with brick on the inside replaced brick round the Washing House and the right of way was fenced off.

The previous practice of allowing workers to walk from the Shifting Room where they had changed their boots to the process building without overshoes was stopped. Boots were now changed at the entry to the process builing.

Such was the pressure for resumption of production however that in spite of the concern on building spacing No.2 Nitrating House and other buildings destroyed or damaged were speedly rebuilt on their original sites and production resumed by the autumn of the same year.

EXPLOSION QUINTON HILL.

SOUTH SIDE.

Result of a serious explosion in the Washing House and Nitroglycerine Store in 1894, destroying these buildings and extensively damaging surrounding buildings including the No.2 Nitrating House.

The subsequent Enquiry did not establish a precise cause of the explosion but did uncover a number of risks associated with operation which demanded attention.

Aftermath of Explosion showing the awesome power of Nitroglycerine

ROYAL GUNPOWDER FACTORY.

EXPLOSION QUINTON HILL. 1894.