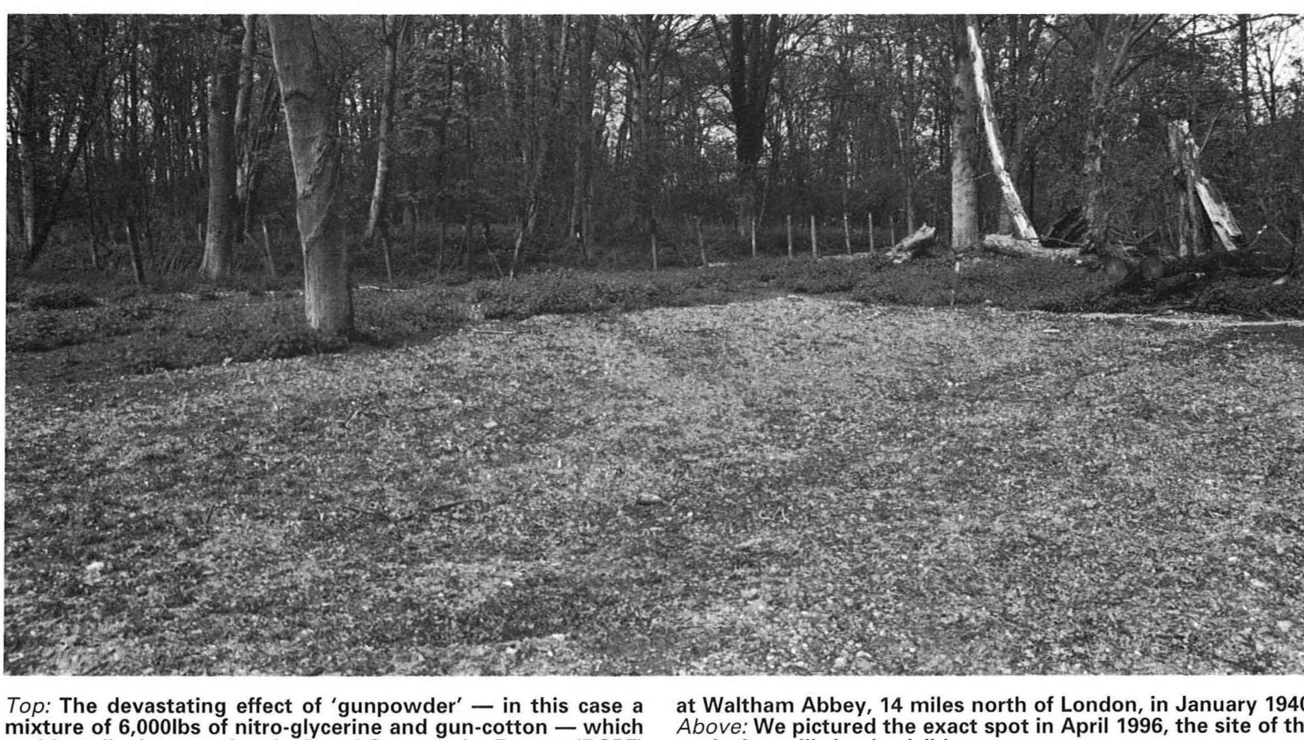
THE ROYAL GUNPOWDER FACTORY

Magazine Articles:

THE ROYAL GUNPOWDER FACTORY EXPLOSIONS 1940

By Bryn Elliott

Gunpowder was used for the first time on the battlefield by the English at Crecy in 1346, but it was not produced in any great quantity for a further 200 years. Eventually, privately owned powder mills were set up in Britain, mainly in the south of England.



Top: **The devastating effect of 'gunpowder' — in this case a mixture of 6,000lbs of nitro-glycerine and gun-cotton — which accidentally detonated at the Royal Gunpowder Factory (RGPF) at Waltham Abbey, 14 miles north of London, in January 1940.** *Above:* **We pictured the exact spot in April 1996, the site of the explosion still clearly visible.**

The RGPF — the 'mother-house of the British explosives industry' — with a colourful history extending back over 400 years, was closed in 1991. In April 1996, we obtained permission to investigate the various explosions which occurred there during the Second World War which cost the lives of ten men and led to the award of three George Crosses and three British Empire Medals. When we reached the site of No. 5 Mixing House (pictured *opposite*), at first glance there appeared little to be seen. It was the realisation that the line of concrete posts in the background still stood in exactly the same positions they had taken in the face of the blast in 1940 that provided the link between the two photographs. *Above:* Closer examination by our author, Bryn Elliott, revealed that although the services that the posts had originally carried at shoulder height were long gone, one small section of pipe still remained firmly embedded in its support.

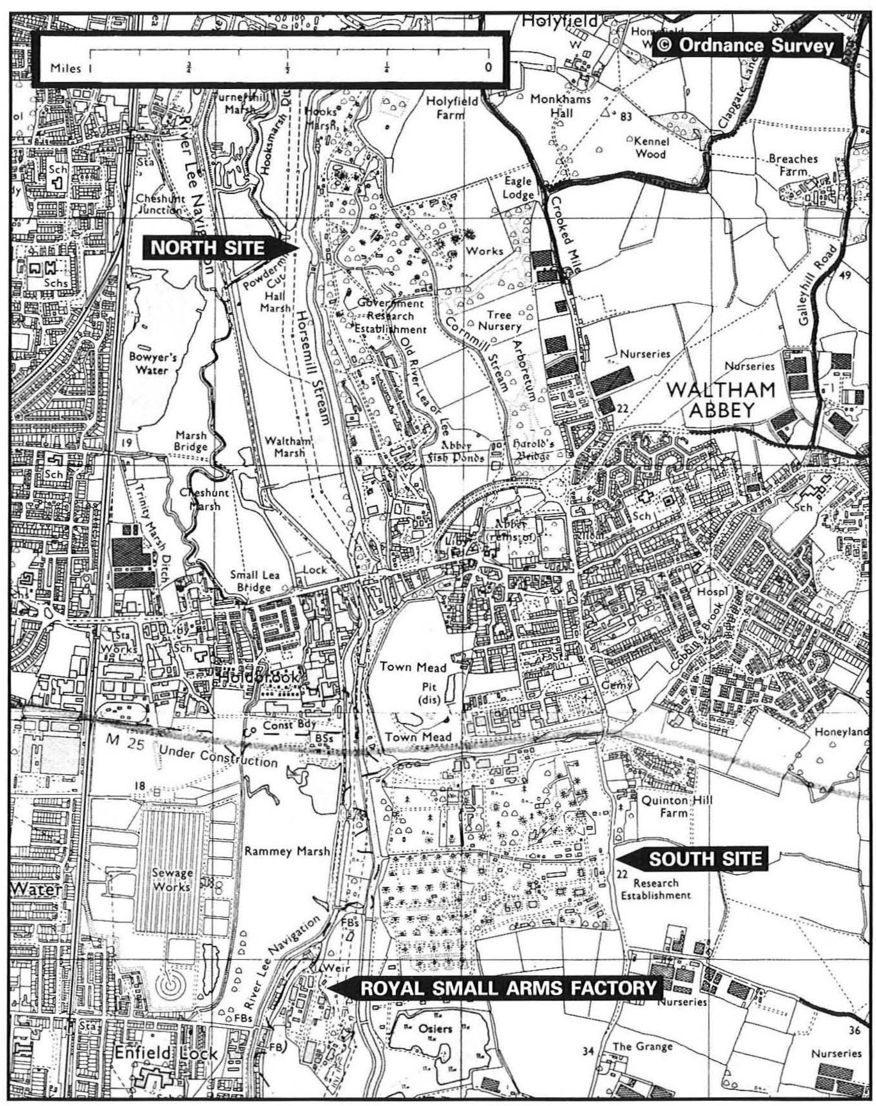
The mills at Waltham Abbey were established to the north of the town reputedly in 1560, so it may be presumed that the products of this ancient factory might have been available to the fleet of Sir Francis Drake before the last great attempt at invasion. The site was in private ownership before 1700, then passing into the hands of the government in October 1787 when it became the Royal Gunpowder Factory [RGPF]. The site, in West Essex and on the border of Hertfordshire, was well placed in the valley of the River Lee 14 miles north of London, and in the early days, the river provided the water for power and transportation.

Many questionable claims are made for the mills in Waltham, including the one that they were the source for the powder intended to blow up Parliament and the King at the hands of Guy Fawkes and his plotting compatriots, river access to Westminster certainly being easy from the factory. Less steeped in fable is the story that it was from this site that a form of artillery rocket was developed for use by British armies from the early 19th century. Known as the 'Congreve rocket', among the targets bombarded by these weapons was Fort McHenry in 1814, a fact commemorated in the line of the United States' national anthem which refers to 'the rockets red glare'. In Napoleonic times the factory was producing some 1,100 tons of powder per year for the war effort.

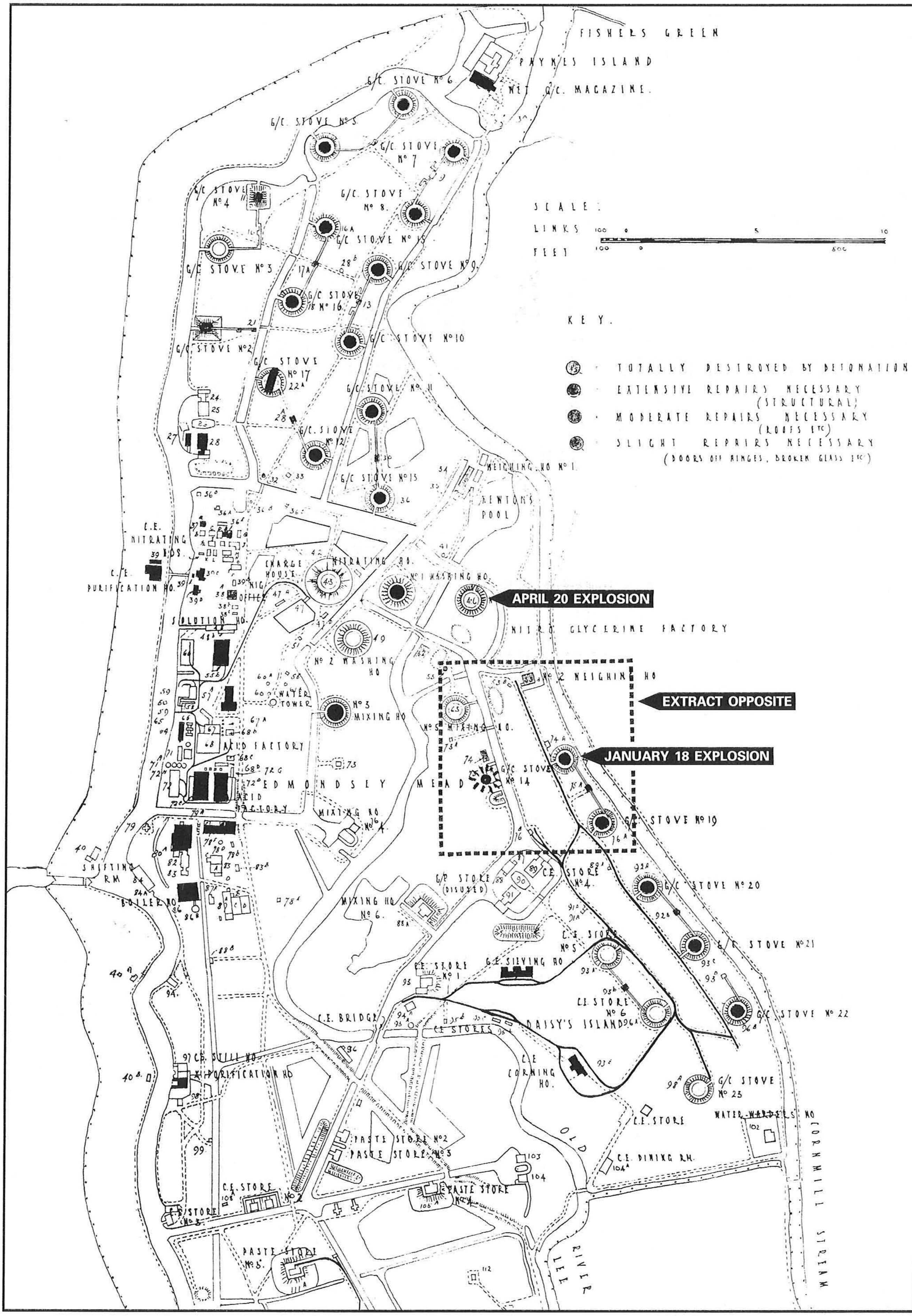
In the middle of the 19th century there was a diversification of effort as two new explosives, gun-cotton and nitro-glycerine, came on to the scene. By 1872, 250 tons of these were being produced and by 1885, the ever-increasing call for these products, as Britain enlarged and defended its Empire by force of arms, resulted in the factory expanding into farmland to the south of the town and building further nitro-glycerine production facilities. The development and production of cordite followed in 1891.

In the early part of the 1914-18 Great War, Waltham was the only government-owned explosive factory and, as such, the 5,000 employees were obliged to operate the processes around the clock to supply the major proportion of the Woolwich Arsenal's requirement to fill its shells. At the cessation of the 'war to end all wars', this production effort was run down, but experimentation continued and a number of important explosives were developed. The scaling down of the factory effort was reversed in the early 1930s with the rearmament programme, and on the outbreak of war, Waltham was producing TNT and was the only site producing the major explosive of this new war, RDX. In effect, through RDX production, it was from here that the Ruhr Dams were burst in 1943.

There were major problems caused by the inter-war shut down. Ever since the factory had opened, virtually all transportation had been by canal barge. Small dumb barges moved the materials around inside the site and delivered the finished product to larger sea-going sailing barges which were pulled down the Lee Navigation to the River Thames and Woolwich. However, following the end of the Great War, the canals had silted up, and instead reliance was placed



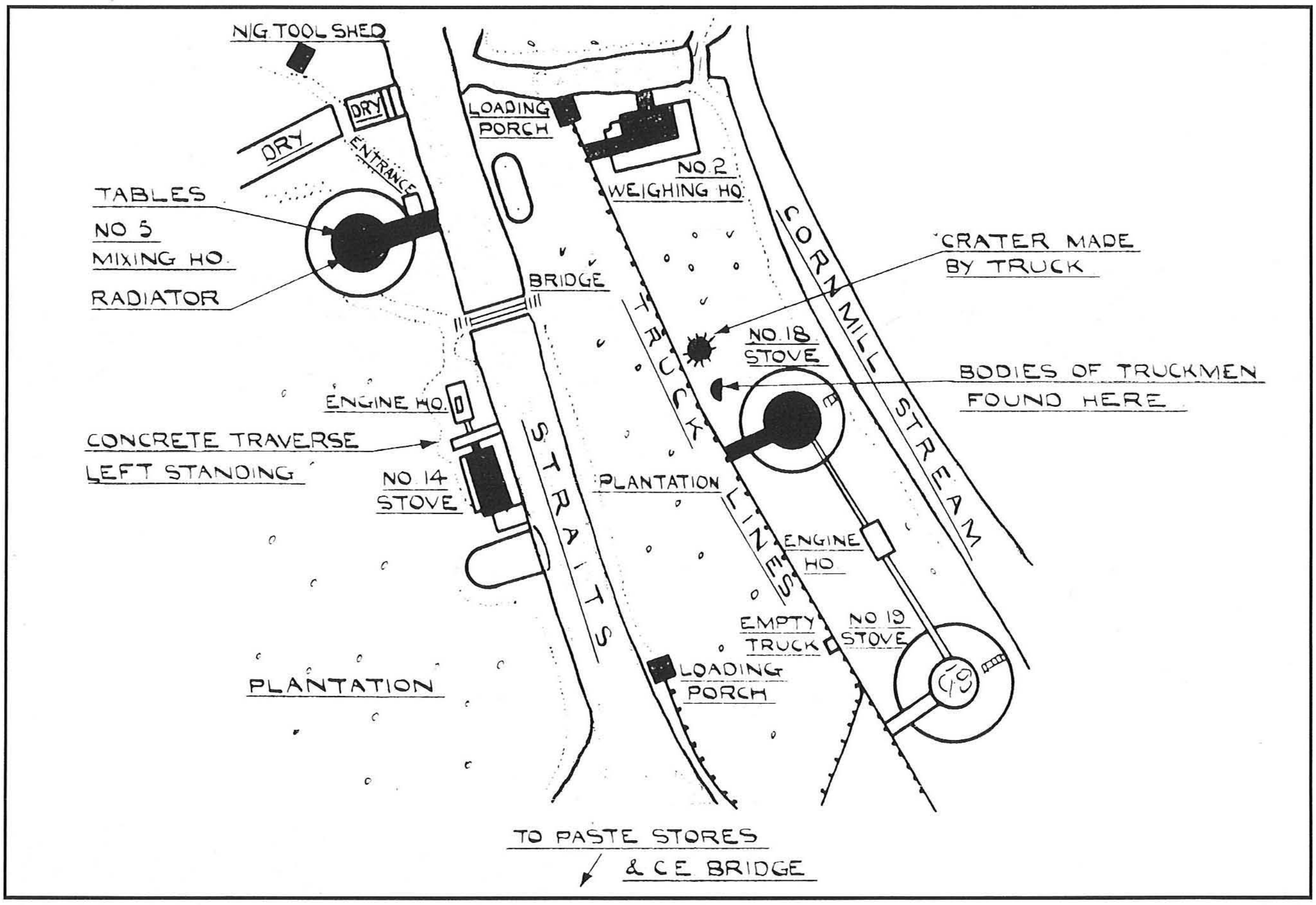
The RGPF developed on two sites on either side of the town of Waltham Abbey, bordering the River Lee (also spelt on some maps Lea) which provided a convenient — and more or less safe — route for the factory products to be moved by barge downstream to the River Thames and the Royal Arsenal at Woolwich. When the M25 was constructed in 1975-86, the RGPF was provided with its own exclusive tunnel beneath the motorway. The Royal Small Arms Factory (see *After the Battle* No. 2) lay just to the south.



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

upon the tramway and a small internal electric railway system. Although the railway connected with the main line from London to Cambridge, it was some months before the silt problem was overcome by a massive programme of dredging which left the railway at full stretch. In the meantime, much of the explosive went through the streets of Essex and London by road. Fortunately there were no accidents!

A greater threat was the lack of skilled manpower to operate the delicate processes within the factory. Although there was a core of trained process workers in the surrounding population, with the passage of some 20 years since the last contraction of the factory, there were insufficient of the right age group to fill the yawning need that war had created.



The plan of the North Site *opposite* was produced to illustrate the explosion on April 20, this enlargement being to cover the earlier accident on January 18. In both cases, they formed part of the Court of Inquiry findings as do the photographs. (PRO)

This resulted in the creation of massive training programmes to integrate whatever workers could be found into a highly dangerous environment. Nevertheless, no matter how much training was given; no matter how long the worker was involved in producing the final product, there would always be accidents involving human error. The materials gave little leeway and any accidents invariably involved severe injury and death.

Precautions included a police force dedicated to rooting out all items of smoking apparatus. In peacetime, workers found with a few flakes of tobacco, a paper, match or pipe on their person, would face a criminal prosecution followed by instant dismissal. In time of war they *might* just escape with the imposition of a £5 fine — a week's wages. On site, the workers wore special protective clothing to reduce the chance of a stray spark, and ward off the chemicals involved in the processes. The hob-nailed boot was banned and stitched leather clogs and slippers were the order of the day. In the most dangerous areas, primarily the nitro-glycerine works, the railway was reduced to a hand-worked tramway with leather-lined carriages running on a spark-free wooden track.

By design, nitro-glycerine trickled from building to building along gutters or, in smaller quantities, was carried about in leather pails. The liquid travelled along a continuous lead gutter by gravity, the whole resembling an outsized domestic rainwater system, carried between buildings supported on substantial wooden trestles. The top of the gutter was open but covered and protected from the elements by a system of heavy canvas sheets.

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 clearly defined interlocking sections of elephant hide and one such building survived into the 1990s. Thick leather buckets, fashioned from the same source, were the rule. 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 outdated. Wooden knives and gunmetal chisels were never to match their steel counterparts. An additional restriction was the paperwork. War or no war, almost every job required a multiplicity of signatures. Workers sat around for days, even weeks, awaiting the final signature on the job sheet, especially if someone as important as the Superintendent was away on other duties. This inertia affected every job in the danger areas of the factory — from dredging to manufacture.

In addition to all these measures, the temperature of the rooms in which the work was undertaken 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. Within the buildings, the heat was by means of a radiator. As most processes required a temperature of 70°F (21°C), the network of pipes was an important feature in winter. Standing instructions were that all work would cease if building temperatures fell below 50°F (10°C).

In spite of all these elaborate measures, there were regular deaths and horrific injuries effecting the workers. Every generation in the local town featured individuals stained yellow by sulphur from head to foot. Occasionally the accidents were horrific enough to hit the headlines. Ten men died in April 1843, five in June 1870, two in August 1890, nine in December 1893, and three in December 1902. In most instances, the subsequent high-profile burials resulted in the creation of a mass grave for some or all of the unfortunates, this topped by a magnificent memorial.

If the worst should occur, a long history of trial and error learning had resulted in specialist construction methods that promised to ensure the least chance of a multiple explosion involving a number of buildings. Structures in the greatest danger of suffering an explosion, both process buildings and the magazines, were provided with lightly constructed roofs of weatherboard and felt or zinc, and walls of a similar light construction lined with zinc or cheaper calico. Beyond these, a substantial wall and protective banks were primarily designed to deflect blast skyward. Each of the buildings was designed to be placed sufficiently far away from its neighbour as to reduce the chances of a sympathetic explosion.

The Mixing House was central to the production process for nitro-glycerine and these photographs illustrate Mixing House No. 3, the most south-westerly one on North Site (see plan page 36) photographed here in 1940 from the west bank of the 'cut'. The latter was part of a series of waterways which linked the various process buildings at the RGPF, each having its own landing stage or 'porch' like the one visible in the foreground. The actual process building was made of wood erected within a circular earth and concrete mound. Should an explosion occur, it was thereby hoped that the blast would be directed skywards to eliminate the chance of sympathetic detonation of the surrounding buildings.

THE PROCESS

The RGPF was not a factory dedicated to the production of one final product, involving a common production process. The series of explosions which ripped through the factory in the early part of 1940 involved only the nitro-glycerine section of the extensive plant, the very fact of the explosions clearly underlining that this was one of the more dangerous areas of production.

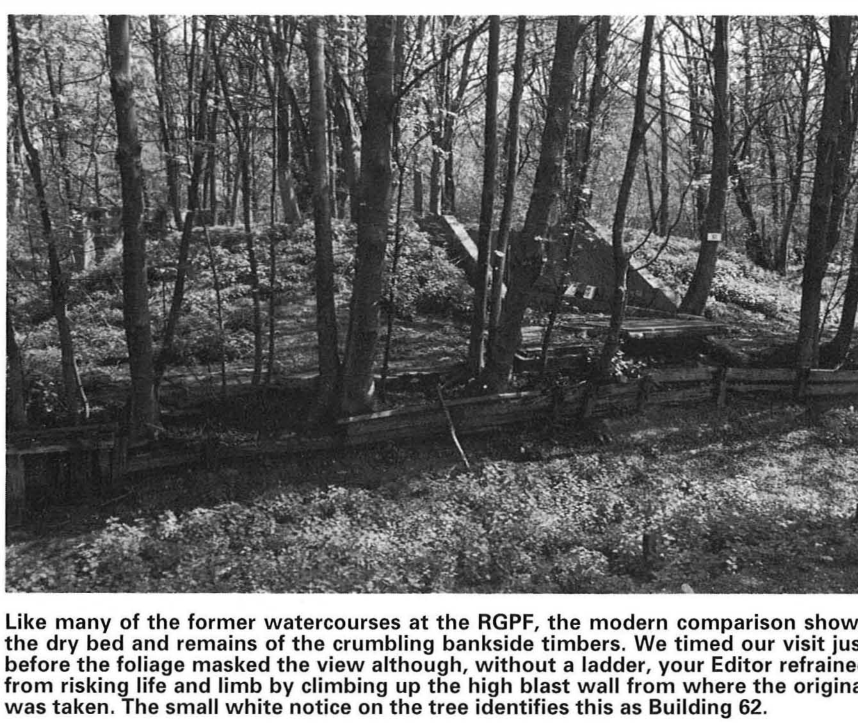
Nitro-glycerine was then produced in large lead vessels called nitrators by the action of sulphuric acid and nitric acid upon glycerine. The process was a very delicate one and very critical. Following the production of the nitro-glycerine itself, two further processes were undertaken. The first was pouring the liquid onto dry gun-cotton in rubber bags, and, secondly, the mixing of the dry gun-cotton 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.

Gun-cotton, was produced in the Gun-cotton Factory section of the RGPF and, as 'wet gun-cotton', was transported in aluminium boxes in compressed cylindrical form by lorry to the nitro site for drying. The 55-60-hour hot air 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 1,200lbs (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 in the process building, a special rubber hose shut off further supply to the nitro-glycerine tank. During its passage, the fluid would contaminate the lead 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.

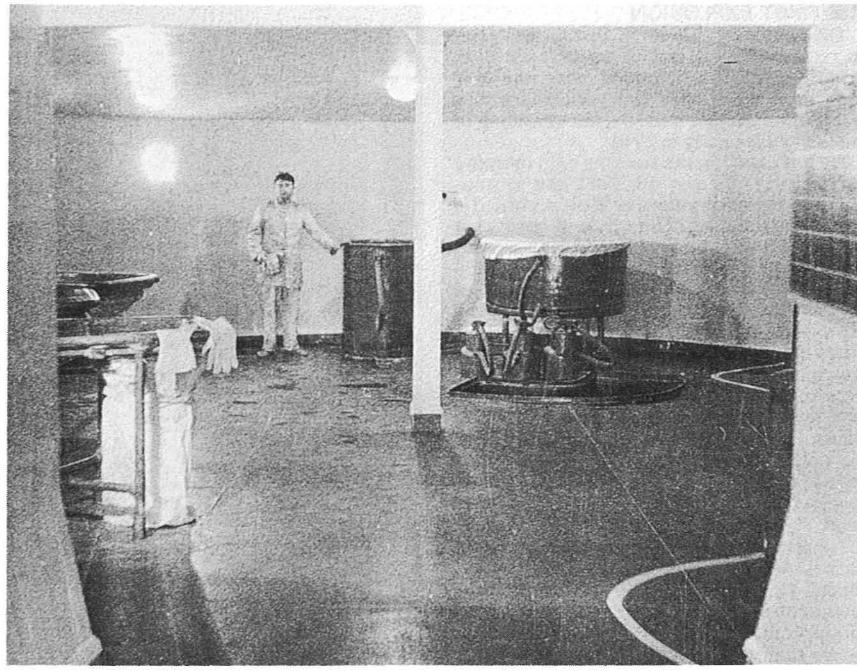
As soon as the nitro-glycerine arrived in the Mixing House, 2oz samples were put in lead bottles and placed out of harm's way under the tank. The bottles were some three inches high and weighed 10½ ozs when empty. Dry gun-cotton, contained in rubber bags, was then brought in from a Weighing House and a measured amount of nitro added. It was generally the duty of the chargeman to pour this on from one of a number of measuring vessels called burettes.

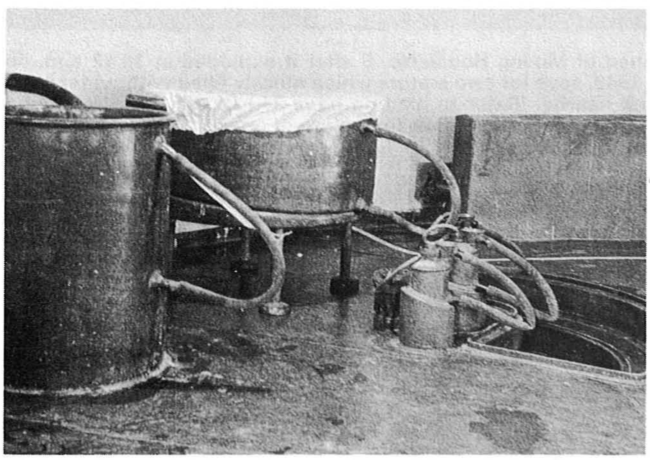
The bags were then either sent away in a barge to another building or put to one side until the initial operation was completed. The separate mixing operation consisted of emptying the contents of the rubber bags

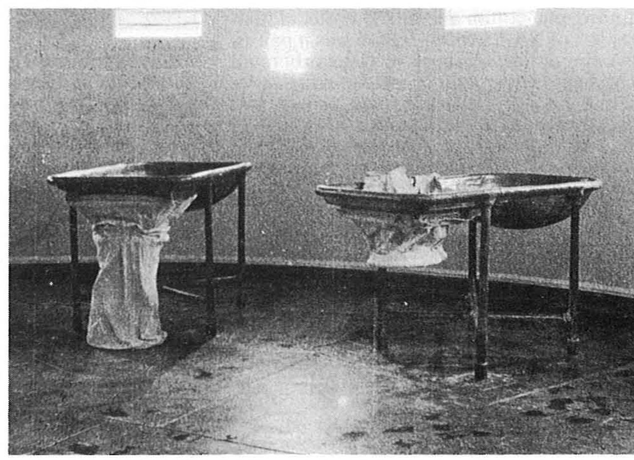


Like many of the former watercourses at the RGPF, the modern comparison shows the dry bed and remains of the crumbling bankside timbers. We timed our visit just before the foliage masked the view although, without a ladder, your Editor refrained from risking life and limb by climbing up the high blast wall from where the original was taken. The small white notice on the tree identifies this as Building 62.

Right: **The interior of Mixing House No. 3 photographed from the porch showing the central pillar, the spark-free floor and lead tanks. The visible wall is the light inner structure. Nitro-glycerine, or Glyceryl Trinitrate (a mixture of glycerol, nitric and sulphuric acids) was first prepared by an Italian chemist, Ascanio Sobrero, in 1846 but the highly volatile nature of the liquid explosive was not brought under control until the Swedish scientist Alfred Nobel mixed it with absorbent inert materials in the 1860s. Nobel also discovered that nitro-glycerine could be combined with other explosives like gun-cotton to make it a more stable product. The production process seems remarkably crude by today's standards where the hazards have been greatly reduced by continuous processes. The liquid nitro entered the mixing house via the rubber tube in the far wall to be stored in the mixing tank beside the operative. Measured amounts would then be run off into 'burettes' which would be added to dry gun-cotton in rubber bags. The mixture would then either be taken by barge to another building to be mixed or, in the case of Mixing House No. 3, stored ready for the separate mixing operation.**







Left: **Close up of the burettes and the arrangement of rubber tube safety overflow pipes from them to the rubber bag on the stand. The 'well' was lead-lined.** *Right:* **The paste-mixing tables were fitted with a phosphor-bronze sieve onto which the contents of the bags were emptied. The material then had to be worked by hand through the mesh by operatives wearing long leather gloves, the resultant mix falling into bags which were then taken away for additional processing.**

One serious problem with nitro-glycerine is its high freezing point 55°F (13°C) so that the maintenance of high room temperatures was critical. However, the transportation of the material in the open air by barge largely negated this precaution, particularly during the freezing conditions encountered during the winter of 1940. It was the hand-mixing process, on a table just like this, that was believed to have been the cause of the first explosion.

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 through to mix it thoroughly and deposit it into the hopper-mounted bag below. The operatives 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.

The mixing house has been derelict since 1945 and the interior building long dismantled, hence we are now looking at the inside of the concrete blast mound. The lead-lined well is clearly visible, as is the opening in the back wall through which the nitro-glycerine entered the room. The porch provided the only pedestrian access.

THE FIRST EXPLOSION

The winter of 1939-40 in Britain has gone on record as being one of the severest ever experienced. This, coupled with the war itself, were to provide two variables with a major influence upon the events unfolding in the Lee Valley early in 1940.

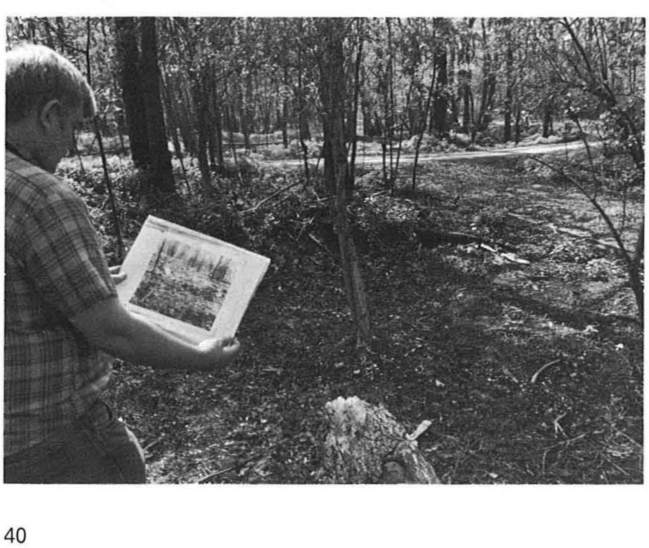
At 10.42 a.m. on the freezing cold morning of Thursday, January 18, 1940, the seismograph in the observatory at Kew recorded a shudder in the earth. The whole of north-east London knew about it within seconds as windows caved in under the pressure, debris rained down, and a number of columns of smoke rose from the secret site north of the town. With the absence of an enemy raid, a series of explosions of that magnitude could only mean one thing. The violent explosions were reported as far away as 25 miles and a man living 90 miles away in the New Forest claimed to have felt the shock. By the time the staff at Kew became aware of the twitch in its recording, the five men directly involved in this minor seismic event were dead.

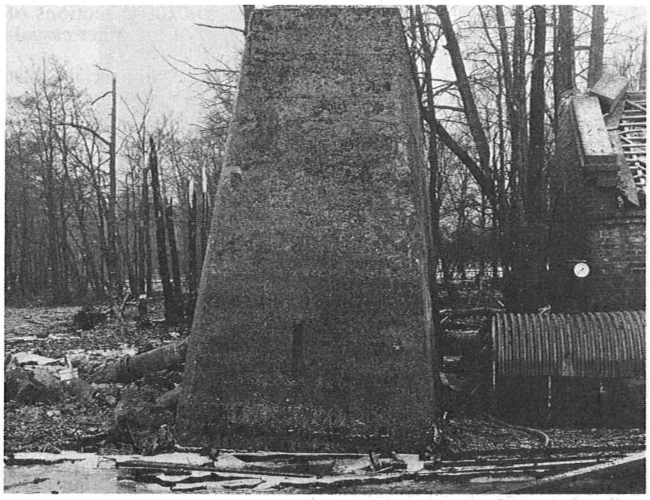
Albert Lawrence, Charles Perkis and John Parkes were working in the circular No. 5 Mixing House building in the nitro-glycerine section of the RGPF North Site pouring the product onto the gun-cotton when something — we shall never truly know what — went wrong. After the explosion of some 6,000lbs of nitro, gun-cotton and mixed paste, all that was left of No. 5 Mixing House was a pair of steaming craters. A shock wave reverberated across the factory and, in spite of a high protective mound — the tried and proven feature designed to deflect the blast safely upwards — the catastrophe was not confined just to the mixing house. The blast also travelled to the east through the canal-side loading bay gap, this shock wave striking a hand-worked paste wagon being pushed by two men northward from No. 20 Stove along the truck lines only 100 feet to the east. The wagon pushers, Bert Kelman and John Robinson, were lifted off the trackway, hurled to the ground and, suffering terrible injuries, both killed. It was Robinson's first day on the job.

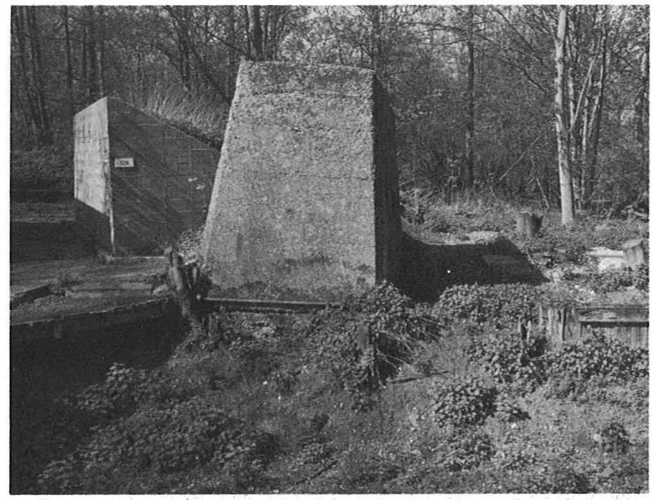
The 8ft-long, leather-lined wagon toppled from the track and the 640lbs of dry gun-cotton packed in 16 bags within detonated.

Above: **Nothing remained of Mixing House No. 5 after it exploded at 10.42 a.m. on Thursday, January 18, 1940, save for two craters which quickly filled with water from the ruptured canal bank nearby. (Refer to plan on page 37.) Of the three men who were working inside, nothing was found save for a piece of one arm.** *Below:* **The view is opposite to that reproduced on page 34.**

Below left: **Bryn Elliott orientates himself to line up the Court of Inquiry photograph** *below right* **showing the spot where the paste wagon blew up. Being pushed along a rail line (visible on right) just 100 feet from the first explosion, it was struck by blast which detonated the 600lbs-odd of gun-cotton within it. In spite of the passage of 55 years, a slight crater still remains — the route of the former truck line now the beaten track on the right. This crosses a new roadway towards No. 18 Stove.**







Left: **Although this massive blast wall stood between No. 5 (about 250 feet away, out of the picture to the right) and No. 14 Stove, nevertheless the ton of gun-cotton in No. 14, which originally stood to the left of the wall, sympathetically detonated. However, although in direct line from the first blast, by some quirk the Engine House on the right still remained standing. The picture was taken looking due west from across the waterway.** *Right:* **For some reason, the upper section of the wall was later removed but the shuttering marks on the end clearly match up. The engine house has since been dismantled. In the foreground, the dry bed of the canal. The rough bridge on the left is a recent addition.**

Although further protected by a substantial concrete wall, Building No. 75 (No. 14 Stove), the next danger building to the south, added its 5,200lbs of dry gun-cotton to the cacophony. The contents of this building were only 17 hours into the lengthy cooling down period and were still unstable.

Assailed from a distance of around 250 feet by the explosion of No. 5, added to the subsequent blast of No. 14 Stove across the canal and the eruption of the wagon load less than 50 feet away, the explosion of Building No. 74A (No. 18 Stove), was perhaps understandable, even though the 5,200lbs of gun-cotton had been drying inside for 37 hours and represented the most stable explosive in the immediate area.

As some of the black, white and yellow smoke from the series of blasts cleared, other sources of fire threw further columns of acrid smoke into the sky, and Building No. 76A (No. 19 Stove) started to burn. In addition, a range of other factory buildings had already been wrecked by blast, four being totally destroyed and several put out of action.

In a newspaper report, one unnamed survivor stated that he had a narrow escape when blown over in the blast. Carrying a bag of gun-cotton in a shed close to the one in which the first explosion occurred, the blast threw him 20 yards, to land on his back — fortunately still holding the volatile bag clear of the ground. If the bag had struck the ground, the chances were that this building would also have blown up. As the occupants of this building picked themselves up and fled, the second explosion occurred. Disorientated, and fearing that they were heading towards further danger, they threw themselves to the ground as a third explosion rent the air and flames leapt some hundreds of feet into the sky. Under billowing clouds of smoke, debris of all shapes and sizes rained down.

Another witness quoted in the newspaper stated that nothing above the size of an inch remained of No. 5 Mixing House and that he had narrowly missed being struck by a 'one ton' lump of concrete travelling through the air at a disconcerting height.

With the truck exploding less than 50 feet away, inevitably the contents of No. 18 Stove containing another ton of gun-cotton also blew up. *Above:* **On a freezing day, the scene shows the shattered remains of the building looking east towards the line of mist-enveloped trees flanking the Crooked Mile from Waltham Abbey, north to Nazeing. The flat material in the base of the crater is the remains of the lead-lined floor. The broken trees are the only indication of the line of the Cornmill Stream hidden behind the rim of the crater.**

Right: **We took the comparison a little further back to show some of the concrete remains today. Many new trees and a new bridge over the Cornmill Stream obscure part of the view, but on this clearer, warmer, day, the rising land beside the distant roadway is no longer shrouded in mist.**

Just 200 feet to the south of No. 18 lay the old dry Stove No. 19. The wooden structure caught fire, this picture giving a good illustration of the method of constructing the inner building inside the protective mound. The view is looking west across the truck line, towards No. 14 Stove and the Engine House.

While a number of the workers in the factory understandably ran from the area of the explosion, there were no reports of outright panic, and many brave hearts stood firm and completed their delicate and dangerous tasks. Thereby many buildings survived that might have themselves blown up if abandoned.

Among the ongoing processes was that inside No. 2 Washing House 150 yards from the seat of the explosions. Two hillmen, William Sylvester, aged 25 years, and Leo O'Hagen, also 25, and Stanley Sewell, 33, a hillman trainee, were working on the most critical stage of the production process when the series of explosions occurred outside. The structure of the Washing House itself was little affected by the blast and the debris raining down outside, but the liquid in their charge remained particularly susceptible to shock and the men could still have left their posts for a safer place. The danger of the situation was heightened by the loss of the all-important heating system.

Sylvester maintained a watch over more than a ton of nitro-glycerine through its final purification process, while O'Hagen and Sewell stayed together overseeing the delicate process of bringing the nitro to a point of relative stability. To achieve this, all three men were obliged to stay at their posts for a further two hours. Subsequently, each was awarded what was then known as the Empire Gallantry Medal. (Later, when the George Cross was instituted in place of the EGM, they received the Cross in its stead.)

Rescuers and the factory fire brigade approached the disaster area and sought to take control of the situation, and by the end of the day most were to be stained with the tell-tale yellow of the chemicals. A swift roll-call in the nitro section confirmed the loss of five men and narrowed down the identities of those involved. Meanwhile, the factory was besieged by the fraught relatives of almost everyone on shift that day. Those outside the strongly-guarded gates did not have the luxury of roll-calls; all they could see and hear meant little except death, and with stringent wartime secrecy, most were not even aware which section of the factory their loved ones worked.

The shattered bodies of Kelman and Robinson were soon found half buried by debris some four yards from the 12-foot-wide crater, some 3ft deep, created by the explosion of the truck. It was the constituents of this settling debris that led to the conclusion that it had been the first explosion — that of the Mixing House — that had killed them, rather than the subsequent explosions. The bodies of these two unfortunates were subsequently examined by Dr Keith Simpson, the well-known pathologist, and found to have died from multiple injuries.

When the danger of further explosions had receded, many helpers, including officers from the town police station, were drafted in to search for human remains inside and outside the factory but only a few scraps of flesh and bone, later assessed to be sections of human arm, were found of the other casualties.

Even as the fires burned, an official Court of Inquiry to look into the disaster was being set up. Under Lieutenant-Colonel J. C. E. Pellereau, six members were assembled to decide upon the probable cause and sequence of the disaster.

Among the aspects to consider were:

(a) Sabotage.
(b) Faulty procedure.
(c) The presence of foreign matter in the mixture.
(d) The condition of the plant.
(e) Impure ingredients.
(f) Acceleration of output.

For some time before the explosion, there had been rumours of sabotage affecting a number of manufacturing centres. These rumours had been taken seriously and the police were tasked with investigating them but, in spite of the gravity of these suggestions, there seems to have been little active investigation affecting the Royal Gunpowder Factory. In theory, it was generally accepted that sabotage of an explosive works was relatively easy. This was not the classic instance of a saboteur introducing a bomb into the factory. The greatest danger to the plant lay in the deliberate introduction of impurities into the dangerous process. Fortunately, self-preservation by the process workers was already designed to screen out all impurities, whether deliberately or accidentally introduced, so it was thought that only poor levels of training and faulty procedures would allow such sabotage attempts to succeed.

That evening, an official communiqué was issued in Whitehall: 'The Minister of Supply greatly regrets that an explosion occurred this morning at a factory in North London. Five men were killed and a number of employees were injured. Fortunately most of the injuries were slight. An enquiry into the causes of the accident is being made.'

Although the majority of London knew the exact location by this time, the defensive note of the press release tried to hide the location from the enemy. In these couched terms, the BBC announced the event on the one o'clock news. Eventually, it apparently became clear that such a tactic was pointless and a further communiqué was issued shortly afterwards: 'The name of the factory where the explosion took place is the Royal Gunpowder Factory, Waltham Abbey.'

At 9 p.m., the BBC bulletin added the name of the factory in full.

This particular picture turned out to make one of the best comparisons for the January blast with a section of the overhead heating pipe still lying where it was left when the burned-out remains of the building were cleared away. Quite how or why it remained there for over half a century is a mystery.

Another good comparison, although one which caused us a lot of head-scratching, was this one which we assumed was taken looking along a road towards one of the blasted buildings on North Site. The Court of Inquiry annotation stated that it showed the 'C.E. Magazine', fortunately also describing it as 'Building 89'. Although this did not appear on the associated drawing on page 37, reference to the plan produced for the Inquiry after the second large explosion on April 20 (page 36) did indicate its location.

Commensurate with the size of the multiple explosions, there had been considerable damage to property off site. The most important local landmark, the parish church of St Lawrence, a vestige of the dissolution of the monasteries having a history going back almost 900 years, drew the greatest attention with the loss of five (plain-glass) clerestory windows completely blown out. Stained-glass windows at the east end of the building that were already boarded up as a precaution against air raids survived.

However, in terms of the scale of glass loss, the glazing of the church was small fry when compared with the acres of nursery glasshouses in the Lea valley shattered in the blast. On a lesser scale, Chaplins, wet and dried fish shop at 43 Sun Street, suffered a plate-glass window blown in and numerous tiles were scattered from roofs near the factory.

With the sheer force of the explosion, the Court of Inquiry had little remaining evidence to allow them to decide the root cause of the initial accident in No. 5 Mixing House, and the result could only be based upon supposition, no matter how well founded that may be. The loss of the two hillmen pushing the truck, the truck itself and the surrounding buildings, Nos. 14, 18 and 19 Gun-cotton Stove's were all known to be as a consequence of the initial blast.

The site was visited by the members of the Court of Inquiry the following day. No. 5 Mixing House was now just two large lakes, the nearby canal waters having seeped through. The location of the former No. 18 Gun-cotton Stove was now a 6-7-foot-deep circular depression with a diameter of 60 feet. Hemmed in by a concrete wall at the north end and an earth mound at its southern end, No. 14 Gun-cotton Stove had blown sideways across the canal and into the trees without creating a crater.

The inquiry quickly homed in on the two most likely causes: the lack of training and the prevailing freezing temperatures. Although it was a rare occurrence, it was widely known among the chemists and longer-serving process workers that a phenomenon known as frozen nitro-glycerine existed, indeed, it was one of the prime reasons for the cessation of work if temperatures fell below 10°C. Where it occurred, the freezing of the nitro created solid lumps which were difficult, and particularly dangerous, to force through the mixing grid. The problem was rare and one that most of the regular staff had never actually encountered. To many of the newer wartime workers it was just one of many things that they had been told about. The Court heard evidence from a wide range of witnesses, most being asked about the possibility of frozen nitro being introduced into the building although the majority discounted this line of explanation. Nevertheless, the Court was inclined towards the theory that it might be that an insufficiently trained worker could have failed to recognise the problem and tried to force a piece of frozen-hard nitro-glycerine through the grid with disastrous consequences. Both Purkis and Parkes might fit that scenario.

The Court heard that No. 5 Mixing House did not undertake its own pouring-on process. Instead, it was one of the buildings which took delivery of the bags by small canal barge and then sent off its mixed product before setting to mix more. It was realised that it might be possible that one or more of the poured-on bags could have frozen at some stage of the journey after leaving the warmth of the supply building, and that this had not defrosted before being worked on. It was found that 60 bags of material had been exchanged shortly before the explosion. The incoming bags had been prepared in No. 2 and No. 3 Pouring-on Houses. Robinson and Kelman loaded at No. 3 and took the boat to No. 2 where they handed the vessel over to Mr. Head before setting off to undertake the trucking duty which was to kill them a short while later. The severe weather had resulted in a need to break the surface ice, this extended the journey to the Mixing House to 25 minutes, which Head claimed was twice as long as normal. He arrived and unloaded just after 10 a.m., some 40 minutes prior to the explosions. Times were rarely more than guesses as factory time-pieces were rare and personal watches absent.

In the absence of precise timing, the question that the Court of Inquiry had to ask itself, but could not answer, was whether the poured-on mixture was outside the relative warmth of the process buildings long enough for a portion of it to freeze. More controversially, it was a question whether one of the less-trained operatives did in fact abuse the resultant frozen lump in trying to force it through the sieve. We will never know.

However, when we reached what we believed was the same spot today we were faced with recent excavations for a canal. To us, this was a strange fate for a roadway but it was only then that the truth dawned upon us: the 'roadway' was not a road after all! Covered with dust and debris from the blasts, the surface of the water of the canal just appeared to take on the mantle of the solid. Much of the wood lining the edge of the canal bank has survived and, although cut down in height, the concrete traverse retains the impressions from the wooden shuttering that was used in its construction. The buildings in the background include a disused gunpowder store.

Left: **No. 2 Weighing House after the first explosion looking south-west towards the Engine House alongside No. 14 Stove. Over to the right is the seat of the explosion.** ***Right:*** **The framework of the footbridge over the waterway still stands.**

In order that production could restart with the least delay, repairs to the damaged buildings were started immediately, a number of the structures being completely rebuilt.

The repairs were urgent, a factor which resulted in outside contractors being rushed onto the site with a minimum of delay. Among these additional workers were some from the Mowlem organisation. Long-term site workers used to their own safety equipment based on rubber, leather and gunmetal, were disconcerted at the sight of the burly outside workers smashing the scattered lumps of concrete with heavy steel sledgehammers. Warnings from the old hands failed to result in these outsiders desisting.

Not long after their arrival there was the inevitable bang as steel met a particle of nitro-glycerine. No one was hurt, but the Mowlem men walked off site as a body and were never seen again.

FURTHER ACCIDENTS

The following month the RGPF was shaken by another explosion. Fortunately, on this occasion on Thursday, February 22, no one died, but three men were taken to the hospital.

There was a link between this incident and the first explosion. One of the pouring-on buildings affected by the first explosion had been abandoned in such haste that one of the workers had failed to shut off the supply of nitro-glycerine before getting clear of the collapsing roof. The result of this was that the floor became covered in a sheet of frozen nitro.

After a great deal of searching, the authorities managed to find two volunteers who were willing to enter the building and remove the material. The sagging roof was shored up and secured with ropes and the pair entered with a steam jet to liquefy the frozen material and then toss sawdust over it, prior to bagging up the mixture and removing it.

These now waste explosives were being burned on an area off to the west near the Powdermill Cut termed 'the burning ground'. This was not far from the area in which the five men were killed in January. The principle behind the process was that the waste material was spread on the ground and when ignited, like most explosives in an uncompressed state, they simply burned fiercely and went up in smoke. Occasionally, and this is what appears to have occurred in this instance, the flames ignited a pocket of powder which had slipped down a small fissure in the ground. This, being effectively contained by the fissure, exploded. Although the area was shaken by the blast there was no damage to private property and the injuries caused were minor.

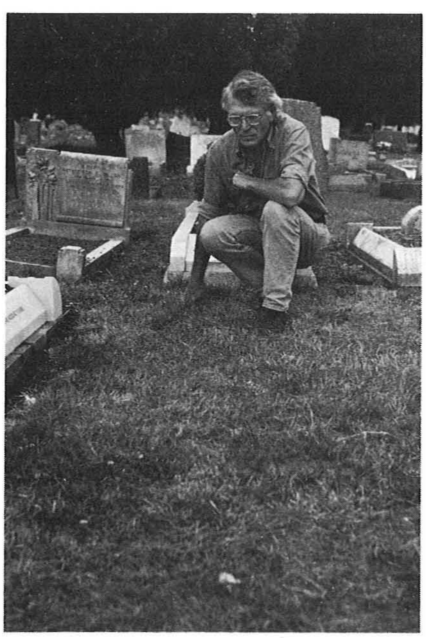
Having just been rebuilt, No. 2 Weighing House (Building 53A) was wrecked again in April so that the modern replacement ***(left)*****, considerably enlarged and bearing a different building number (S27), bears little resemblance to the original. The footbridge is hidden in the trees.** *Right:* **An unexpected discovery in the nearby undergrowth was the remains of the old nitro-glycerine 'gutters' 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 more usual canvas cover. It may be significant that this trough appears to have led towards the site of the ill-fated No. 5 Mixing House.**

Left: **The reliance on gravity for distributing the nitro is well shown in this photograph showing the gutter snaking down from the mound of No. 2 Washing House and over the cut beside the blasted Washwater Settling House. It was in No. 2 Washing House that three men, William Sylvester, Leo O'Hagen and Stanley Sewell, were working on the most critical stage of the whole process: the nitration of the glycerine when the risk of a spontaneous explosion is greatest. Not only was the material then specially sensitive to shock or vibration, but the hot water and air service necessary to maintain the temperature of 70 degrees on that cold January morning had been put out of action by the explosions elsewhere on the site. The three men stayed at their post to monitor more than a ton of nitro-glycerine going through its final purification process, their courage and devotion to duty being acknowledged by the award of the Empire Gallantry Medal — replaced later by the George Cross when the new highest award for civilian gallantry was instituted in September 1940. (Mr O'Hagan died in 1968, Stanley Sewell the following year, and William Sylvester in March 1996 during the research for this feature.)** *Right:* **Were it not for the sharp eyes of Ray Sears, a local historian who accompanied us on our expedition to the RGPF, we might never have pinpointed the spot and thus have appreciated the importance of the picture. The spring growth was beginning to shroud the view of the mound around No. 2 Washing House when Ray spotted a building number sign hidden in the nettles. Much of the support structure for the nitro-glycerine gutters remains, in spite of being abandoned since the end of the war.**

Two of the less injured were a couple of workers from the Building Works Department, Bob Boswell and Cyril Eagles. Cyril had been well out of the way at the time of the first explosion setting up sandbags at the Sandhurst Hospital in the RGPF. This pair were tasked with dismantling the wooden scaffolding from the previously damaged Acid Factory. They had all but finished when the bang went off and threw them sideways. The corrugated iron acting as a black-out measure to mask the glow from the retorts was ripped off and showered down on them. The scaffolding had to be re-erected to undertake yet more repairs.

As if this incident on the burning ground was not embarrassment enough, on Monday, April 8, another accident at the factory killed one of the workers. Although there was no explosion this time, nonetheless Nathaniel Evans, aged 32, of Enfield, was fatally injured by extensive acid burns and died in hospital.

With these albeit minor incidents weighing heavily, and the shooting war having started for real on the Continent, there is little doubt that when in mid-April another massive explosion ripped through the RGPF some of the workforce were gripped by a state of despair.



As for the casualties, the few pathetic fragments of Albert Lawrence, of Albury Road, Enfield Wash, married with four children; John Parkes of Charlton Road, Edmonton; and Charles Perkis of Forest View Road, Walthamstow, both married with one child, were buried in one coffin in Waltham Abbey New Cemetery in Sewardstone Road (see page 49). *Centre:* **Ray and Bryn stand at the spot where the two truckmen were found buried under debris. Both bodies were so badly shattered that recognition was impossible but the inquest held at Walthamstow on January 22 accepted identification from identity discs. Albert Kelman, married with three children and living in Brecon Road, Ponders End, was laid to rest in Grave 7337CON in Enfield Highway Cemetery** *(left)*, **and John Robinson, of Bowood Road, Enfield, also married with three children, in Square N6** *(right)* **in Abney Park Cemetery, Stoke Newington, now an overgrown nature reserve.**

brick foundations and crashed down with such effect that a number were scalded by the spilling mugs of tea!

Later the same day, another Court of Inquiry was set up, again under the leadership of Lieutenant-Colonel Pellereau. The investigating group visited the scene but, like in the January incident, the strength of the explosion left them with little tangible evidence to determine the root cause of the accident. The rebuild of the Mixing House was examined lest it have a bearing but no fault could be found in its construction so they looked elsewhere.

Although the proceedings for the first explosion had taken place both speedily and in the full glare of publicity, understandably with the war now having started with a vengeance on the near Continent, the latest incident was played down and the newspapers were not allowed to publish the true location of the blast until after the inquest almost two months later. To all but the locals, the site of the loud bang that had reverberated across the capital remained 'North London'.

As before, one of the first causes suspected was sabotage and the question was raised as to whether the police at Scotland Yard should be consulted but this potential reason for the disaster was quickly ruled out. However, although the deliberations of the Court may have satisfied them that there was no question of sabotage, the press, muted though it was by censorship, raised the spectre of a Fifth Columnist in the midst and, at one stage, the 'suspicious' movements of a specific workman were highlighted. The result of this diversion of effort was that Scotland Yard was eventually brought in and Detective Inspector John Scurr, stationed with the Metropolitan Police J Division at their headquarters in Hackney, gave evidence to the proceedings on April 26. Predictably, he cleared the man and was unable to provide a renewed link to the sabotage theory.

Whilst the blast took place in the same general area of the production facilities, on this occasion it appeared that the cause might be a little different in that the weather was warmer and it appeared to involve the deaths of hillmen with a relatively long history of service. So, there remained a hope that there might be a reason, other than a lack of training leading to human error, for this accident.

ANOTHER FIVE DIE

The second major disaster in 1940 occurred within the North Site nitro-glycerine section at 9.14 a.m. on Saturday, April 20. The seat of this explosion was No. 2 Paste Mixing House, a structure sited immediately to the north of the earlier blast. This was one of the buildings which had been completely rebuilt as a result of the damage, and was of similar design and use to that involved in triggering the series of blasts in January, all the major features of the original design being reproduced in the rebuild.

Again five men were killed, a further 15 being injured, six severely. The building was totally destroyed as were the bodies of the three occupants within, the only remains found being a section of skull. Those of two other men were found floating in one of the aqueducts.

Whilst a number of other structures were affected by the blast, on this occasion there were no further explosions or fires. The flimsy design of the building and the strength of the surrounding mound worked exactly in the manner designed and few other buildings suffered severe damage. One reason behind this was the smaller amount of explosive involved as it was estimated that No. 2 Mixing House had contained a total of 3,800lbs of nitro-glycerine and gun-cotton of which 1,260lbs was nitro.

Whereas the January explosion had damaged up to 20 buildings badly enough to require rebuilding, this time — other than the site of the blast — only five were damaged. In both explosions, Building No. 45, (No. 1 Washing House) and Building No. 53A, (No. 2 Weighing House), received such damage as to require a complete rebuild.

To the workers within the factory, the danger of sympathetic detonations in neighbouring buildings remained. The greatest risk was to No. 1 Washing House, across a canal and 55 yards to the east, where three hillmen were working. The chargeman, Hugh Burns, with Edward Sollis and W. T. J. West were inside the Washing House with a ton of nitro only half way through its production process when the roof came in on them. Burns was injured in the collapse but worked himself free and remained with the other pair to see the nitro-glycerine carried through until it had reached a safer state of purification. For their devotion to duty, all three hillmen were awarded the British Empire Medal.

Cyril Eagles had again been out of the way of the blast, this time walking along Long Walk to the west. He recalled that a number of others who might have been expected to be closer to the explosion had fortunately sloped off for their half-hour morning meal break a little earlier than scheduled. Their injuries were less in the line of duty. The wooden canteen building this group had been in was lifted up off its disintegrating

Top: **Three months later, another devastating explosion rent the air at Waltham Abbey. This time it was No. 2 Mixing House (Building 46) which went skywards but the protective mound largely confined the blast. Looking north-west from the porch, we see the Washwater Settling House in the background. Although it appears intact, in fact it was only the roof that remained.** *Above:* **The original report stated that after being wrecked twice in a year, No. 2 Mixing House was to be abandoned and rebuilt on a different site to the north beside Newton's Pool. Our comparison shows that clearly someone changed their mind about the re-use of the old site.**

At the time, three men were working in the building: Francis Keene, David Lewis and Thomas Galvin. This time there could be no suggestion that frozen nitro was the cause as the temperature was almost 70 degrees (21°C) so the Court of Inquiry had to look elsewhere for an explanation. It was the discovery of a piece of skull near fragments of a sample bottle carrier that led the Court to believe that the chargehand, Francis Keene, might have dropped one of the bottles on the porch so setting off a chain-reaction with the 1½ tons of explosive inside the building. It was believed that the sample carrier had just been delivered to the Mixing House as the bodies of the two men on the delivery round — Harry Monk and Leslie Raby — were found blown into the nearby watercourse.

Francis Keene, aged 26 years, was the chargehand inside the building. With him were a 36-year-old Welshman, David Lewis, and Thomas Galvin, a 41-year-old married man. All three had worked in the factory since before the war, the latter pair for three and four and a half years respectively. Keene had only taken the post of chargeman a week before the blast, replacing the usual man who was on leave but from the evidence given to the Court, it was clear that Keene was an utterly reliable worker, it being this reliability that led to him being given the post in the first place.

The two bodies recovered from the water, a feature variously referred to by witnesses as the aqueduct or 'the cut', were of local Waltham Abbey hillmen, Norman Henry 'Harry' Monk, a fully-trained hillman, and Leslie Raby, a hillman learner. They were both aged 27. Both were employed in support of the local Mixing Houses so it was initially assumed that they had the misfortune to have been passing the building at the wrong moment when they were blasted into the water which ran only 18 yards from the Mixing House.

An overriding worry was the continued lack of experience exhibited by the majority of the workmen. The Superintendent, Mr P. G. Knapman, was quoted as telling Court that 'our labour at the moment is appalling'. His disquiet was further reinforced by comments from one of the shop stewards who made a statement with regard to allegations of accelerated output, the suggestion being that the process workers were being pressured into ever greater levels of production. However, the Court took the opinion that as there was evidence that the rate of work had not increased above 92 bags per shift, there could be little credence given to this aspect.

It was the finding of the remains of a sample carrier in the water near to the spot where Monk and Raby had been found that provided one of the major clues to the final outcome of the investigation. The position of other fragments of the sample bottle carrier and the small section of skull, ascertained to be from the body of Keene, were also deemed important clues. The bodies, the sample carrier and the section of skull all lay on the same side of the seat of the blast in No. 2 Mixing House — the nitro tank. Although some of the wooden fragments from the carrier had floated off downstream prior to recovery, there was never a logical explanation for the loss of 18 lead sample bottles as it might have been expected that a maximum of 12 would have been lost in the blast.

It was known that conditions in the building appeared to be normal. The area was seen to be clean and the internal temperature of the building had been recorded by Raby on an earlier visit as a comfortable 21°C. One of the witnesses, Mr Cuckow, the assistant foreman of the nitro-glycerine section, reported that he had visited the affected building only minutes before the incident. Although, in line with standing practice, he had not entered the building, he stated that all appeared normal and that he believed they had just completed pouring-on and that Keene was clearing up as Lewis and Galvin had started to mix. It was circumstantial evidence, but it might be expected that samples would be taken at this time. This, and the relative positions of the bodies and debris, suggested the possibility that the primary reason for the presence of Monk and Raby near to the Mixing House was not accidental after all.

It was suggested that Raby had gone to the Mixing House and left the sample carrier in the porch. Calling Keene, Raby had then walked out, clear of the building, and towards the cut to speak with Monk whilst awaiting the call to return and pick up the samples for testing. Unfortunately, neither man was far enough away from the building when it inexplicably blew up. Whilst considering that there was an equal possibility that gun-cotton dust on the floor might have been set off by having a bag dropped onto or dragged across it, the most likely cause appeared to be that Keene had dropped one of the sample bottles as he took them to the porch.

In their report, completed on May 20, the Court settled on blaming Keene for the accident and then sought to put recommendations for remedial action to stop such an accident occurring in the future. However, these ideas were so wide ranging that it was clear that there was little real idea of the true cause. It was suggested that the very need for sampling within the Mixing Houses should either be removed altogether or, alternatively, the keeping of sample bottles should be further restricted in number. The Court were also not happy with the use of the lead bottles as their opacity hid the extent of the contents. Foreign bodies in the mix were not wholly ruled out either, recommendations to further reduce the incidence of these also being made.

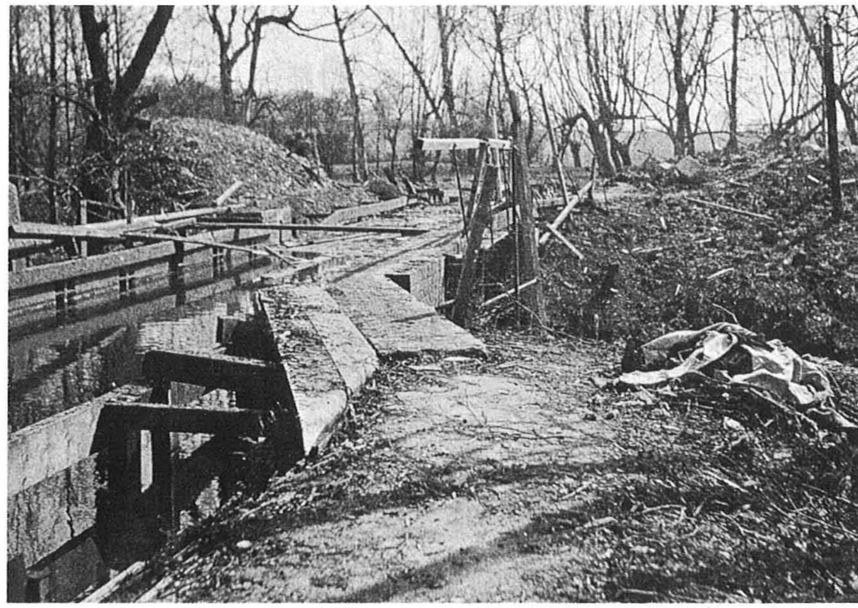
In addition, the report drew further attention to the design of the steam heating radiator, although it had been examined again and again as a source of potential problems. As a measure designed to improve the supervision of unskilled workers, it suggested that the buildings be entered when visited, although this measure would require a radical change in the rules governing the number of men allowed in the building at any one time. Further thought was also given to the building of a completely new nitro-glycerine section within the factory, which would remove the situation whereby the whole production capability was halted by the loss of a single building.

The same view is today virtually unrecognisable due to subsequent rebuilding. In the background, beyond the re-instated mound, is the aqueduct alongside which Monk and Raby met their deaths. The new No. 2 Mixing House was rebuilt in 1941 off to the left as Building 46R. On the extreme right is the ornate sluice gate filling Newton's Pool where underwater experimentation took place.

The inquest for the April incident did not take place until Friday, June 7, and it was reported in a fairly muted manner in the inside pages of *The Enfield Gazette and Observer* on the following Friday. In spite of censorship, the paper was allowed to print a quote from Mrs Keene given at the inquest that, prior to his death, her husband had complained to her that 'there was too much speeding up at the factory and there would be another explosion before long'. Giving evidence, she stated that her husband was distressed at the conditions created by the speeding up of the dangerous processes. Keene had been a shop steward for the nitro section and it was known that on two occasions he had brought this to the notice of the authorities without success.

William Lewis, the brother of David, had travelled from the family home in Wales to the inquest. He confirmed that David had expressed similar disquiet. Lewis had regularly given vent to his complaints about the pressure to produce more and yet more and, a few weeks before his death, he had been hauled up in front of the foreman. He achieved a move within the factory but, ultimately, it had failed to remove him from the danger. The Court of Inquiry had been told of a number of instances where three individuals had requested moves on various grounds but with 3,000 workers on site this was not considered significant. On the other hand, Mrs Maude Galvin did not support the allegations of speeding up from her own knowledge of her husband's work.

The two local men pulled from the water were buried in Waltham Abbey New Cemetery in Sewardstone Road. Norman Monk was buried in Plot 53A and Leslie Raby, only married a matter of months before his death, was laid to rest just one grave space away. Raby's parents, Alfred and Minnie, lived all their married lives in a house in Denny Avenue overlooking the cemetery. Devastated at their loss, they were also separated from their son in death, their own final resting place being in Section D right near the back of the house they once occupied.



The pathway where Monk and Raby were killed was photographed for the record. At this point, an aqueduct (on the left) is carried in an iron trough over the waterway running below it at right-angles.

Left: **The iron of the one-time aqueduct (Bridge 20) is now smashed and no longer carries water although the canal which runs below still feeds Newton's Pool. However, from the relative levels, it is clear that the waterway beneath was not intended to be navigable.** *Right:* **The footpath can still be discerned.**

Bryn and Ray seek out the graves of Harry Monk (behind) and Leslie Raby (in the foreground) in the cemetery on Sewardstone Road. (Three of their colleagues who survived, Hugh Burns, Edward Sollis and W. T. J. West, were awarded the British Empire Medal for their devotion to duty.)

Not far away, the scant remains of the other three men were buried in a single casket on Monday, June 10, in plots 123/124/137/138 of Section O. This spot was right alongside the communal grave of three of the employees who had been killed in the January explosion. However, unlike the deaths occurring in the Royal Gunpowder Factory in the Victorian era, no stone was ever placed to mark either grave, and it was not until *After the Battle* made its initial enquiries that all members of the long-serving cemetery staff were made aware that the area of grass over the graves was the final resting place for six men killed at the RGPF.

After this second explosion, there were renewed efforts to rebuild the damaged buildings. No. 2 Mixing House, already completely rebuilt after the January explosion, was resited a little way to the east on spare ground beside Newton's Pool, the underwater testing facility. Here it was hoped that the ill-fated No. 2 might be far enough away to survive a third disaster!

In the event, there were to be no more serious explosions at the Waltham Abbey factory. The site received its fair share of attention from the Luftwaffe in the ensuing Blitz and, being in the south-east close to London, was clearly placed in an awkward strategic position. It was long held that a well-placed stick of bombs would destroy not only the factory but, with collateral explosions, the whole of the surrounding town as well and, in time, production was moved to other sites, locations hopefully beyond the range of all but specific attacks. A number of incendiary bomb fires were started on the site, but never the big one.

In 1943, the site changed from its rôle of explosive production to that of an experimental station. At the end of the war, the old name of the Royal Gunpowder Factory passed into the history books and the first of a number of relatively short-lasting titles substituted, these name changes reflecting a changing rôle in the modern world. Finally, it undertook the task of rocket propellant testing. Whilst the amounts of explosive required were thus reduced dramatically, the contamination of the site was such that it was never again a safe place to work. Until the end, there were to be more small on-site explosions as continued disposal activities on the burning ground took the same dramatic turn that had occurred in February 1940. Fortunately, however, there were no further deaths.

Looking south, towards the M25 motorway overbridge on Sewardstone Road, no marker or memorial indicates the last resting place for six men. Only the well-tended area of grass between the block paving and the war graves marks the spot where the scant human remains were buried from the two major wartime disasters at the Royal Gunpowder Factory.

Remaining a secret place to the end, it retained its position in the front line of development. At the time of the 1982 Falklands War, activities included the final testing of the engine for the British Aerospace Sea Skua air-launched anti-ship missile. Untried in battle and with these trials still incomplete, the military flew helicopters into the site, often during the dead of night, to take every test round available for onward transmission to the South Atlantic battleground. The Sea Skua undertook, and passed with flying colours, its final firing trials in the hands of the men off the Falklands. As if that were not all, much of the specialised explosive and other equipment required by the Special Forces was in such short supply that they too moved in and requisitioned all they could lay their hands on.

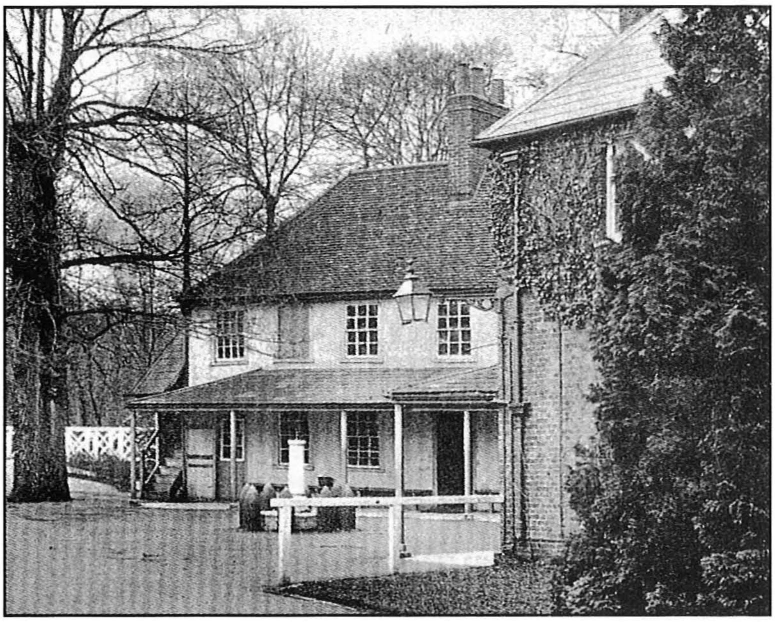
During the early 1980s, the government privatised and then sold off the sprawling South Site. Subsequently, after Royal Ordnance was sold to British Aerospace, the site was progressively closed. At the time it was thought that, in spite of the known contamination, the site could be quickly turned around and sold off as prime building land but the underlying contamination was found to be far more extensive and a speedy sell off was not to be.

Both sites of the former gunpowder factory were finally closed for all explosive-related activities on June 30, 1991. The 190 acres of North Site, where the 1940 explosions took place, remained in government hands as the Royal Armament Research & Development Establishment but plans were soon proposed to investigate the possibility of turning it into a museum telling the story of the explosive industry. The Ministry of Defence placed the site and its future form in the hands of agents, Civix Ltd., and a locally formed Trust Steering Committee, but at the time of writing (May 1996) its future remains in the balance and it is currently closed to public access.

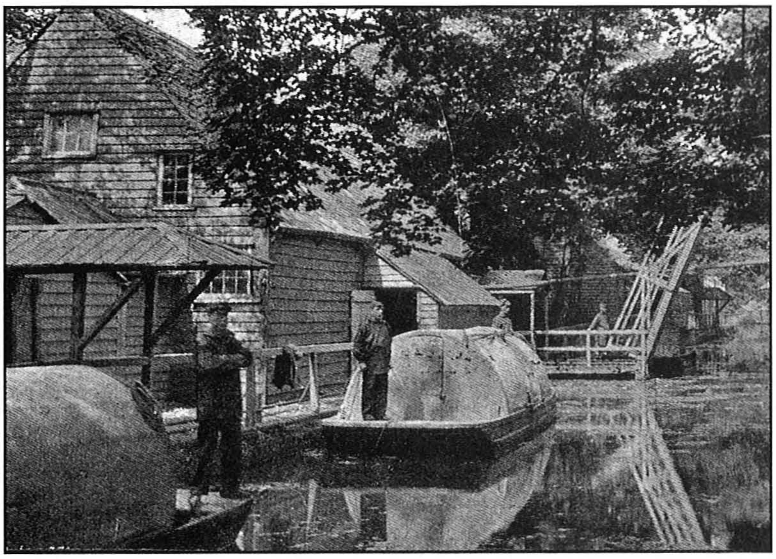
One of the many dry canal beds excavated in the decontamination process of the former RGPF. This is the one that encircled the site of the C.E. Store No. 4 and the disused Gunpowder Store. Should the proposed Gunpowder Museum project go ahead, it is envisaged that this and the other waterways would be filled with water once again and be plied by electric-powered replicas of the original canal boats.

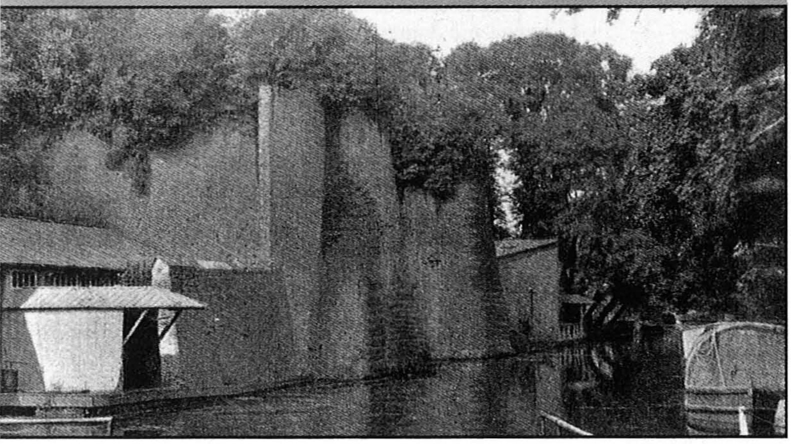
Waltham Abbey Powder & Cordite factory, 1899

Researched by GRAHAM SACKER



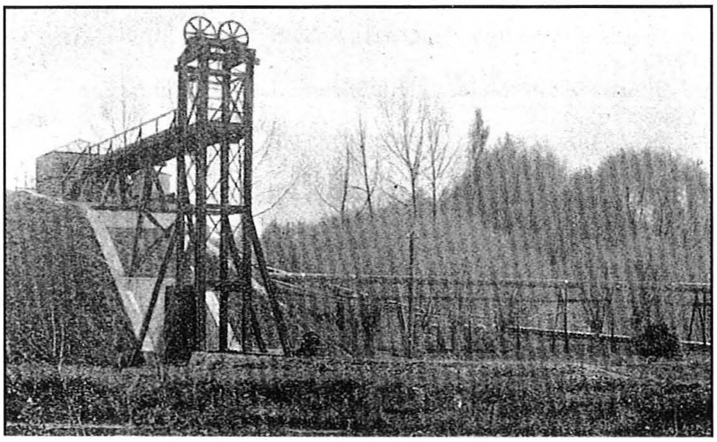
Employing 870 men and boys, situated one mile north of Enfield Arsenal, on and connected to the Lea Navigation canal, the Waltham Abbey factory covered an area of 302 acres.

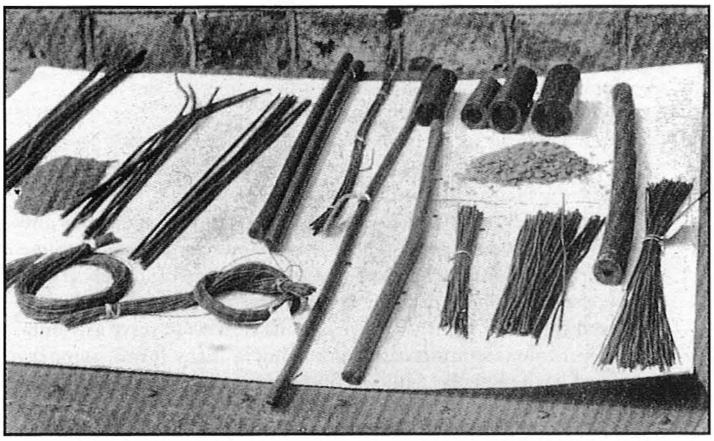




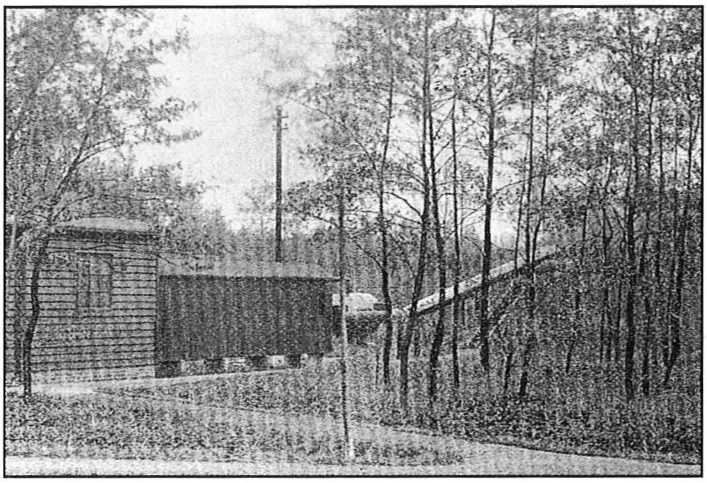
290 separate buildings, comprising corrugated iron and wooden huts, were situated at considerable distances from one another. Of flimsy construction so as to offer little resistance in the event of an explosion, the huts were positioned between, in some cases, high earth banks with brick ramparts and in most cases, plantations of poplar and alder trees. They were positioned alongside four miles of navigable waterways which enabled the explosives to be transported easily and with a minimum of danger. All the buildings were, however, linked by an extensive and tortuous series of steam heating pipes which kept an even temperature in the work places throughout the winter months.

In 1899, command of Waltham Abbey was in the hands of Colonel John Ormsby RA, who had wide experience in matters of ordnance and warlike stores. His post had, until a few years before, been chiefly concerned with production of black powder, but, at the turn of the century, cordite was the propellant then in favour.

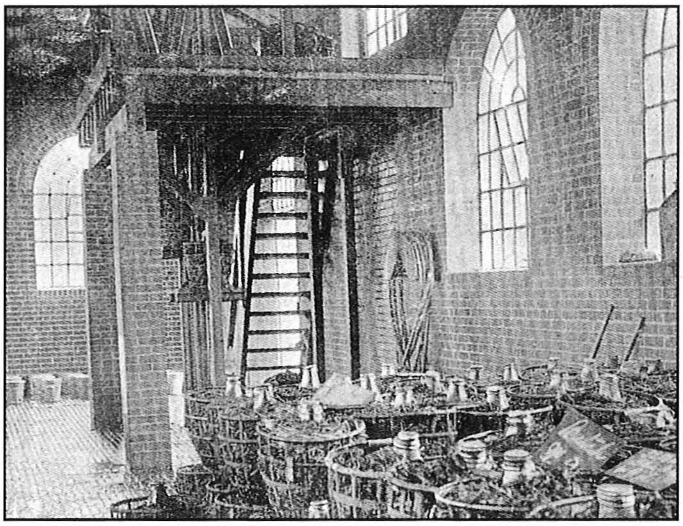




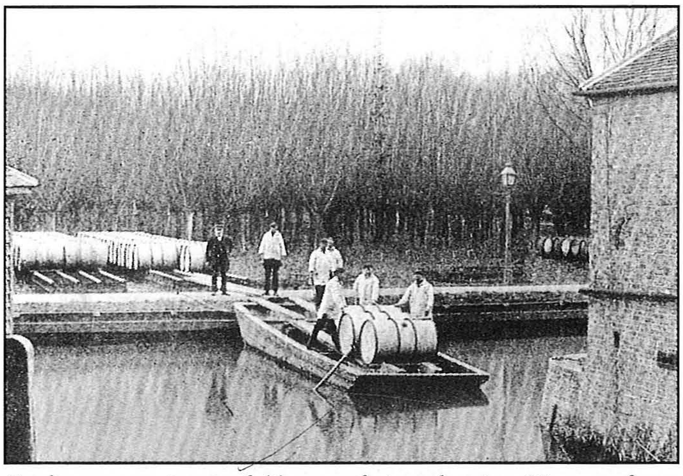
A brown, cord-like substance, having as its base nitro-glycerine and gun cotton, forced into a mixture by the addition of acetone it was drawn out in a variety of sizes and shapes. In the illustration, a number of these can be seen, from .01" in diameter, for use in pistol cartridges, up to the .5" rope used for the charge of the 12" breech loading wire wound naval gun. All the components for the production of the cordite, with the exception of acetone, were manufactured within the factory.



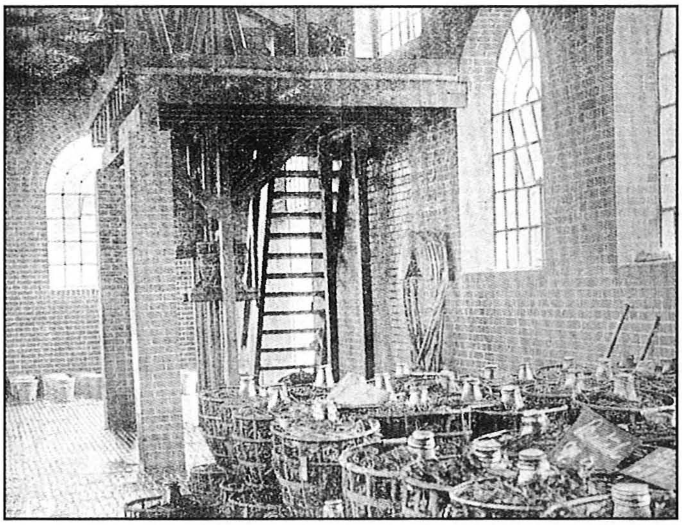
Another product was the explosive substance known as Lyddite, of which picric acid was the chief constituent. The acid stained everything with which it came into contact a bright yellow and those men working in that particular part of the factory were easily recognisable by their yellow tinged skin and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

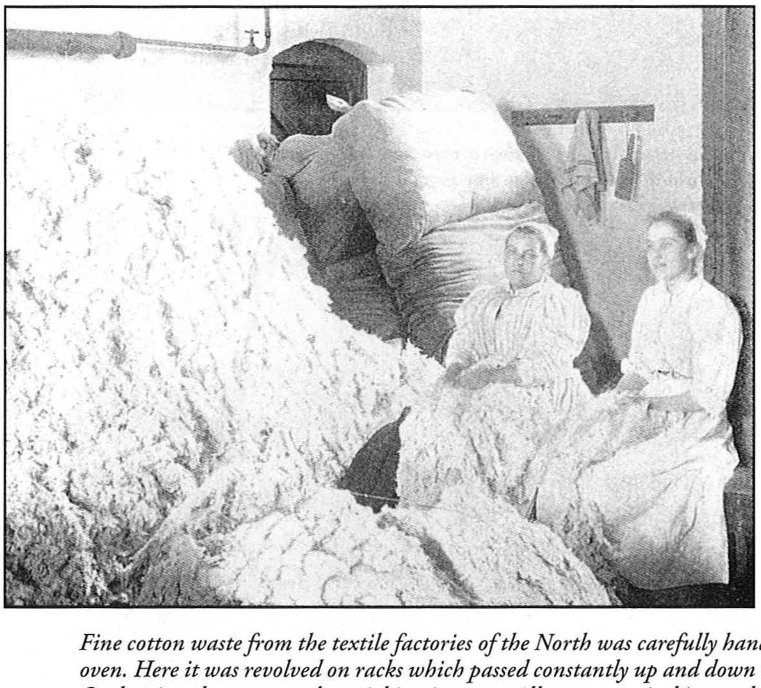


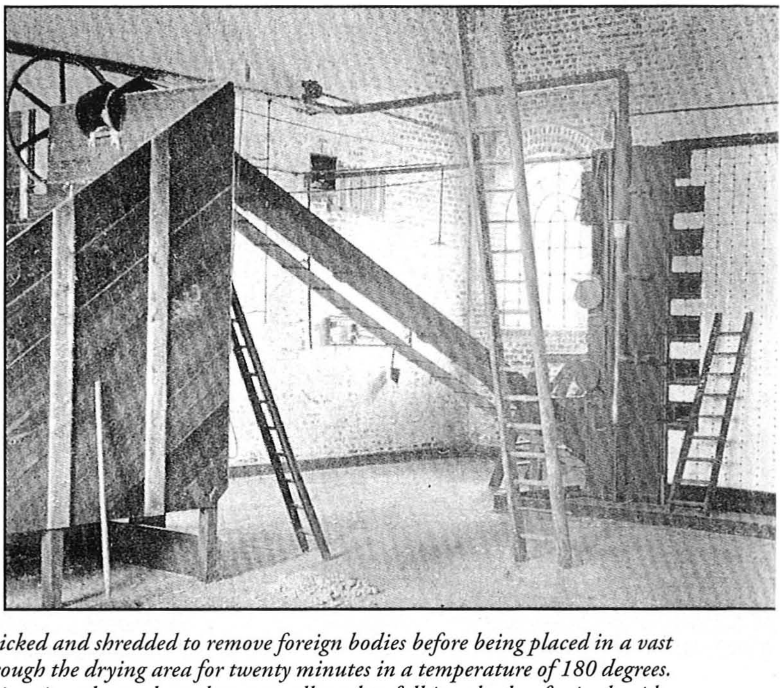
Gun cotton was produced by the action of nitric and sulphuric acids upon cotton and was, in its own right, a powerful explosive. To make it, carboys of acid were positioned near to the mixing boilers. Hoisted some 10 feet above ground level, the contents were tipped through a lead conduit, the nitric 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.



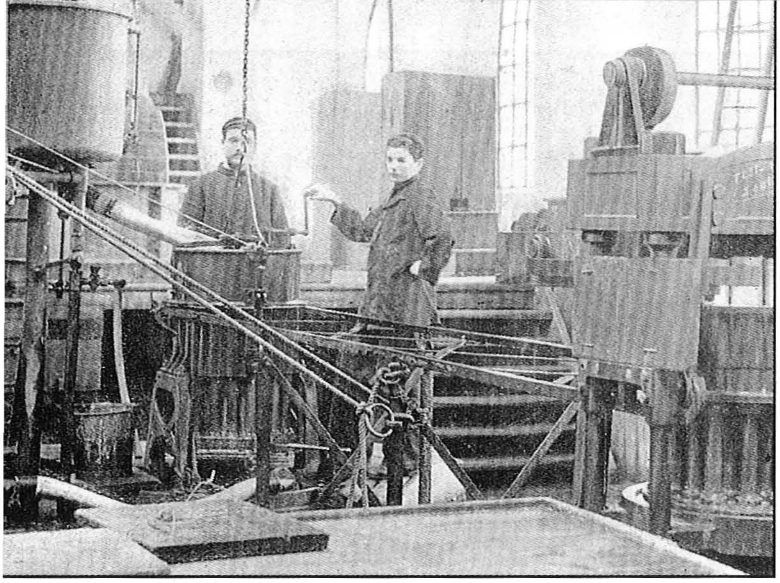
Cordite was a mixture of 44 parts of nitro-glycerine, 28 parts of gun-cotton, 15 parts of acetone and 4 parts mineral jelly. The jelly was used simply to enable effective mixing of the other substances. Acetone, a derivation of acetate of lime, dissolved and amalgamated the gun cotton and nitroglycerine for the purposes of moulding both into shape. The excess solvent was removed by drying under gentle heat.



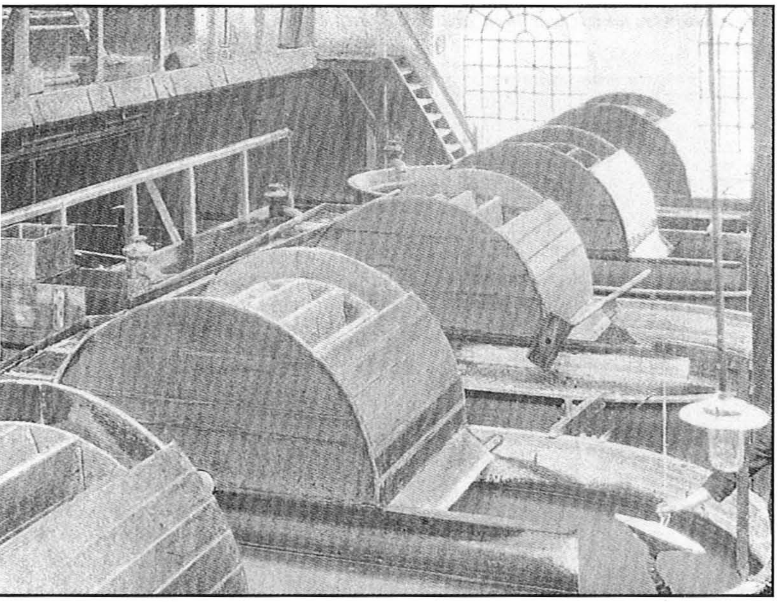




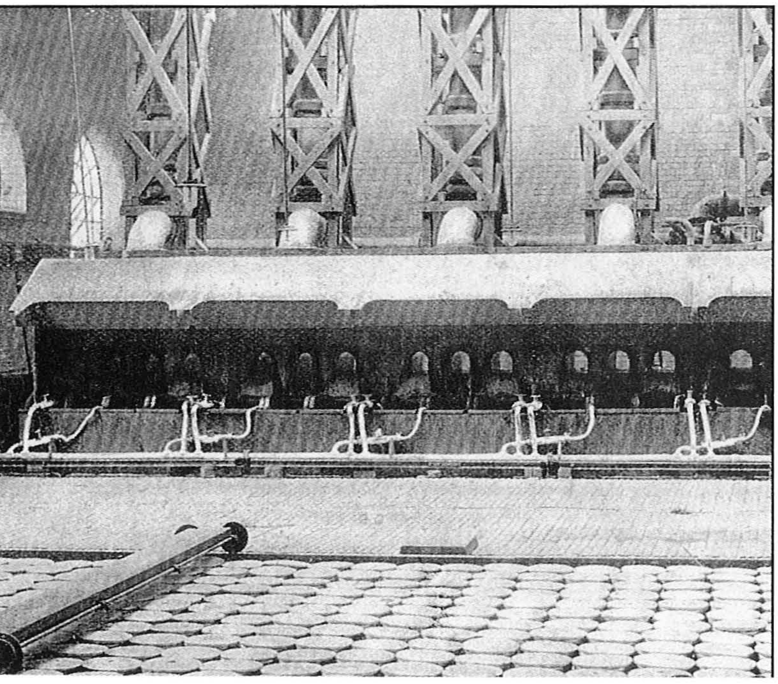
Fine cotton waste from the textile factories of the North was carefully hand picked and shredded to remove foreign bodies before being placed in a vast oven. Here it was revolved on racks which passed constantly up and down through the drying area for twenty minutes in a temperature of 180 degrees. On leaving the oven, packs weighing just over 1lb were sent in bins to the nitrating plant where they were allowed to fall into baths of mixed acid.

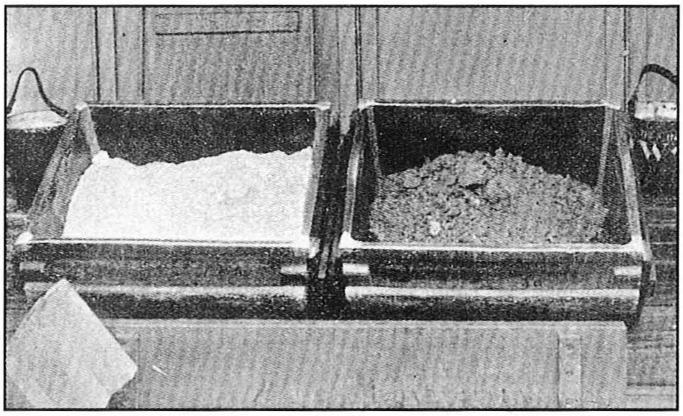


Each pack would soak up some 14lbs of acid during a five minute immersion, after which the excess was removed in wringers. In this area the fumes given off by the acids were extremely corrosive - workmen being issued with free worn-out army clothing which soon fell to pieces in these processes.



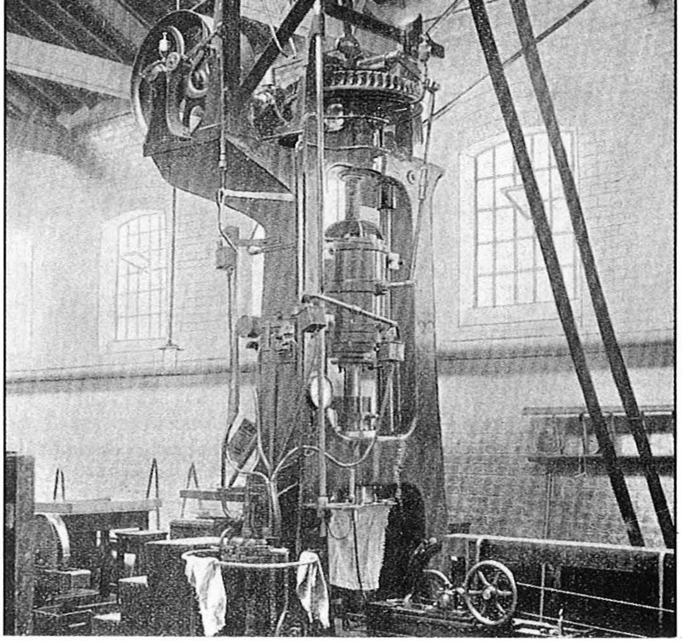
The cotton was then washed thoroughly to remove all trace of acid and later boiled in huge vats for a period of 72 hours. After wringing out, the material was placed in bags and taken to the pulping room where it was minced and again thoroughly washed. The excess water drawn off, the remaining cotton was transferred to a press and formed into discs. Having still too much water content, these discs then passed through another press where they were subjected to pressure of 7 tons per square inch, reducing their size by half and the water content to 14%.

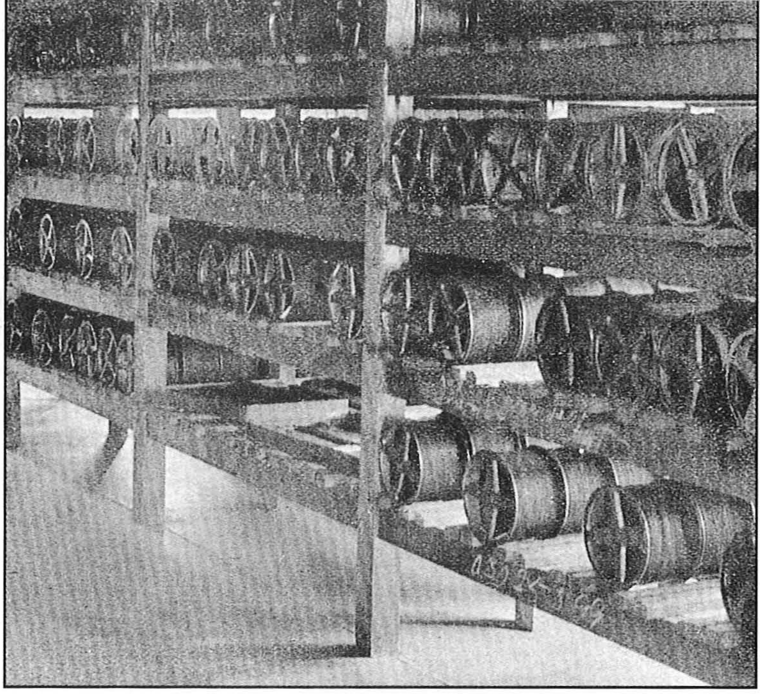




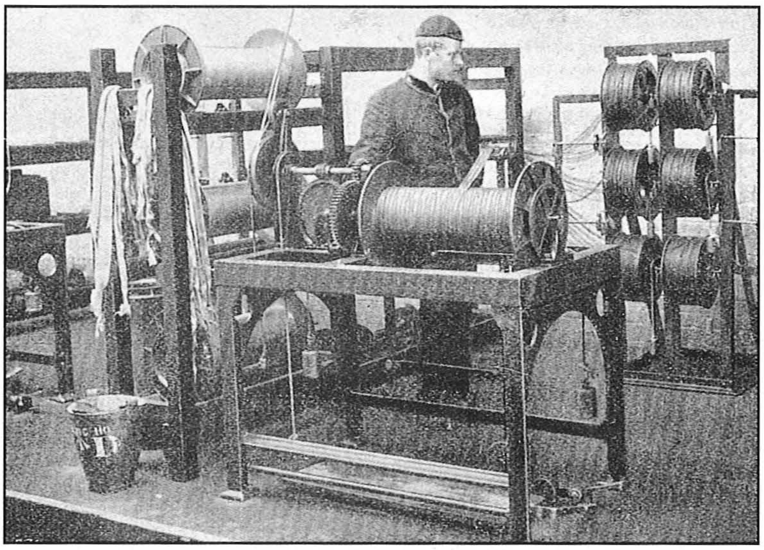
The nitro-glycerine part of Cordite was obtained by the action of nitric and sulphuric acid on glycerine, resulting in a heavy, oily fluid, straw-like in colour. Nitro-glycerine is exceedingly sensitive to concussion. For ease of handling and to limit possible damage by explosion, relatively small quantities were dealt with in each of the factory buildings. 44lbs of NG was mixed with 28lbs of gun cotton, 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 three and a half hours. At this point 15lbs of acetone and 4lbs of jelly were added and a further three hours of mixing took place.

Incorporation complete, the cordite was taken in lots of 20lbs weight to the pressing room. Here it was loaded into a cylinder and subjected to

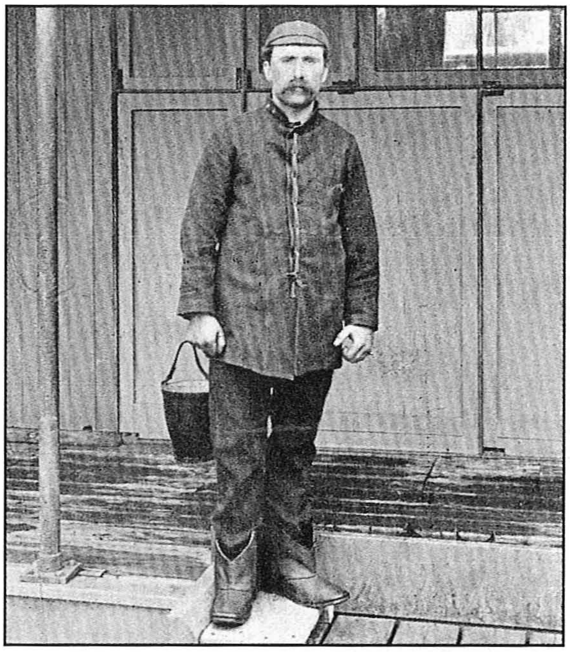


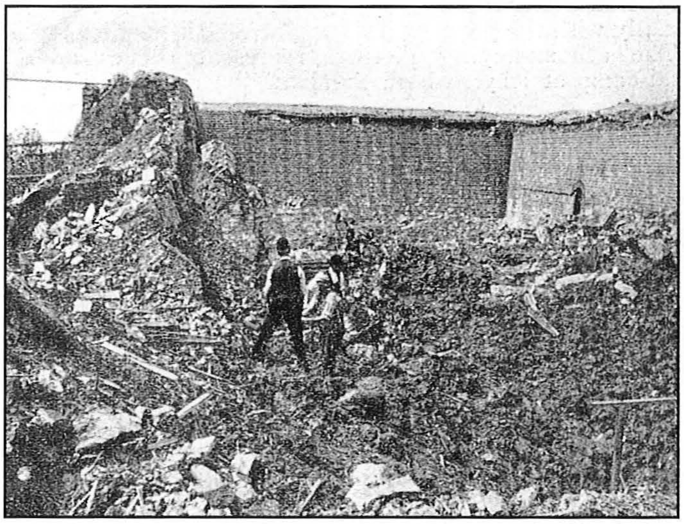


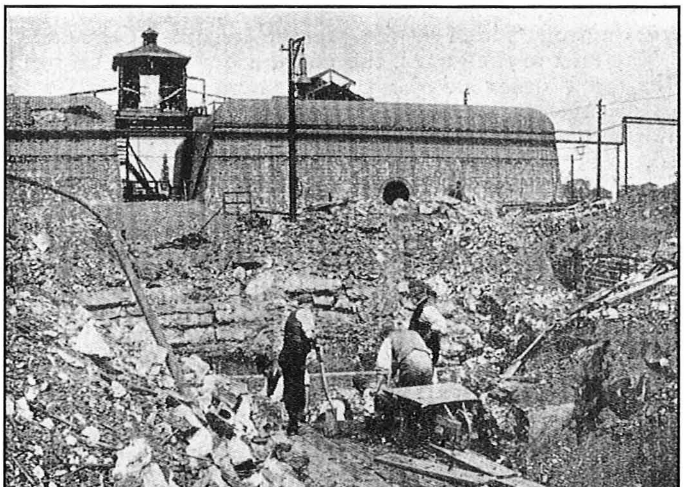
hydraulic pressure of 600lbs per square inch. Escape hole sizes being previously chosen from between .01 to .5 of an inch, the finished cordite was extruded into a grooved block and cut into lengths or wound direct onto drums. In order to remove excess acetone, the cordite was removed to a drying room 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. On those drums destined for use in rifle and pistol cartridges, ten reels of the dried explosive were placed on a machine and ten strands, one from each reel, were twisted and blended onto one new reel. Six of the new reels were again blended, as in the illustration, into one rope, consisting of sixty separate filaments. When cut to one and quarter inch lengths, these charges formed the 30 grains of propellant needed for the .303 ball cartridge. No cutting was carried out at Waltham - this hazardous process being delayed until the last possible moment, once the drums had been transferred to the Enfield factory.







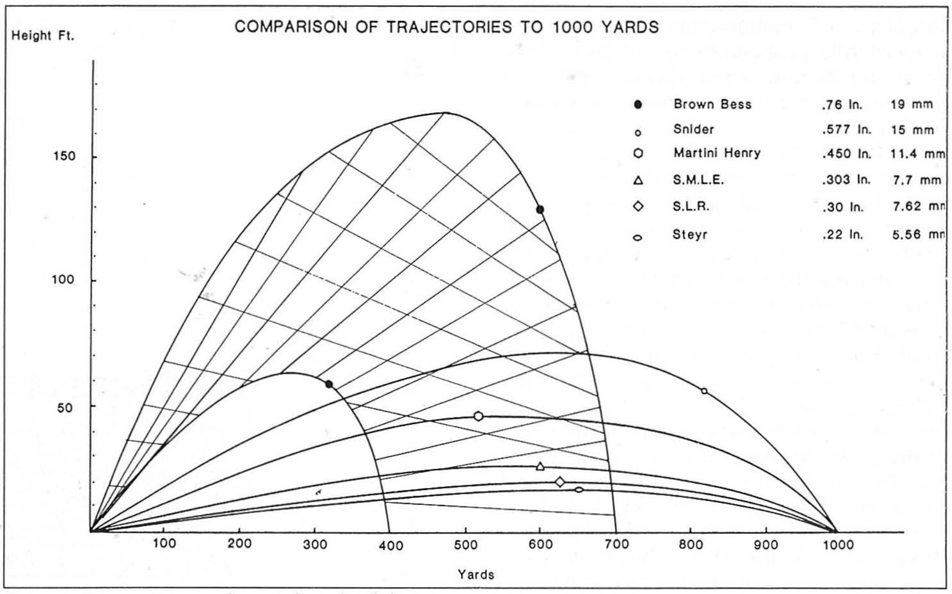
All workers at the explosives factory were subject to the most stringent conditions which required daily physical searches for metal items or matches which might have caused a spark to ignite the contents of a workplace. Similarly, special clothing without buttons and pull-on boots without nails were the order of the day. Despite precautions, there were a number of incidents where buildings and ramparts were destroyed. Cordite was, however, an effective and durable propellant - charges taken from old cartridges found on Great War battlefields and having been exposed to the elements for eighty years will almost always ignite immediately when consigned to flame.

An Informal History of Gun Propellants

Part V

Smokeless Powders: Improvements, Developments and a Bit of Theory

Ian Thompson



A comparison out to one thousand yards of the trajectories of some major military rifles of the last two hundred years. Note that the Brown Bess was not capable of carrying that distance and that, as shown by the shaded area, the balls could, for a given elevation of barrel, range anywhere between 400 and 700 yards. The progressive flattening of the trajectories is primarily due to increases in muzzle velocity which, in turn, was made possible by improvements in the propellants.

BY THE LATE 1880s when the first serviceable smokeless powders were starting to become available, most armies and navies could scarcely contain themselves in the rush to rearm. The main controlling factor was the cost, and it was no small sum that was under consideration; at one stroke almost their entire stock of weapons had been relegated, at best, to second-line service with the militia or reserves. Another very large expense was that of erecting the necessary plants to make the new powders together with supporting services for manufacturing nitric and sulphuric acids, refining cellulose etc. For many it was their first essay into modern chemical technology and hence even more expensive and traumatic. Another option was of course to buy the NC from a friendly more advanced neighbour, but the problem then was to decide just who was friendly, to what extent and for how long — a problem which remains today.

Certain economies could be made with small arms, in particular where it was possible as a stop-gap measure to merely load the old ammunition with a reduced charge of smokeless powder to duplicate the original ballistics, thus reaping the benefits of a massive reduction in smoke and in fouling while gaining time to consider the next move.

By this stage, repeating rifles, machine guns and automatic light cannon had been around some time but had not caught on to any great extent since blackpowder posed a very severe limitation on their operations. There had also been a continuing pressure for even greater reductions in the bore of military small arms in order to further flatten the trajectory, reduce the recoil and to lighten the load that the infantry was forced to carry. Once again, blackpowder was no help, for it was a simple geometric fact that as the diameter of the bore was reduced, so the ratio of the surface area of the bore to its cross-sectional area was increased, and hence the deposition of solids in the bore was also increased. The average bore of military rifles was at the time around .40 to .45 inches and further reduction seemed impossible if a worthwhile rate of fire was to be maintained.

Such was the rate of progress at this stage however, that within very few more years, all the major powers of the world were equipped with small calibre — about .30 inch — repeating rifles firing a smokeless powder of their choice, France with a derivative of Poudre B, Germany with a derivative of Ballistite and England with Cordite Mark 1. Other lesser powers took out manufacturing rights for one or another of these powders, or in many cases just blatantly copied them without bothering about the niceties. Commercial manufacture also became common and many of the traditional cartridges were offered in three loadings, the original blackpowder load, a smokeless load duplicating the blackpowder load and another smokeless load of improved performance. As late as 1911, Eley Bros. were advertising such cartridges under the titles 'Blackpowder Express', 'High Power Nitro Express' and 'Nitro Cartridges for Blackpowder Express'. All of which probably caused a great deal of confusion for all concerned.

It was also quickly discovered that the new smokeless powders were much harder to ignite than their predecessors and that the large charges needed a fair-sized blackpowder igniter as well as a primer to get them going uniformily. Within a few years it was noticed that the Cordite sticks near such igniters began to show signs of pitting and spots of discolouration, which was attributed to localised degradation catalysed by the sulphur in the blackpowder. The official title of such spots was 'sulphur corrosion' but other more graphic slang terms were much more common. The cure was obviously to remove the sulphur, thus leading to yet another, and possibly the last, grade of blackpowder — the sulphurless series which were generally designated by prefixing their normal title with the letter 'S'. Apart from a few minor uses in igniters or pyrotechnics, blackpowder was finished.

We have mentioned from time to time that the main feature of the new gelatinised smokeless powders was that they could burn on the surface and that this was the most common way of controlling their burning rate; it may now be a good time to enlarge on this. The concept of surface-only burning is really quite simple and applies to many similar processes in everyday life. For instance we all know that to make the fire burn more brightly for a short time, we must add wood cut into small pieces, i.e. with a large surface area; that the bigger logs, i.e. those with the smaller surface area, burn more slowly and that the logs get smaller as they burn — it is a simple as that. Another feature is that the flame does not sit directly on the surface of the solid, but is separated from it by a layer of gas or vapour. In a time sequence, the events are as follows; firstly the solid base material must be heated to get things going, this heat decomposes the surface of the solid to give off inflammable gases which mix with each other (or with the air in the case of our log fire) in a layer above the surface of the solid. These gases then ignite and radiate some heat back to the solid which decomposes the surface to give off more gas etc. The intermediate zone where all the preliminary action occurs is often called the 'fizz zone', and if all goes well in that zone, an equilibrium state is set up as shown in the diagram, and the combustion carries on at a steady rate. Note that the solid itself does not burn directly.

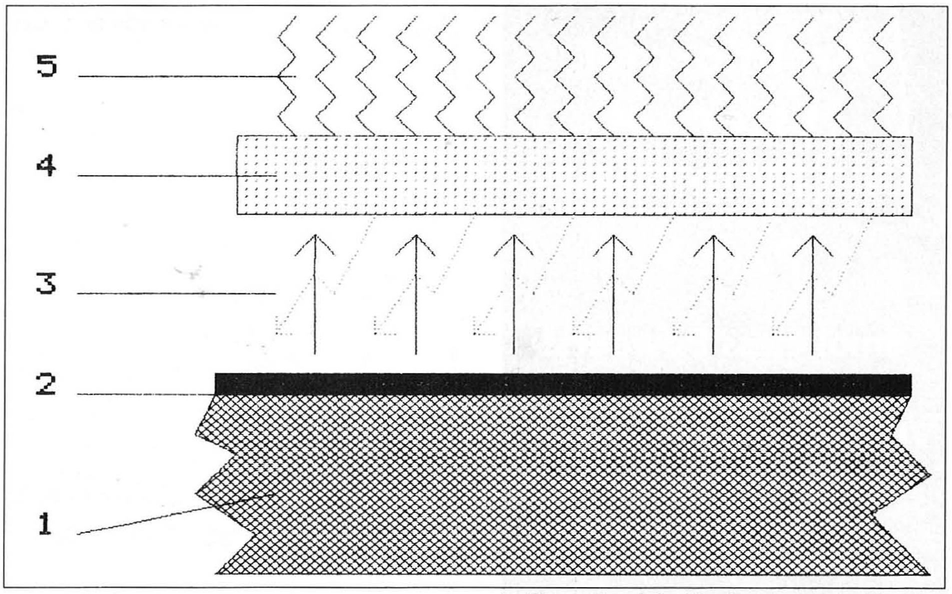
If we look at a slab of propellant, say a cube or a cylinder, we can see that as the burning progresses, the slab gets smaller, thus the area which gives off the gas gets smaller, the amount of gas gets smaller, the heat output gets smaller etc; in other words, a general slowing down as the burning progresses. If however we consider a slab with a hole in the middle with both the inner and outer surface burning, we can see that as the outside area of the slab progressively decreases, the surface area of the hole correspondingly increases; and it becomes possible to design a shape where the decrease is nicely cancelled out by the increase, thus giving a constant overall burning rate. Fortunately for all concerned, the simple cylinder with one central hole is just such a shape, and that, combined with its simplicity of manufacture is why most modern rifle propellants are of that configuration (the hole is not always visible as it may be covered by some form of surface coating).

As far as the individual grain is concerned, the factor which controls the total time of burning and thus the suitability or otherwise for a given gun system, is the web thickness, and this may be defined as the least distance through which one flame front must burn into the grain before it either consumes that grain, or meets another flame front. For a simple shape such as a solid Cordite rod or a cube of the old black Pebble powder, this web thickness is obviously equal to half of the total thickness of the grain, for there are two flame fronts each burning inwards from opposite sides of the grain — hopefully to meet in the middle.

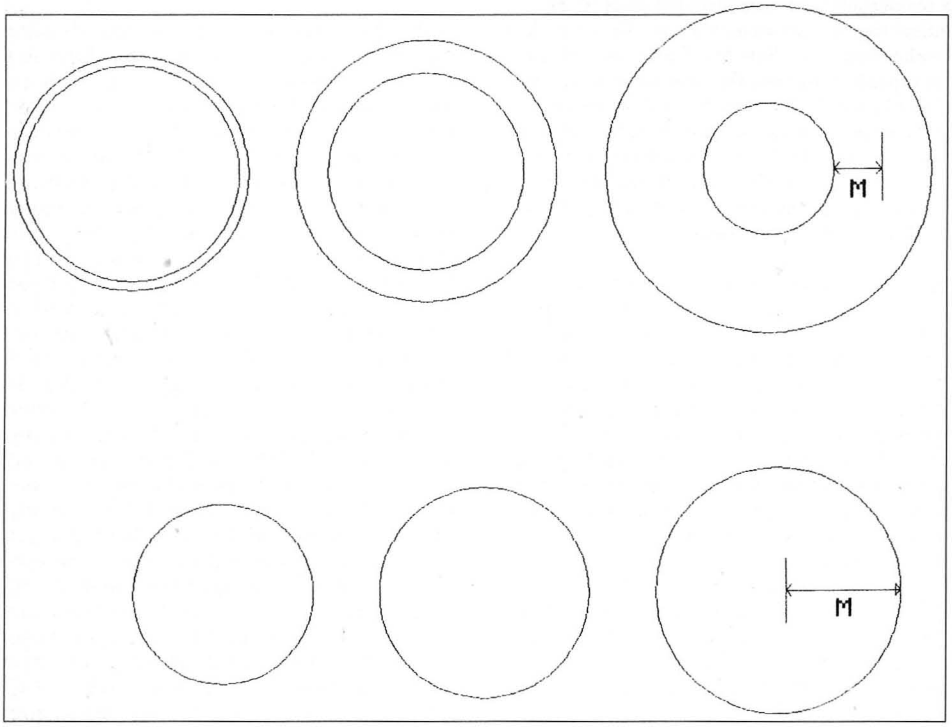
The design of the very large blackpowder Prism grains in the 1880s showed a good grasp of this concept, for the hole down the centre gave rise to another flame front which would then burn outwards to meet the other inward-burning flame front in the middle of the solid portion of the grain. These grains, though apparently enormous, thus had an actual web thickness not much greater than that of the much smaller Pebble powders, and their size was made possible by the slack-burned charcoal used in the Cocoa Powder from which they were generally made.

Unfortunately the fact that the blackpowders were heterogenous mixtures other than true solids meant that grains made from them were relatively fragile and would quickly break up when exposed to the pressure involved in a gun firing. Thus only a very limited range of shapes could be made from them. The new smokeless powders however had as their basis nitro cellulose rendered homogeneous by the process of gelatinisation, thus much larger, more complicated grain shapes suddenly became possible, and the performance of the guns increased yet again as a direct result.

This was not of any real significance for small arms where the total burning time is very short — typically a quarter of a millisecond or less. The larger guns however, having a burning time of several milliseconds, could make full used of the concept and a lot of thought and effort went into the many designs which quickly appeared. Ideally such grains should be easy to manufacture, rigid, mechanically strong, able to pack densely together so that the chamber volume could be minimised yet not so densely that the initial flame front could not spread quickly and evenly, and capable of burning away completely with no wasteful slivers. Quite a stiff specification as you will agree, and by no means all of the grains designed over the years went even close to satisfying it; many I suspect having been designed more as an ego-trip for the designer than to satisfy any real need. The modern trend is rather towards that of ease of manufacture with few shapes existing other than that of a simple cylinder having one or more circular holes running the full length.



An illustration of the 'Fizz Zone' concept of burning of propellant surfaces showing:
1: The cold, unaffected propellant.
2: The heat affected surface layer which is decomposing.
3: The Fizz Zone in which the decomposition gases are flowing away from the surface and radiant heat is flowing back.
4: The flame zone where the gases ultimately burn.
5: The burned propellant gases streaming away.



Left: A sketch showing, to the same scale, the web thickness and several stage of burning of (1) a solid rod such as the original Cordite Mk1 size 3¾ and (2) a tubular grain such as the later Cordite MDT 5-2.

An extension of this line of thought will show that powders which are required to burn very quickly, eg for a shotgun or a pistol, will need a very small web thickness and a very large surface area, and this is provided by making them as thin flat flakes or discs, with or without some additional perforations, similar to those illustrated.

Another feature of smokeless powders and one readily covered by our 'fizz-zone' concept, is that the burning rate varies greatly with the pressure, and this is explained by noting that at high pressure, the intermediate layer of hot gas is compressed and thereby reduced in thickness which causes more heat to be fed back to the solid which accelerates the burning rate to give more gas and so on; a process which can either settle down into a new, faster equilibrium, or can self-accelerate into an explosion if the pressure rise is not controlled. Conversely, if the pressure is decreased, the gas layer is expanded and the whole process is retarded. Indeed if the pressure is reduced quickly enough, the flame front can be pulled right away from the grain and the propellant flame goes out, making it possible to recover partially-burned grains for inspection and investigation; a process known as 'interrupted burning', and a valuable tool it can be.

It is also possible to control the burning rate of a propellant by a number of other methods, eg by varying its chemical composition, by impregnating it with a faster or slower burning compound, or by coating the surface with such a compound. All of these procedures are used in modern propellant manufacture, sometimes singly, sometimes together, depending largely on what the designer is trying to achieve and what equipment is available to him. That however, as they say in the best soap operas, will be revealed in a later episode.

To return to our history; after very few years of service a number of problems began to emerge with the new smokeless powders, mainly those concerned with the inherent chemical instability of the NC itself. From the moment of its manufacture, NC shows a tendency to reject the nitrate radicle that had made it into a propellant in the first place, and to try to revert to its original state. Each such rejection releases one nitrate radicle inside the grain and also a small quantity of heat, and by a most unfortunate coincidence, both the nitrate and the heat tend to speed up the process whereby another nitrate radicle and more heat is produced. Just to make things worse, if that be possible, propellant is a very poor conductor of heat, thus it is relatively easy for a minor amount of instability to set up a small 'hot-spot' which accelerates the local rate of decomposition leading ultimately to a high enough temperature for the propellant to self-ignite. This tended to occur where large stocks of the old-style propellants were held in a fairly small space, such as a warships magazine, and many ships were lost that way; one French cruiser was completely wrecked while unattended in a dry dock; and there is some evidence that the Spanish/American war was started in error over a similar incident aboard the USS MAINE.

Cordite proved to be relatively free from problems due to the happy presence of mineral jelly stabiliser, but proved to be prone to another problem of its own.

While England remained faithful to its Cordite family of propellants, other countries were developing related series consisting of NC alone — the single base types. Much has been written over the years on the 'advantages' of one type as against the 'disadvantages' of the other, including such ill-informed statements as one being 'old-fashioned' whereas the other is 'the latest thing'. As we have seen above, they were developed within a year or so of each other some 100 years ago and each have certain properties that better suit them for certain applications than for others (and vice-versa, if you can make sense of such a statement). The double base types are more energetic and hence use a lower charge weight and volume to give a required performance; but the flame temperature is higher and the gun barrel may thus suffer as a consequence. Single base types on the other hand are easier to produce and use fewer strategic materials in wartime, but they generally need more solvents and take longer to dry. Double base types are softer and more plastic and hence can be made into a greater variety of shapes, including very long rods; while single base types can only be made into short rods which are easier to load but often do not burn as regularly, and so on and so on. In military applications the differences can be very real, but for handloaders the choice is less critical and often limited anyway by what is, or is not, available.

The brittle nature of the single base types means that they can only be produced in a limited range of shapes more or less approximating a cube or a sphere. This is an advantage when measuring such a charge by volume or when pouring it into a cartridge case, but is a major disadvantage when making bag-charges for large cannon; Cordite rods can easily be bundled together and sewn into a simple silk bag, but the short single base rods must be sewn into an elaborate 'corset' to stiffen such a bag enough to make it possible to load and to ram. A further complication is that this corset must burn away completely before the next charge can be loaded, and this may seriously affect the rate of fire of the gun, or the safety of operations. Again more of a military problem than one of the sporting shooter.

It is possible to ramble on and on with this subject without coming to a definite conclusion, let alone overcoming any firmly-held prejudices. Perhaps it can be likened to driving on the left hand side of the road or on the right; neither is inherently correct or even intrinsically better — you just make an initial choice and then stick with it, for it can be very awkward to change later for no apparent benefit.

And with that nice piece of home-spun philosophy we will close this episode and begin again next month looking at somewhat more recent events.

Shotgun propellant grains, in this case Hercules Unique, showing typical very thin web and the very large surface area. Such powders are also often recommended for use in handguns as the ballistic requirements are very similar.

The Spoils of War

by Richard Cuthbertson

THE FATHER of a friend of mine returned to this fair country in 1947. He had fought the Japanese for three years and his Regiment had remained in the Far East for the following two years. They were glad to be getting home to see loved ones and discard the uniforms donned to protect their country and it's interests, but donned out of duty and not desire. In their years in the East the men of the regiment had picked up many objects as momentoes. Bayonets, swords and handguns were popular. A lot of men had small pistols in their kit bags looted from the surrendering Japanese. They were momentoes, curious, soldier's booty. That was all.

Three miles off the coast the transports hove to. A voice stated over the tannoy the list of items that the returning troops were not allowed to bring into the country. The ship would be searched and those found in possession of the prohibited articles would be heavily punished. The strictest punishment was reserved for those in possession of firearms. My friend's father said that from the time of the announcement and for a good few minutes after the transport was surrounded by splashes as the returning troops divested themselves of that which was deemed offensive and illegal. Such was the way we treated our returning heroes.

Before the First Great War my grandfather was in a Northern Pals regiment. He had joined the regiment, as had his friends, partly for social reasons and partly to act in defence of this realm. In the opening stages of the war these regiments, mustered from the great industrial cities, performed with great valour. Having trained together in musketry, they performed with great proficiency and the opposing Germans believed that they were attacking well situated machine guns not Northern Lads with bolt action Lee Enfields.

Somewhere along the line after both wars the British Establishment began to distrust those who had so freely shed their blood. Ideas akin to present Swiss attitudes were discarded and the ownership of firearms was frowned upon. The Russian Revolution and the subsequent upheavals in Europe frightened those in power, even at the peak of their power. Those who had fought for the democracies were not to be trusted with the weapons that had maintained those ideals.

This attitude was also prevalent at the end of the Second World War. Armed insurrections occurred throughout Europe and again the Government became concerned as to the political make-up of the returning troops, hence my friend's father having to drop his momentoes in the Channel. At about the same time, arms freely given to Home Guard units by American citizens, light sporting rifles and such, were reclaimed and destroyed by the British Government. The donors were never compensated nor was it ever mooted that these weapons be returned to them.

Was it a bureaucracy that saw fertile ground for legislation in arms control or was there, after that war, a real fear of insurrection? The latter I doubt. Combatants were too happy to have returned home alive. The violent overthrow of the domestic government was never their concern and in England armed crime was still an aberration. Yet through the fifties and increasingly with the suspension of capital punishment, Home Secretaries became obsessed with the desire to control firearms and shotguns. A few appalling armed crimes became an incentive to increase control even though it was well known that the criminals who committed these crimes were already outside the law and certainly, contrary to the expectations of some 1920's MP, were hardly likely to reflect about their planned crime in the time that would elapse between the application and issue of licence prior to the purchase of a weapon. Soldiers returning from the Falklands were also subject to the warnings and the Customs blitz as they approached this country's borders. Many tried to smuggle in momentoes and a number were caught and fined. They were able to fight and die on some faraway island at the behest of their government, armed with the most effective weapons available, but not considered responsible enough, trust worthy enough or, perhaps, even too criminally inclined to bring souvenir weapons home.

One remembers some years ago airmen warily guarding RAF bases. There was always the possibility of a terrorist attack and yet, for some reason, these soldiers carried empty weapons. I believe a few years ago terrorists were approached by a guard and subsequently they fired a hand gun at him. The guard could not return fire because his weapon was unloaded. Shortly after this incident the policy was changed but it serves to illustrate the attitude of the authorities. I suppose there is always the likelihood that the airman on guard at Biggin Hill could have walked down the road and robbed the local dry cleaners with his FN. Better to guard against that very real possibility than prepare against the remote threat of terrorist attack.

It's the Kipling's Tommy Atkins poem all over again. Soldiers used by their political masters in combat with the most lethal of weapons should be trusted when the fighting is over. They have seen the foulness of war and the power of modern weapons. They have killed and seen their comrades killed. It is appalling to think that on their return they are treated like errant school boys. There is an awful hypocrisy involved, an hypocrisy perpetrated by our political masters.

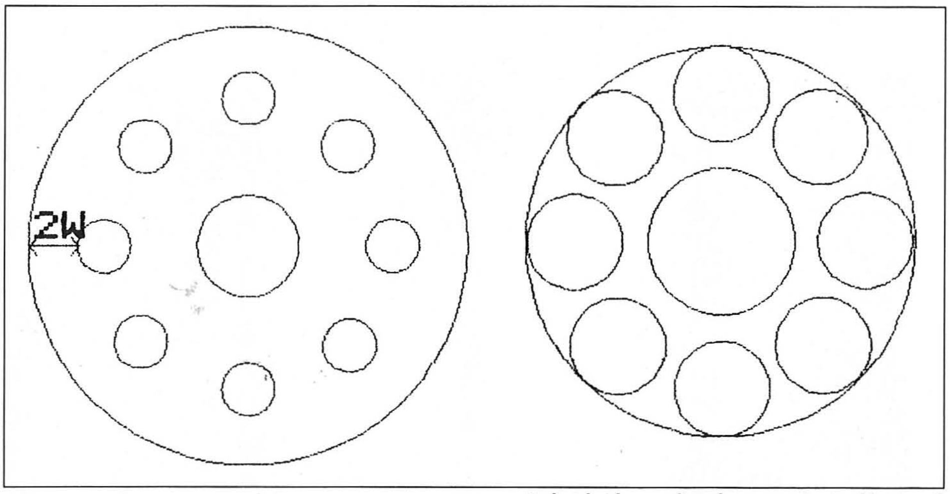
Prime Minister Major was presented with a Kalashnikov in the Gulf. He was photographed holding it in an inoffensive way, rather as if he was presenting a cricket bat. I doubt that Customs and Excise would have ordered the weapon thrown overboard on approaching British air space or that they would have searched the Prime Minister's Samsonites but I knew that it's future was uncertain. It would be either scrapped, deactivated or presented to some worthy institution. I was, therefore, not at all surprised when, a few weeks later, the Prime Minister was photographed donating the weapon to the Imperial War Museum. No-one in this country from private citizen to Prime Minister would have been allowed to go to a range and fire that weapon. There is no good reason, just a distrust between the governing and the governed that leaves a sour taste in the mouth of any one who would aspire to be a good but armed citizen.

An Informal History of Gun Propellants

Part VI

Mainly Big Guns and Wartime Muddles

Ian Thompson



A sketch of a mutliperforate grain, in this case 9 holes, showing the original Web Thickness, 'W', and the remaining shape after it has been about half-burned. The grain design shown is pretty poor, as a tenth of a millisecond or so later there would probably be a lot of slivers, ie irregular shaped pieces of unburnt propellant left after the main body had burned through and broken up.

THE NEXT major event in our somewhat rambling history is World War I, and this proved to be quite an eye-opener as far as gun propellants were concerned, as it was indeed for many other things as well; it could even be termed a watershed between the technologies of the ancient and the modern worlds. Just as World War II was dubbed the 'phyicists' war, so may World War I be called the 'chemists' war, although the mechanical engineers may feel that they too deserve a mention. A massive amount of military equipment of hitherto undreamed-of complexity and efficiency had been made since the introduction of smokeless powders some 25 years earlier, but the full potential of all this equipment had never been fully explored; nor even was the need to do so widely appreciated. There were virtually no tactics devised to make use of the greatly improved rates of fire and of the increased ranges of the new guns; no workable system for transporting such equipment into the field and of maintaining it there, and little thought given to problems of producing the new materials in the quantities and to the timescales demanded by such a war.

In 1914 there were just two grades of Cordite, Mk.1 and MD. Within the period covered by this paper there were some twenty times that number. The total rate of production of Cordite throughout the UK was about 20 tons per week in 1914, but within one year this had risen to over 200 tons per week from just one factory.

It is an historic fact, and a matter of no small wonder and concern, that much the same conditions of unpreparedness existed again at the start of World War II some 25 years later. Of course, it can never happen again, can it?

Many of the developments in propellants which suddenly became apparent in that later war had their origins in the earlier war, but were never fully exploited then or during the intervening years of 'peace'. Such developments are thus almost impossible to put into any really historic order and will be covered here in a more or less random manner to suit this story as it unfolds.

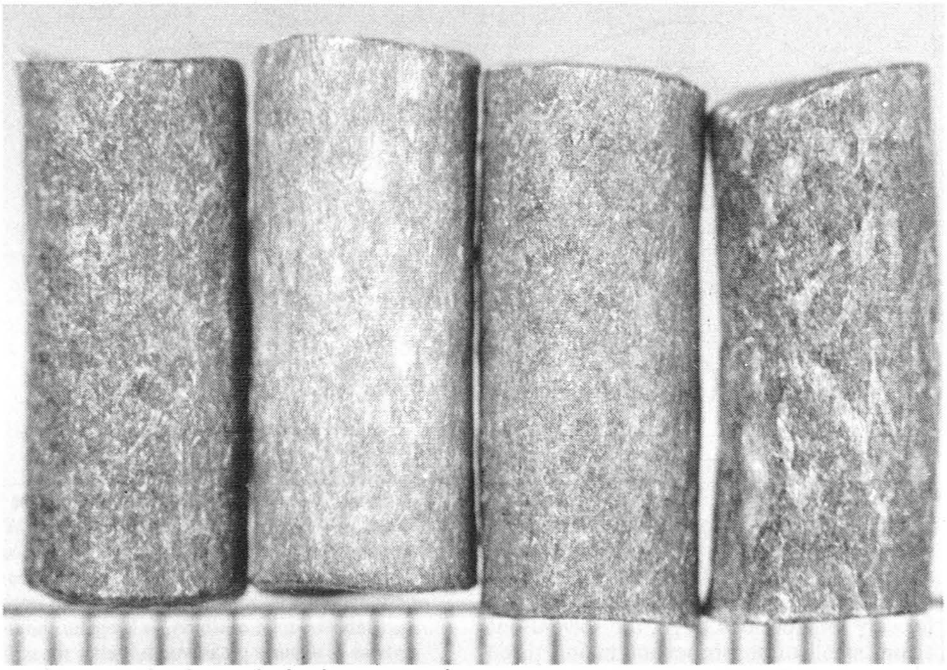
In peace time it had been considered quite acceptable when making Cordite to add as a solvent a large quantity of acetone to the dough of nitro cellulose and nitro glycerine to speed up the gelatinisation of the NC, despite the fact that it was then necessary to stove the grains at about 50°c for very long periods to get the solvent out again; small arms propellant taking three days, and cannon powders up to five weeks. In war time this delay was completely unacceptable, for not only did it slow down the rate of production, but it represented a significant hazard with several hundred tons of propellant exposed at any given time. The alternatives were equally unattractive. The solvent could not simply be omitted, as the mixing operation then became too slow and too variable, nor could it be left inside the grains as it slowly evaporated anyway, changing the shape of the grains and their ballistics as it did so. Furthermore the solvent, like most other chemicals, was in short supply and full recovery was essential if production was to be maintained. The chemists settled down to study the whole process of gelatinisation to see if they could find ways of circumventing these and other problems.

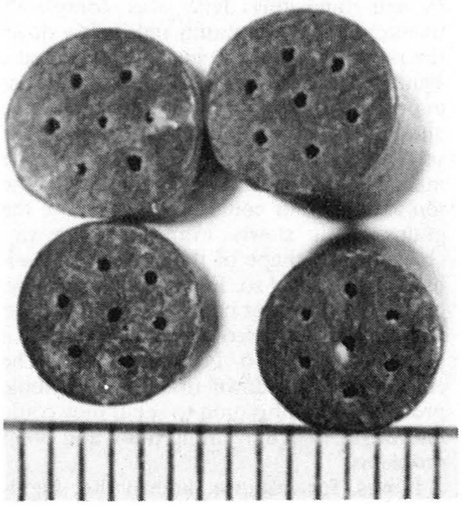
It was, for instance, known that highly nitrated nitro cellulose as used in making the existing Cordites was soluble only in acetone whereas the lower grades could be dissolved in the more readily available solvents ether and alcohol. A new family of Cordites were thus introduced using this new solvent process and having an increased nitro glycerine content to offset the lower energy content of the lower grade nitro cellulose. Such powders were named RDB (Research Department formula B) and were very widely used, being almost completely interchangeable with Cordite Mk.1 in the larger guns.

Further research at Waltham Abbey, the original home of government powders some 150 years earlier, led to yet another family of Cordites making use of the newly developed stabiliser 'carbamite' (ethyl centralite) in place of the traditional mineral jelly. This material first used in Germany in World War I, proved to be a very good stabiliser and to have the additional attractive property of greatly speeding up the incorporation of the nitro cellulose into the nitro glycerine during manufacture. This reduced the need for solvents and in turn reduced the need for the prolonged stoving which as a side-effect caused such a lot of distortion in the larger grains. Such powders were named Cordite W in honour of the place of their birth, and further work along the same lines led to yet another family of naval Cordites, the SC (Solventless Cordite) series, in which the solvent was virtually eliminated by working the paste of nitro cellulose and nitro glycerine at higher temperatures and rolling pressures. This admittedly was a somewhat hazardous operation, but to did do away with the equally hazardous drying period of the conventional Cordites. A perfect example of 'winning on the swings but losing of the roundabouts'.

Later on during World War II as the supplies of carbamite dwindled, another series was introduced, the WM (Waltham Modified) family in which part of the carbamite was replaced by mineral jelly, the same material which had earlier been supplanted by carbamite. Two further grades, HW and HSC, where the 'H' stood for 'Hot', were introduced to give higher energy contents for increased performance in anti-tank and anti-aircraft guns. These powders very closely resembled the original Cordite Mk.1 which had been made obsolete decades earlier. Strange things happen in wartime.

Despite such help in reducing production times, the existing government powder factories and the private contractors were quickly swamped with orders beyond the normal capacity of their plants, even had they been able to get all the new raw materials in the required quantities. New factories were erected and put into production, but these then served to aggravate the supply problems and the shortage of skilled labour. This in turn lead to severe quality control problems, and so on. It was possible in many cases to simplify a few of the production processes such as washing and purifying on the ground that the propellants were no longer required to have a shelf-life of twenty years or so — they were often fired off in a period more like twenty days, having been transported almost straight from the factory to the gun breech. This concept was a big help in many ways; but it too had problems in that the powder lots produced in this manner had to be segregated and





Elevation and end view of a few large grains of propellant suited for a medium calibre field gun. The distortion caused by the loss of solvent on drying is clearly visible in such large grains, as is the lack of a surface coating – in cannon powders any moderators etc are normally incorporated in the mix during manufacture. The scale divisions are in millimetres.

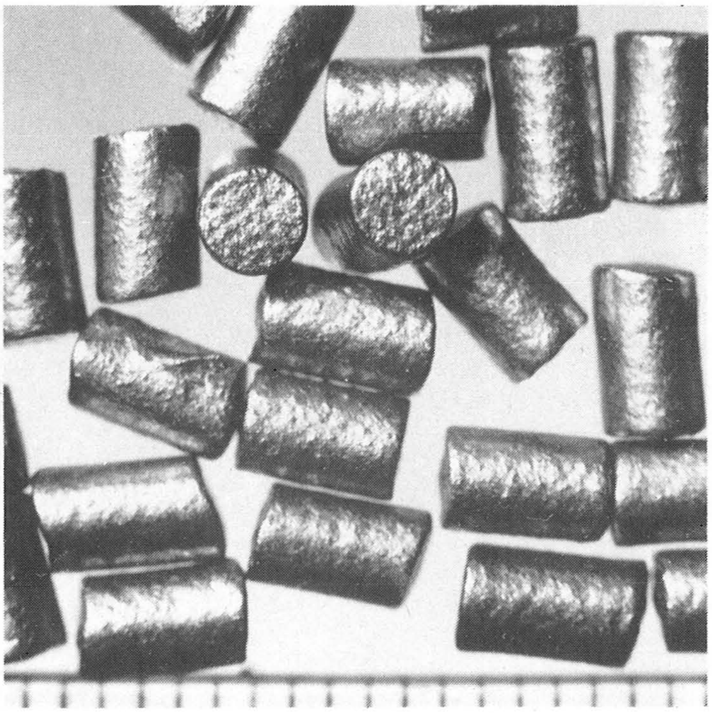
carefully monitored to see that they were actually fired within their limited lifespan and not left in some outlying depot to become a safety hazard in years to come.

The only short term solution to this dilemma was to import propellant from overseas, but this too had its drawbacks. Europe was, of course, closed and the only alternatives were thus from the 'Empire Countries' or from America. The countries of the then British Empire generally used the same propellants as did the 'Mother Country', but only the larger of them had any worthwhile manufacturing capacity of their own, let alone any to spare. America's actual production was minute but her potential was enormous; the problem was that America had settled almost entirely on single base powders and hence her materials were rarely, if ever, directly interchangeable with those of England. On a weight basis the double base Cordites were more energetic than the single base types, hence a larger charge weight of the latter was needed to maintain the performance of a given gun; but this larger charge may or may not have actually fitted into the gun chamber. The situation was eased somewhat by the fact that the shorter rods of the nitro cellulose powders tended to pack more densely into a given space, but even so there were few occasions when a direct substitution was possible. The requirements of the two powders as regards primers and igniters also differed greatly.

A number of options were thus available, with one or the other being adopted at least temporarily in most cases. It was possible to import the whole system; gun, ammunition and all, but this was not very attractive as the American systems were generally outdated. In some cases an existing nitro cellulose powder could be used with only a minor compromise in performance: in other cases it was necessary to conduct long involved firing schedules to set up new range tables; in yet other cases a minor change in grain size or composition could make the necessary difference. Overall it was a very confusing time for all concerned and often the nett result was that there was scarcely enough ammunition available to stop the birds from nesting in the barrels of those guns already emplaced at the front — there were certainly no reserve stocks.

Significant improvements were also made in the single base propellants, the first of which was to get over the objectionable tendency of such powders to absorb moisture from, or release it to, the atmosphere as the ambient conditions changed, with consequent changes to the ballistic performance. It was discovered that the addition of around 10% of a plasticising agent, dibutyl phthalate — known as dBP for short, largely eliminated this problem and such powders were known as NH (Nitro, non Hygroscopic) to distinguish them from their unmodified relatives. Since this dBP was scarcely even inflammable, its presence further lowered the energy level of the single base powders, making even heavier charges necessary. It did however lower the flame temperature and hence further reduced the wear on the barrel; it also served to soften the texture of the grains making them less brittle and fragile, which was another of the problems with the early single base powders.

Another problem soon arose with these NH powders in that the muzzle flash from some of the larger performance naval guns could be dazzling even in daylight, and quite precluded such guns from being fired at night. Little was known of the events occurring just outside the gun muzzle and work was put in hand in this area, now known as the science of Intermediate Ballistics. It was soon discovered that there were in fact two distinct and largely independent types of flash, one occurring very close to the muzzle



A number of grains of propellant as used in a modern light automatic cannon; the multiple perforations can be seen in a few of the grains which are end-on. The scale divisions are in millimetres.

and the other quite a bit further out. The first, the primary flash, was a result of the incandescent propellant gases becoming exposed to view, while the secondary flash was caused by some of these gases mixing with the air and re-igniting. It was also found that the single base and the double base propellants varied greatly in such flash characteristics. The addition of a few percent of a metallic salt such as potassium sulphate, or of cryolite, was found to suppress the flash, but to increase the smoke; hence two parallel families of propellants often existed, one flashless (using the code letter F) for night firings, and the other of low smoke for day firings.

The continuing search for other propellants having lower flame temperatures led to the discovery of nitro guanidine (true nitro compound this one), which was given the code name of 'picrite', possibly in the hope of misleading the enemy into believing that is was some sort of relation to the picrates, which are high explosives rather than propellants. The new material appeared to have all of the ballistic properties necessary to completely replace nitro cellulose with the exception that it, like blackpowder before it, could not be gelantinised to form coherant grains. It was however found possible in many formulations to replace up to 50% of the existing nitro cellulose with picrite to give powders of exceptionally low flame temperatures and with very little tendency to flash; in fact picrite proved to be a good flash suppressor and was sometimes used for that purpose alone. The code letter 'Q' was given to this picrite and the limiting factors to its use were largely those of availability and of the physical strength of the grains rather than of any ballistic property.

We have devoted quite a lot of time to the chemistry of the various propellants, and, as important as this parameter may be, it is but one of two main factors affecting a powders performance in any gun system, be it a piece of heavy artillery of a humble shotgun. The second factor is the geometry or shape of the grains involved. As explained in an earlier article in this series, propellant grains burn only on the surface, and hence control of this surface area gives control over the amount of gas being produced at any given time, and hence of the chamber pressure in that gun system. Most simple shapes such as cubes, spheres, flat strips and solid rods will progressively decrease in surface area as they burn, thus the rate of gas evolution drops off with time giving such shapes the name of 'degressive burners'.

It is however more desirable in most gun systems to have an increase in gas evolution rather than a decrease, ie. to have progressive burning powders, or at least a neutral condition. The normal compromise in small arms powders is to extrude and to cut the propellant into those familiar short cylinders having one central perforation in each grain, which gives a constant surface area and hence a constant gas evolution throughout the burning. If you have any doubts about this statement, you can easily check it by dragging out your compasses from your old school bag and drawing a series of circles to represent the successive stages of burning of such a grain. While you are at it and still keen, you can also draw a larger grain having 29 perforations and can then verify my statement that such grains now very popular for light automatic cannons, are progressive.

Both the single base and the double base powder families were made in a wide variety of such shapes each of which required a set of code letters and numbers to designate the specific size and shape of the grains concerned, thus by the time that the powder charge for a given gun had been completely specified by composition and by geometry, so many letter and numbers were in use that the result could look rather more like the first chapter of a good sized book than like a code which was originally meant to simplify things. For instance the title 'Cordite MDT 5-2' specified that modified Cordite, drawn as a tube having an outside diameter of 5 hundredths of an inch and an inside diameter of 2 hundredths, as loaded into many millions of .303 rounds; FNH/P/M .022 signified a single base, non hygroscopic, flashless powder containing potassium sulphate and drawn as a multiperforate grain of the diameter shown, as used in the 40mm Bofors guns; and Cordite RDBSF 20 indicated the use of the Research Department formula B type of Cordite in the form of square flakes 0.2 inches across. It was all further complicated by the fact that the rules changed fairly frequently.

As a finale to this article I would like to divert slightly from our field of gun propellants to tell a story of that close relative, the solid-fuel rocket. You may recall that in an earlier article I described how, when Cordite was first made over 100 years ago, it contained 5% of Mineral Jelly originally added more or less as an afterthought in the very minor role of a lubricant, but which very quickly showed itself to have a very major, if unintentioned, role as the stabiliser which made Cordite into a useful propellant.

Of course such things can no longer happen in these days of expanded knowledge, high technology, computer modelling etc, but one certain event must come pretty close to it. Quite a few rocket grains are also extruded, even though their diameter may be measured in feet rather than in hundredths of an inch as for gun propellant grains. These large heavy grains would obviously cause rapid wear of the extrusion dies, thus not very many years ago, one bright engineer got the original (?) idea of incorporating a few percent of 'dry soap', ie lead stearate, into the propellant composition to reduce this expensive wear, and thereby promptly achieved something that the ballisticians had dreamed of for years — a propellant which burned at a steady rate over quite a large range of pressures. Without the help of this 'lubricant' many modern rockets would not be able to perform as they do. Is there nothing new in this world?

Table 1

Showing a few of the more common additives in gun propellants and their typical uses.

Material		Purpose 1	2	3	4	5	6
Dinitro Toluene	DNT		*	*		*	
Methyl Centralite				*	*	*	
Ethyl Centralite		*	*	*	*	*	
Diphenylamine	DPA	*					
Dibutylphthalate	DBP				*	*	
Potassium Sulphate					*		
Graphite							*

Notes

1	indicates use as a	Stabiliser
2	indicates use as a	Moisture Barrier
3	indicates use as a	Deterrent
4	indicates use as a	Flash suppressor
5	indicates use as a	Burning-rate Controller
6	indicates use as a	Surface Glaze

ROYAL ORDNANCE FACTORY BIRTLEY

John Popple-Crump

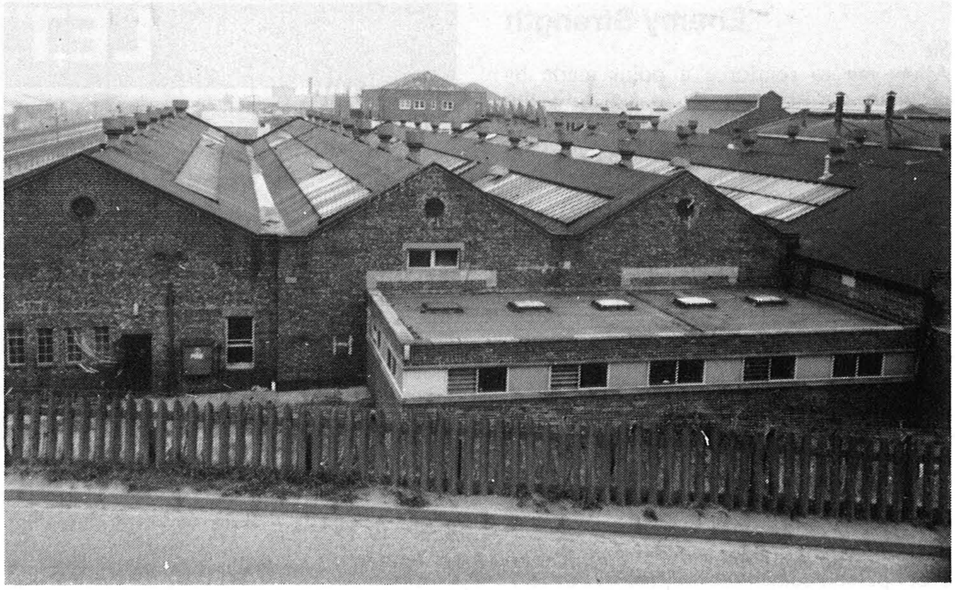
UNLIKE the majority of old ammunition factories, Birtley is still in operation, presently under the management of Royal Ordnance Plc.

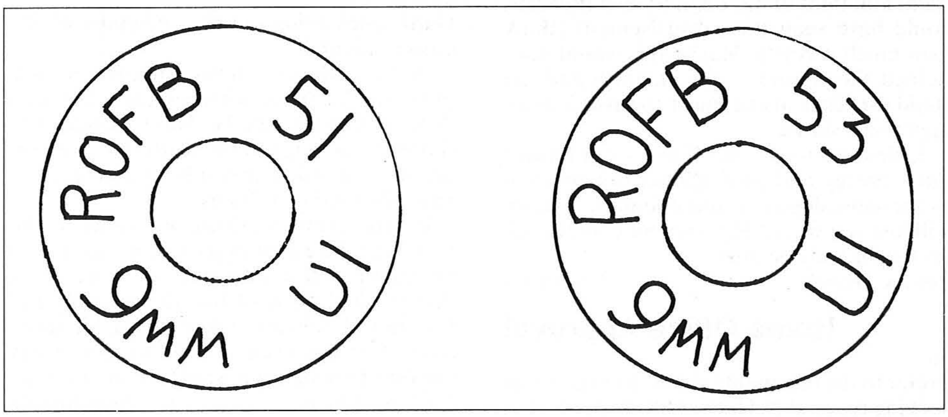
Located on the outskirts of the small industrial town of Birtley in County Durham, the factory was originally erected in 1915 as part of the National Projectile Factory programme. During World War I, the factory was dedicated to the manufacture of artillery shells, and although it was closed down in 1919, the site was retained in situ as a War Reserve facility.

The site was re-activated in May 1936 as a Royal Ordnance Factory, and became operational exactly one year later, making large calibre munitions, which entailed a great deal of turning on lathes.

The only Small Arms Ammunition made at Birtley were a series of 9 mm 2Z 'INSPECTION' rounds – the correct title being 'Cartridge SA Inspection 9 mm U Mark I', during the Korean War period. Made for use by Service Armourers when servicing weapons, these cartridges were turned from solid bar metal, a technique in keeping with the factory's traditional function of turning large calibre projectiles and shell bodies.

Two types of 9 mm 2Z 'INSPECTION' rounds were made at Birtley. An early type made around 1951 was turned from solid steel, but later types had bodies of turned brass with screw fixed heads of turned steel. Usually, these rounds were tinned all over as an aid to identification. The headstamp included the place of manufacture, date, and the 'INSPECTION' identification code 'U'.





Top: The former Royal Ordnance Factory, Birtley, now operated as an ammunition factory by Royal Ordnance, a division of British Aerospace.

Above, right: The early form of headstamp used at Birtley. Left: A later one.

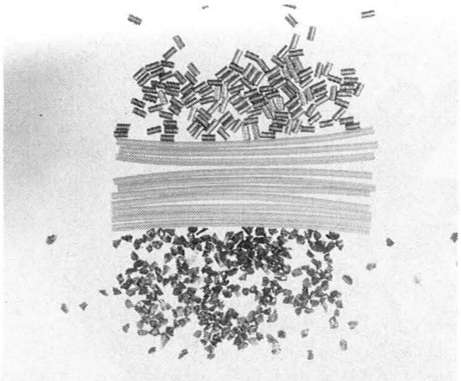
Below: The Birtley factory from another angle.

An Informal History of Gun Propellants

Part VII

Small Arms: A Finale?

Ian Thompson



The big three of rifle propellants: extruded, single base, single perforate IMR grains (top). Double base Cordite MDT-5 from the 303" Mk7 (centre). RFG2 blackpowder from the .45" Martini Henry.

THE LAST TIME that we specifically addressed the topic of propellants for small arms was to cover the introduction of smokeless powders in the closing years of the 19th century. Within a very short time thereafter the classic division had occurred into the double base type such as Ballistite and Cordite, and the single base types such as the French Poudre B, with the countries concerned having made their choice, from which they were not easily, if ever, diverted in later years.

England had firmly settled on Cordite and the early patterns of the .303 inch rifle cartridge were designed for, and used, a charge of 31½ grains of Cordite Mk. 1 extruded as solid cords or rods and cut to an overall length to suit the inside dimensions of the cartridge case — about 60 such strands making one charge. The official designation of this propellant was 'Cordite Mk.1, size 3¾; which signified that the material was Cordite Mk.1 and that it had been extruded as a solid cord through a die of .0375 inch diameter. The final size of the cord was somewhat smaller due to shrinkage when the solvent was later removed during the final drying process.

As mentioned in an earlier article, the chemical composition of this material was 58% NG, 37% NC and 5% Mineral Jelly, which proportions had been designed to give a propellant in which the oxygen and the fuel had been fully balanced, ie one with the highest possible energy content. This had the desired effect of keeping the required charge weights very low, but it also had the undesirable side effect of making the flame temperature very high, typically 2800°C, which proved to be rather more than the barrel steels of the day could comfortably withstand. Erosion of the throat and at the commencement of the rifling was noticed in Metford rifles after as few as 500 rounds, which was quite unacceptable from both the economic and strategic points of view. The change to the deeper Enfield form of rifling some seven years later reduced this problem to more manageable proportions, but it did not really get at the root cause — the high flame temperature of the propellant.

In 1910 a new form of Cordite was introduced for small arms, designated Cordite MD (ie MoDified), in which the NG content had been reduced to 30%, the NC content increased accordingly and with the Mineral Jelly content remaining at 5%. This new material was considerably less energetic than its predecessor as the flame temperature was now a mere 2200°C, thus the charge weight had to be increased to a nominal 37 grains rather than the earlier 31½ grains. Of itself this caused no immediate problems, for there was plenty of spare space in the .303 case to accommodate the extra propellant.

An unlooked-for result of this reformulation however was that the burning rate had also been significantly decreased, thus a greater surface area of propellant was needed to maintain the necessary rate of gas evolution during firing. After a series of calculations and firings, it was demonstrated that the new grain shape would have to be hollow tube rather than a solid cord and that the dimensions would need to be .050 inches outside diameter, by .020 inches inside diameter with the length being, as before, that of the cartridge case. This new propellant was named 'Cordite MDT, 5-2' to signify that it was the Modified formulation, extruded as a Tube with, respectively, the outside and inside dimensions of the extrusion die being given in hundredths of an inch.

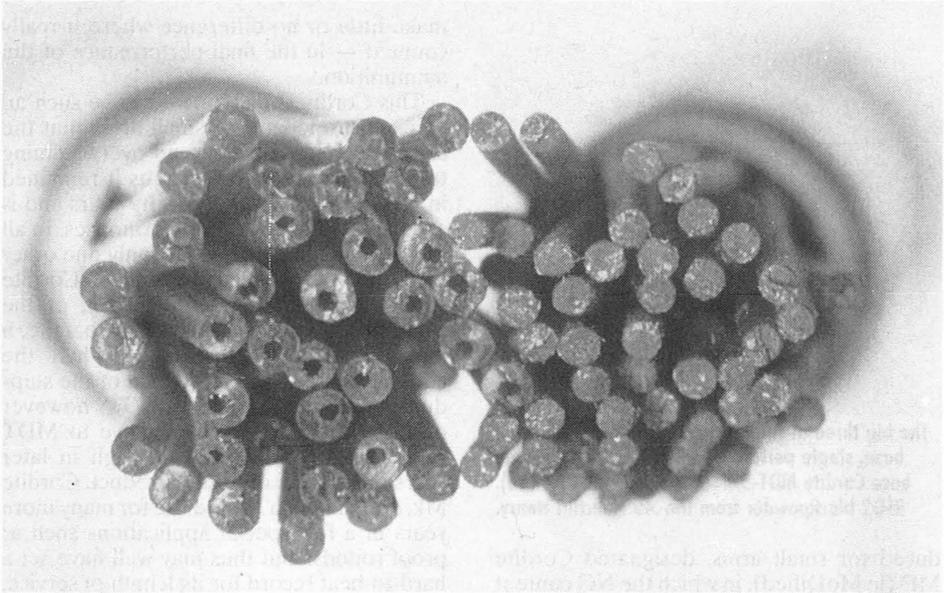
This altered grain geometry caused no worries in the propellant factories; quite the reverse in fact for the new material with its lower liquid content was much stiffer and easier to handle. It did however cause perpetual troubles in the ammunition factories where it was discovered that although there was plenty of room inside the case to accommodate either charge, the bundle of the new tubes was so much larger than the original bundle of rods, that it would no longer fit through the neck of the case during loading. A number of options were thus available, with various factories choosing the most suitable to them; either the bundle could be pushed into the neck of the case in two or more increments, or the whole bundle could be pushed into the neck of a partly formed case and the final necking operation performed on a loaded case. Some factories fixed on one or the other of these processes and stayed with it through thick or thin, while others switched between them as circumstances dictated, but it all seemed to make little or no difference where it really counted — in the final performance of the ammunition.

This Cordite MDT proved to be such an efficient propellant for small arms that the armed services could see no overwhelming technical need to change; thus it remained in general service for over fifty years and is still being produced in some countries. In all those years there was in fact only one other variation in the small arms field, Cordite CDT, in which part, usually ½%, of the Mineral Jelly was replaced by Carbamite, a more efficient stabiliser which had the added feature of easing several of the steps during production. This CDT however officially remained an alternative to MDT rather than a successor, although in later years it was the more usual product. Cordite Mk.1 remained in limited use for many more years in a few special applications such as proof rounds, and thus may well have set a hard-to-beat record for its length of service.

One very prominent feature of England around the turn of the century was the presence of the 'Empire', that far-flung group of colonies which ranged from the Arctic across the Equator to the Antarctic and which tinged red the globes and atlases in every drawing room. Hunting in the more remote of these colonies was a very popular sport, and a number of commercial firms such as Eley Bros, Kynoch etc specialised in catering to the every ballistic need of such intrepid men. Generally the propellants used in the special 'African' of 'Indian' big-game cartridges were Cordite or a close derivative, but the continuing demand for powders more suitable for use at high ambient temperatures led to the development of a number of single base types as well. One such, the 'Neonite' series, became quite popular and was later the only powder considered acceptable for use with the boat-tailed bullet in the .303 Mk.8 rounds of WW2. It also formed the basis for the current series of single base military small arms powders and gives a very good illustration of how even a relatively small but continuing commercial development can be an asset in the defence of the country.

The other European countries, like Britain, generally remained faithful to their initial choice of propellants; Germany standardised on Ballistite and variations thereof, although in wartime they proved themselves to be masters of using whatever was to hand; France stuck resolutely to single base derivatives of Poudre B; Russia stayed with its own single base materials and Italy largely used derivatives of Cordite.

On the other side of the Atlantic, the then immature United States of America tended, mainly for political reasons, to hedge its bets on propellant development as indeed on most military matters. Private contractors were used to design and manufacture the early smokeless rifle propellants, and at any given time the current service powder could therefore be either single or double base depending on the preferences of the contractor in use at that particular time. Such powders were generally not even fully gelatinised but were variations of the bulk powders which had been popular in Europe some twenty years earlier. In 1906 the army eventually had their way, with a government factory, the Picatinny Arsenal, being built to

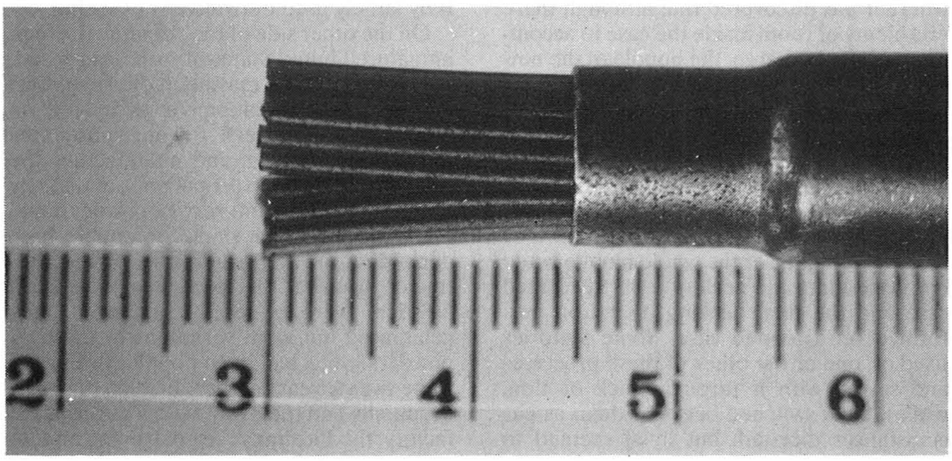


Two main types of Cordite for the .303" cartridge. The original Cordite Mkl solid rods of 0.0375" diameter (left). The later type, Cordite MDT5-2 (right), single perforate rods of outside diameter 0.050" and inside diameter 0.020".

cater for the military needs. In this respect they then reached a par with the overseas countries where almost all such production was in the hands of the government, but America had the added advantage of a very strong commercial propellant business catering to the needs of the civilian population; a business having not only a production capability, but a research and development capability as well.

In 1909 the first government small arms powders were released from the new factory but, initially, the quantities were pitifully small. Under the impetus of WW1 the government built another two massive new plants and leased them for production purposes to two of their largest private manufacturers, du Ponts and Hercules; a choice which was to be reflected in the course of future American developments in propellants, both military and civilian for many years to come. The total production from these plants had by 1918 reached a staggering 200 tons per week of small arms propellants alone, but by then of course the shooting was all but over and the plants were slowly converted to make synthetic silk, lacquer and other cellulose based plastic products. There were also enormous stocks of finished powders in military magazines and these will re-enter our story at a later date.

A bundle of Cordite Mkl size 3¾, 31 grains in weight and consisting of sixty sticks, which make up the full charge for a .303" Mk2 cartridge.



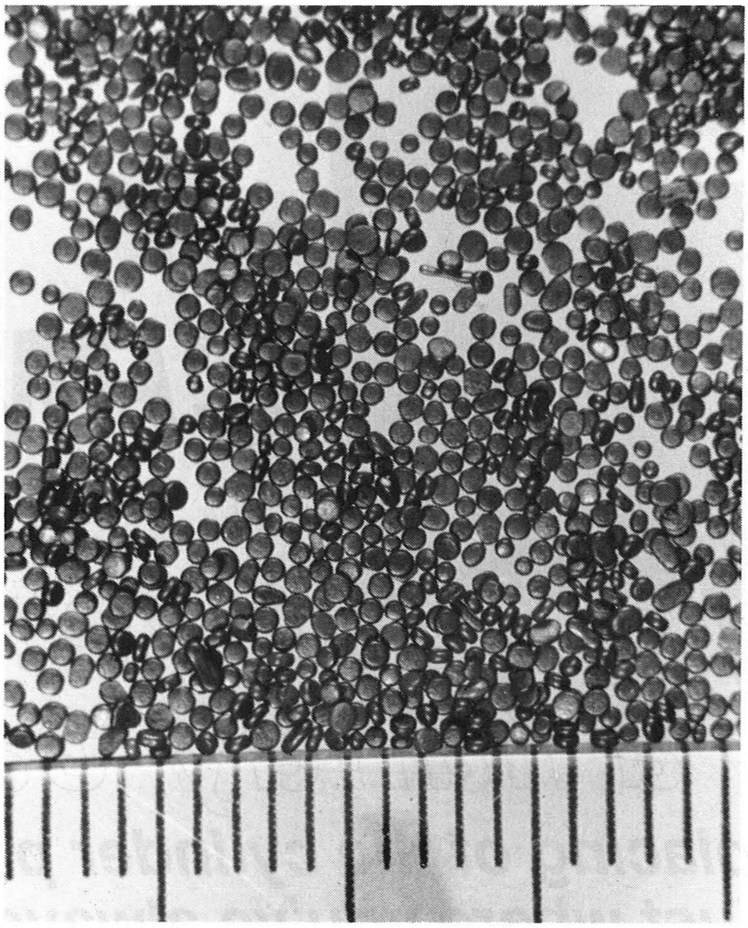
The main American small arms powder of this era was designed for use in the .30/06 cartridge and was officially known as 'Pyro DG' signifying that it was a single base (Pyro) powder containing Diphenylamine as the stabiliser and having the grains coated with Graphite. This powder was comparable with the contemporary line manufactured by du Pont and widely known as the MR (Military Rifle) series. The other major commercial manufacturer, Hercules, showed a strong preference for double base powders, a preference which continues to this day, as do many of the wild stories generated over the 'erosive' properties of such powders. It is quite true that double base powders such as Cordite Mk 1 containing up to 60% of NG are much more erosive than most single powders, but this is not a significant factor in modern powders where the content is rarely above 20%.

The British army had meanwhile been experimenting with a 7mm high velocity rifle and had achieved a good degree of success apart from continuing problems with barrel erosion and excessive muzzle flash, both of which they attributed to the use of Cordite as the propellant. Attempts to design a more suitable base powder were interrupted by WWI, thus a contract was let to du Pont in America to carry on the work. This they did using the German developed system of coating the individual grains with a layer of some slow burning material as an initial burning rate deterrent. The general idea proved to be quite workable but was never used for its original purpose as the Pattern '14 rifle had meanwhile been dropped to allow full production of the existing Short Magazine Lee Enfield No.1 rifle. Du Pont however continued the development of the process and from it produced their IMR (Improved Military Rifle) series which are still so popular today. One member of that family, IMR No.16, was adopted by the British as an alternative small arms powder in WW! under the designation of 'NC (Z)', ie NC powder type Z, and many many tons of it were loaded into .303 and other cartridges which then bore the suffix 'Z' after their usual distinguishing code number.

This deterrent coating, of up to 10% of the total propellant weight, was mechanically applied to the outside of the grains near the end of the normal production process and had the effect of reducing the initial burning rate for a short time until the projectile had begun to move up the bore whereupon the full burning rate was restored to fully accelerate the bullet. The pressure was thus kept low during the early stages of burning when the volume available for the gas was at minimum, but was caused to increase later when the volume was higher. Peak pressures were thus reduced which allowed the use of heavier charges to give higher velocities. There are a number of materials capable of filling this role as deterrents, the most common being DNT (Di Nitro Toluene) or methyl or ethly centralite, with the latter becoming more popular these days as it can also serve as a stabiliser, and even to some extent as a flash suppressor and plasticiser.

For a short time another IMR series existed distinguished by the fact that they bore a code ending with the number'½'. These powders contained a few percent of metallic tin which was intended to combine with any copper fouling in the bore of a rifle to produce a brittle alloy which would then be swept away by the next shot. They served their purpose well enough but were soon made obsolete by the introduction of better alloys for the bullet jackets, and are now of historic interest only.

It was the 1930s before the first really new development occurred in small arms propellants, and this was due to work done by the now-defunct Western Cartridge Co. to make use of the enormous stocks of powder left over from WW1 some 15 years earlier. These powders still contained a lot of expensive and potentially useful NC but were not directly usable for their original purpose as the all-important stabiliser had been depleted to an unknown extent by the passage of time and could not be replaced by any existing process. The chemists devised a system wherein the old propellant was mechanically broken down to a slurry in water to remove any unwanted degradation products and was then dissolved in suitable solvents to produce a thick lacquer containing the purified NC. To this lacquer was added the required amount of stabiliser and other necessary ingredients, and then the liquid was squirted through nozzles to make small droplets of a controlled size which on drying became spherical balls of propellant. Unfortunately



A sample of ball powder showing typical, almost spherical shape of the grains. This sample has been rolled to constant thickness to ensure that the web thickness is uniform.

the sphere is not a good shape for a propellant as the surface area changes so greatly during burning, but this problem too was solved by impregnating the grains with a small quantity of NG, then coating them with a deterrent such as DNT, and then finally glazing them with graphite.

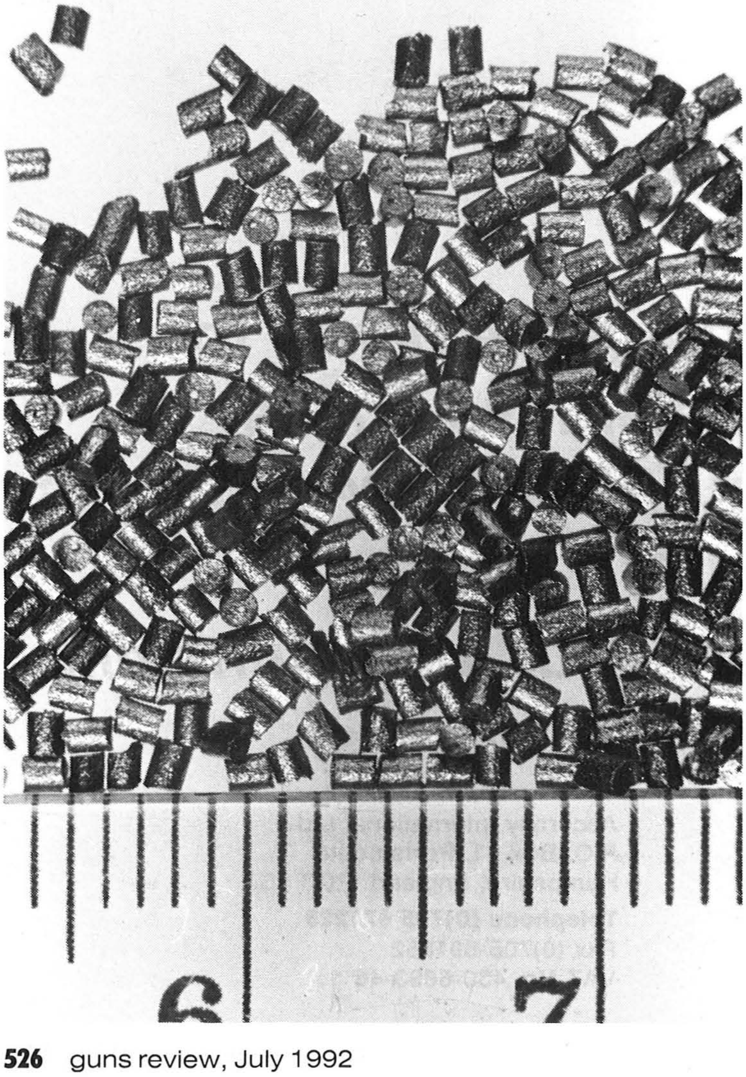
This process, and its numerous variants, eventually became the property of Olin Corporation who today market the powder widely under the Winchester label. The characteristic spherical grains give this powder its most famous properties, to wit the ability to flow smoothly and evenly into powder measures etc, and its very bulk density which allows higher than normal charges to fit into a given sized case. At different stages of burning, the deterrent coating and the NG content play their part in giving good velocity at relatively low pressure.

One problem remains however in that it is a bit difficult to put this material into either of our classic categories of single or double base, for while it does contain both nitrocellulose and nitroglycerine, the nitroglycerine is not fully incorporated into the nitrocellulose. By our definition, it is thus neither 'fish nor fowl', and to avoid further argument it may be easiest to create another class, 'sesqui', ie one and a half, to cover this and the other similar materials which are becoming popular these days.

That pretty well brings us up-to-date, for there have been few if any significant developments in small arms propellants since WW2; improvements certainly, but not major changes. There are a few types of 'caseless' ammunition appearing lately, but this is something of a misnomer in that generally they use a case of sorts formed from the propellant itself; the only thing lacking is the traditional brass case. For such rounds the outer layer of propellant granules is moulded, with or without a binder, into a case, priming composition is added to the base, the remainder of the propellant poured in and the bullet bonded into place. The main advantage claimed for such systems is that the brass case representing some 40% of the total cost and 50% of the total weight has been eliminated, and depending on the application this may be worth the extra expense - it could for instance virtually double the capacity of the magazine in an aircraft. As far as small arms go, the main advantage seems to be that the gun mechanism can be simplified and speeded-up by removing the need for an extraction cycle, and while this can be significant in military applications, it does not appear to offer much to the average sportsman who is not in all that much need of 'firepower' and who often reloads his cases anyway. Heckler and Koch are the foremost exponents of such systems at present, and while they certainly have had their share of problems over the years, the present system seems to work pretty well.

Other space-age systems such as lasers, liquid propellants, electromagnetic or plasma propulsion etc are even further into the future, particularly as far as small arms are concerned, so I feel quite safe in closing-off this series by predicting that, for quite a few years yet, there will be more or less conventional guns firing more or less conventional projectiles by means of propellants that are easily recognisable as direct descendants of those that we have already discussed.

Happy shooting.



A sample of typical IMR rifle powder showing the characteristic rod shape. The single central (well, almost central) perforation is also visible in a few of the grains, in others it is blocked by the surface coating.

EXPLOSIVE PRODUCTION WW2.
T.N.T. was manufactured at four Royal Ordnance Factories- namely, pembrey, Irvine, drigg, and sellafield. The great factory at Bishopton, in renfrewshire, was the principle source of cordite, and also produced tetryl and R.D.X. during the war the eight factories among them produced some three-quarter million tons of explosive material.

PEMBREY.
The largest supply of T.N.T., tetryl, and ammonium nitrate was produced here.
The factory buildinds are spresd over 500 acres of dune and sandhill, which furnish at once an effective screen and a safeguard against widespread damage in the event of an explosion. Consequently but little of the factory itself is visible to the passer-by, though its existence and activities are kept in evidence night and day, first by reason of the yellowish nitrous fumes discharged from its tall chimneys, and secondly by the occasional smoke and glare of burning T.N.T. , extracted from bombs and shells no longer fit for service.

The R.0.F., Pembrey, is no mushroom growth. It was originally owned and operated by the great firm of Nobel, but was taken over by the War Office in 1914. In the interval between the two world wars the factory fell into disuse. With the approach of the Second World war the Factory was once more taken over, reconditioned, and largely rebuilt. Production began in December 1939. Today the whole area is enclosed by a high boundry fence.

The Factory today employs 1,300 people, of whom about 50 are women. Its full strength during the war was 3,000.

The principle warlike products are T.N.T. and tetryl

PRODUCTION OF T.N.T.
T.N.T. is manufactured by treating with nitric acid a substance known as mono-nitro-toluene, this substance having been made at a previous stage by the action of nitric acid on toluenr (a derivative of coal-tar).

Nitration Building.
A long row of so-called nitration pots can be seen, in which the acid and the mono-nitro-toluene- described hereafter for convenience as the nitro-body- are to be brought together. The process is not without risk, as we have gathered from a notice-board outside the entrance, which states precisely how many operators and how much material may be introduced into the building at one time. For the same reason the process is divided into a series of separate operations: that is why there are 16 nitration pots in the row. These are vats about 4-feet high standing on a level floor, and are made either of lead or cast-iron, neither of which is affected by the corrosive action of acids used.

The essential feature of the process is that it is continuous. The nitro-body is fed into pot 1, and passes through the remaining 15 pots to flow continuously from pot 16 as Trinitrotoluene-T.N.T. The nitric acid necessary for this transformation is introduced into several pots along the row.

In the action of the nitric acid on the nitro-body water is formed and must be removed, otherwise the concentration of the nitric acid would be reduced and the action slowed down or stopped altogether.
To absorb this water so as to allow full play for the nitric acid, sulphuric acid, which has an affinity for water, is caused to flow in the reverse direction from pot 16 to pot 1; so the whole process becomes a continuous counter-current operation, the nitro-body flowing in one direction and the acids in the opposite direction.

Each nitrating pot is lined with coils of piping, through which hot or cold water can be passed to control the temperature, and is fitted with a stirrer (a swiftly revolving vertical paddle) to bring about intimate mixing of the acid and the nitro-body.

Now comes the manner in which the ingredients of these intimate mixtures are separated at each pot and caused to flow in opposite directions. Into each pots fits an archimedean screw lift which continuously lifts the mixture from each nitrating pot to shallow vessels, one to each pot, placed at the back and slightly above each pot. These vessels are known as separators. In the separators, which are unstirred, the acids (being heavier) sink to the bottom and the nitro-body floats on top. By means of weirs in each separator, the ingredients of the nitration pot, thus separated, can be conducted in different directions.

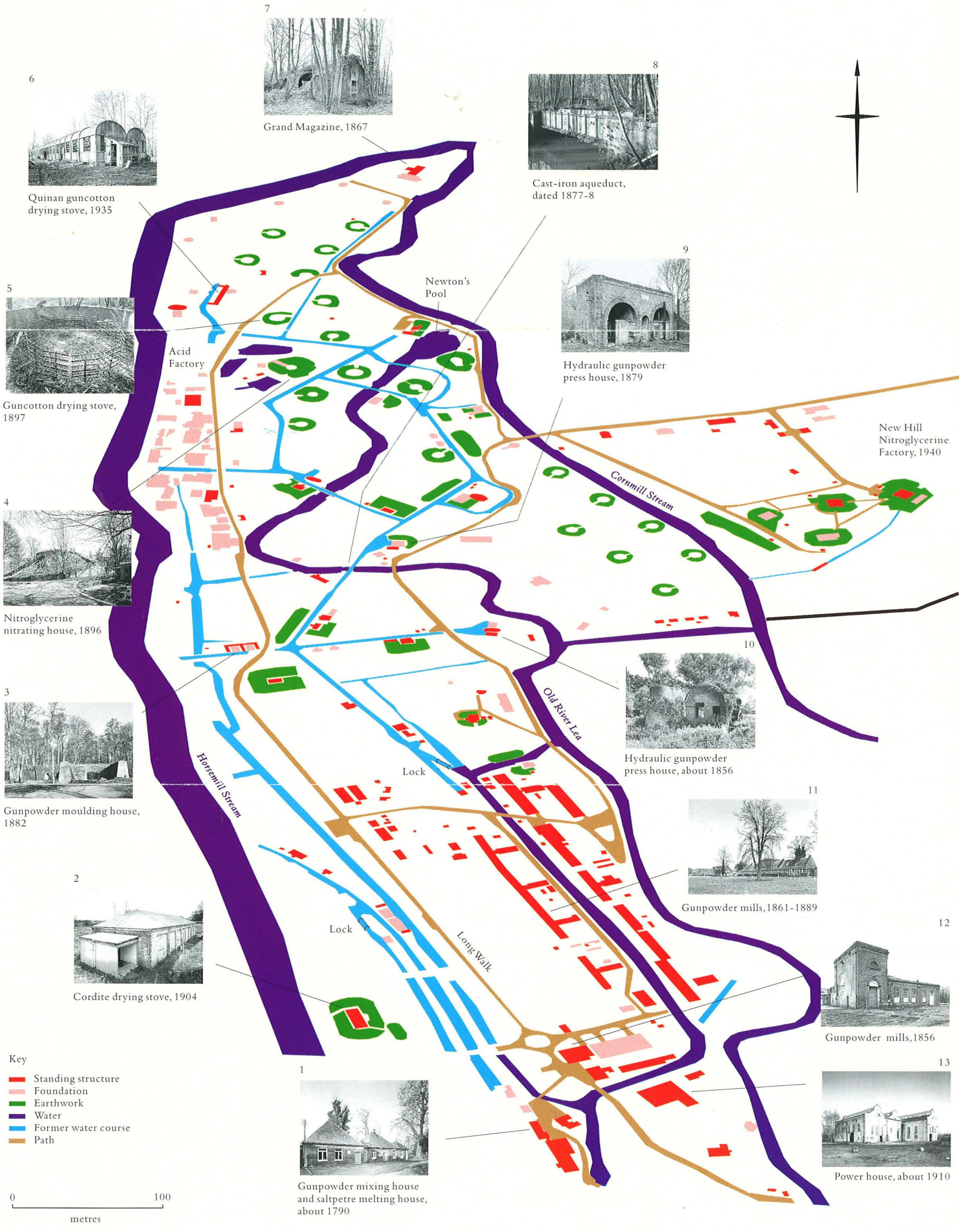
If we look at, say, pot 8, the nitro-body overflows along a gutter to nitration pot 9 for further nitration, and the acids flow along another (and lower) gutter to pot 7 : and this is the manner by which the transfer is arranged at each pot.

By the time the acid mixture reaches pot 1 it is known as spent acid. It consists in the main of sulphuric acid diluted by the amount of water absorbed from the reaction. It is recovered, reconcentrated in special plant and used again and again.

Perhaps the most important instruments in the Nitration Building is the thermometer; for if the temperature rises suddenly, and above a certain point, at any pot, something is wrong - seriously wrong - and immediate action is called for. if this happens, an emergency apparatus is set in motion, which promptly drains the entire contents of the overheated pot into a deep water-tank outside the building. In the case of imminent and general danger, all sixteen pots can be emptied at once by the operation of a single lever.

The T.N.T., now a viscous yellow fluid, has next to be passed through various purification processes and then to be cooled and solidified. This is effected by running it over water-cooled phosphor bronze drums until it has hardened, and it is then scraped off. The T.N.T. falls away in flakes and is packed in bags and boxes and dispatched to a Filling Factory

Waltham Abbey Royal Gunpowder Mills



Waltham Abbey Royal Gunpowder Mills

Gunpowder, and the explosives and propellants which followed it, provided a form of energy which changed the world by encouraging trade, exploration, mining, and civil engineering, as well as serving the military purposes of conquest and defence.

History

Gunpowder production began at Waltham Abbey in the mid 1660s on the site of a late medieval fulling mill. The gunpowder mills remained in private hands until 1787, when they were purchased by the Crown. From this date, the Royal Gunpowder Mills developed into the pre-eminent powder works in Britain and one of the most important in Europe.

In the surviving structures, the earliest of which date from the Crown's acquisition of the mills [1], we may trace the evolution of gunpowder technology to its ultimate form in the late nineteenth century, with production on an industrial scale [3, 9, 10, 11, 12]. The development of new chemical explosives ran in parallel with this refinement of gunpowder making. Remains of this activity include two nitroglycerine factories, one dated 1896 [4], the other 1940, and drying stoves [5, 6], where guncotton was dried before being mixed with nitroglycerine to form cordite [2].

During this century Waltham Abbey was responsible for research and development of high explosives, including Tetryl, TNT and RDX.

Production at the factory ceased during the Second World War in favour of sites less accessible to German bombers. After the war it became the principal government research establishment for investigating non-nuclear explosives, often reusing existing buildings for a second, third or fourth time. Since the site's decommissioning in 1991 the Ministry of Defence has undertaken its decontamination, so that access can be provided to this secret world. Here the visitor will find a remarkable landscape which has evolved into a final state of mysterious complexity. There are over 300 structures, 21 listed buildings, and a profusion of waterways, surviving in a park-like landscape of 71 hectares. More than two-thirds is a Scheduled Ancient Monument, and 34 hectares are designated as a site of Special Scientific Interest including the largest heronry in Essex. Although not a conventional museum, displays and presentations will introduce the visitors to the site and help them to explore and understand its history.

The future

The Royal Gunpowder Mills at Waltham Abbey is an industrial monument of major national and international importance.

To safeguard the site in perpetuity the Waltham Abbey Royal Gunpowder Mills Charitable Foundation (WARGPM CF) has been set up, whose charitable Foundation Trustees administer an income generating endowment fund and a contingency fund, both established by the Ministry of Defence. A Heritage Lottery Fund grant has also been secured, for expenditure on the restoration and interpretation of the site, the development and management of which will be in the hands of Waltham Abbey Royal Gunpowder Mills Company Limited (WARGMCo Ltd),set up by the Foundation.

This concept of partnership reflects the way in which the success of the project so far has been achieved, through an alliance of local and national interests. It will also provide a vision for the future in which the site will be interpreted in it's entirety as a comprehensive record of the men and women who worked here, the processes they developed, and the environment they occupied. All will be set within the context of the local, national, and international importance of the site.

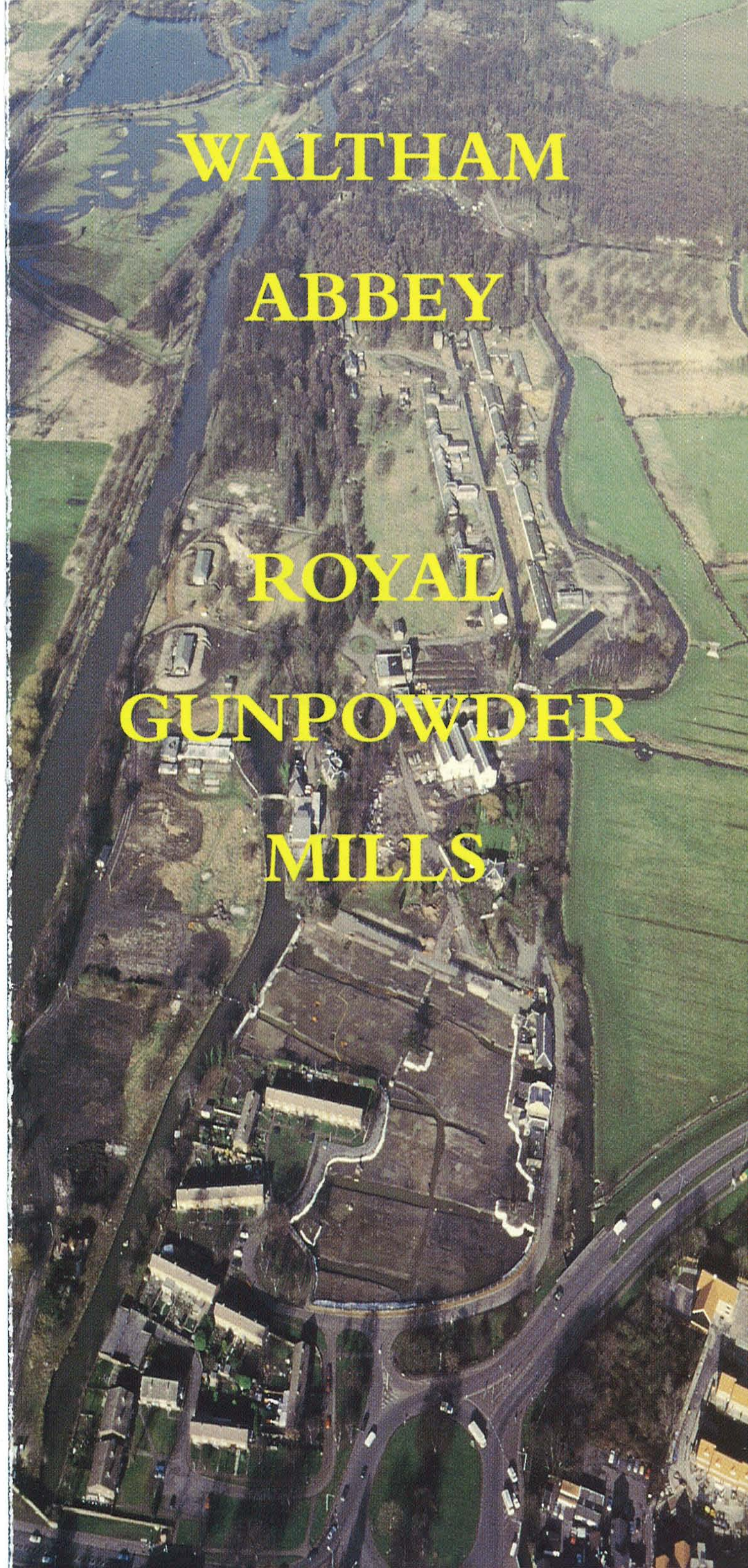
It is hoped that Waltham Abbey Royal Gunpowder Mills will be open to visitors by the year 2000. Until then the nature of the landscape means that only limited access can be allowed, by special arrangement.

The photographs used in this leaflet are from the National Monuments Record. Copies of these and the detailed archive associated with them are available from the NMR:
Call 01793 414600:
Http://www.rchme.gov.uk

For futher information about the project please write to:
WARGPM Project,
Powdermill Lane
Waltham Abbey,
Essex.
EN9 1BN

NATIONAL MONUMENTS RECORD

WALTHAM ABBEY ROYAL GUNPOWDER MILLS



the on-going maintenance of the buildings and the land. They also have control over development, and to see that the 'Deed of Gift' from the MOD is adhered to.

In order to manage and run the site, a separate charitable company has now been formed with nineteen trustees whose job it will be to open the site in the spring of 2000 and implement the business plan, made possible with a grant of six and a half million pounds from the National Heritage Lottery Fund.

"*The* rocket's *red* glare"

American National Anthem reference to the Congreve rocket developed at Waltham Abbey

None of this would have been possible without the steering committee which was formed nearly four years ago to work out a plan and make it viable. In order to make sure that we had maximum local input, and expert help – the Committee was formed with a member from each of the following – Waltham Abbey Town Council, Epping Forest District Council, Essex County Council, English Heritage, English Nature, Lea Valley Regional Park Authority, The Royal Commission on the Historical Monuments of England, The Ministry of Defence and our previous MP. To all these people we owe a debt of gratitude for all the time and effort that they have put in.

Putting this plan into practice is now the job of the Waltham Abbey Royal Gunpowder Mills Company Limited – all unpaid volunteers. Approximately half these people are from the local community, the rest have been chosen for their proven skills in education, museum expertise, business management and other skills necessary for the success of our exciting venture. The committee is advised by specialist consultants, Prince Research Consultants based in London.

As with all such sites volunteer work is essential, we will need help from people with knowledge of waterways, railways, water mills etc, in fact anyone with time to give can provide valuable assistance.

If you have a hobby or an interest as well as the time, then why not contact:

- ***The Chairman of the 'Friends of the Gunpowder Mills' –***
  Mr Norman Paul, 24 Anglesey Close,
  Bishop's Stortford, Herts CM23 4PE.

- ***For other information contact:***
  Chairman of the Board of Trustees,
  Don Spinks, Rosemead, Pynest Green Lane,
  Waltham Abbey, Essex EN9 3QN.

- ***Press enquiries should be directed to:***
  Andy Mansfield, 13 Horrocks Close,
  Ware, Herts SG12 0QL.
  Telephone: 01920 486466.

WALTHAM ABBEY ROYAL GUNPOWDER MILLS

A message from the Chairman of the Waltham Abbey Royal Gunpowder Mills Company Ltd.

Don Spinks
Chairman WARGM Co. Ltd.

"*The* mother-house *of the* British *explosives* Industry"

Royal Commission on the Historical Monuments of England

Waltham Abbey Royal Gunpowder Mills has been a name familiar to the local community for over 400 years. It is now over 200 years since the Walton Family handed over the site to the government, and until 1997 it has remained 'secret', in the sense that only the workforce and on occasion the emergency services have managed to get past the gates.

In the spring of 2000 all that will change – the site will be open to the public for the first time. I am the Chairman of the charitable company formed to manage the future of the site and our aim is to interpret the site in its many and varied forms.

- There is the story of the manufacture of gunpowder in its early and primitive forms.
- There is the history of the site during the Second World War where many achievements including the manufacture of RDX, the explosive used in the famous Dam Busters Raid, which was made at Waltham Abbey, ensured that the site played an important part in the Allied victory.
- The site has been a research establishment, and there are more stories to tell about experiments in rocket propellants, and Waltham Abbey's participation in Britain's post war rocketry programme, including work on the propellant for the 'Blue Water' missile.
- There are still stories to be discovered, There is a great deal of archaeological investigation still to be completed and many details about experiments carried out at the Gunpowder Mills are still on the secrets list. These will slowly be told over the coming years as government papers become available under the '30 year rule'.

- However, the story we have to tell is not all about War, there is the story of the social history of the site, and the importance of the many thousands of women who worked there, reaching a peak of over 3,000 women in World War One.

There is much more to this site:

- Because of its importance to the nation it is protected as an ancient monument.
- On the site are 21 listed buildings, some of which were built at the time of the Napoleonic Wars, and the site contains some of the finest examples of industrial archaeology in the world.

"The most important site to the history of explosives in Europe"

English Heritage

- Of the 175 acres the site occupies, approximately 80 acres have been designated as a Site of Special Scientific Interest. Two thirds of the site is a Scheduled Ancient Monument.

For the last 200 years, part of the site, which was originally planted with Alder trees for the manufacture of charcoal, an essential ingredient of gunpowder, has been a haven for wildlife as well as containing some rare species of plants and aquatic life. The site is home to Fallow and Muntjac deer, birds are abundant – apart from having the largest heronry in Essex, it also boasts large flocks of over wintering Siskins which feed on Alder seeds.

Of interest to bird watchers and students of nature, or as an education resource, the ecology of the site offers a rare opportunity for study. To keep it in its natural state, and for the wildlife to continue undisturbed, access to it must be controlled, but we aim to place unobtrusive cameras with video links to a building away from the most sensitive areas.

There are many more stories to tell, such as the one and only listed telegraph pole that I know of – because it still stands with its original insulators and traces of wire! – yet another of the 'firsts' on this site, the miles of yet to be restored canals, the water powered hydraulic press, the small gauge railway – all neglected and waiting to be restored in the future, and it is now to the future that we must look – whilst we have enough money to open the site and tell our story, it will take a lot of time and a lot more money before we can complete the task.

The last story to tell here is how the site became available, it starts in the Spring of 1991, when the Ministry of Defence decided to dispose of the site.

The Town Council decided early on that it should be managed by a Charitable Trust. This theme has carried on and the site is now owned by the Waltham Abbey Trust Company Limited.

In 1997, after spending several million pounds to decontaminate a large area of the site, the Ministry of Defence handed it over to seven trustees together with five million pounds as an endowment fund. The trustees have invested this money to ensure that the site remains in perpetuity for the benefit of the public – the interest and earnings from the endowment will guarantee

"The largest and most complete in Europe"

18th Century