The Last of the Powder Men!   Part One

Background

Gunpowder was produced in Waltham Abbey from the 1600's until the mid 1940's, when production ceased at the Royal Gunpowder Factory (RGPF) and the site was transformed into a research establishment. But that was not quite the end of the tale. In around 1980 an experimental pilot plant was built with the aim of producing small 20 kg quantities of gunpowder for the MOD.

The MOD had previously purchased gunpowder from ICI Nobel Ardeer, Stevenston, in Scotland, but the maintenance of the massive old gunpowder plant combined with low demand made production uneconomical. The MOD had a problem, because a fuse powder was still needed for a small number of their ’stores’. Other gunpowder sources were investigated. One was in Yugoslavia and quality tests described the material as ‘not too bad’ but, unfortunately, it was sited within the Soviet Block at the time! Italian gunpowder was also tested, but was described as 'rubbish'!

A Gunpowder Assessment Programme was set up to see what could be done. This involved RARDE Fort Halstead, Waltham Abbey and ROF Chorley. Dr. Chris Evans was given the task of initiating the Waltham Abbey part of programme, which turned out to be by far the largest chunk of the the workload.

The Waltham Abbey Team

Chris was the Section Leader in charge of the project in Waltham Abbey and he and myself carried out the bulk of the effort involved here. Janet Etchells also took part in the early days, but left to join the HSE for more lucrative opportunities. Tony Kosecki joined us for the later stages. Pat Edmunds and John King were our industrial stalwarts, with Stan Berry helping out on the charcoal plant.

One lunchtime a few of us PR scientists went to the Green Dragon for a glass of ale and a sandwich. Janet came along and insisted she bought a round. She opened her handbag, to extract her purse, and a couple of spanners clattered out onto the table! There was a roar of laughter from the boys, but she had shown herself to be a true engineer! She had a moped at the time and kept the spanners for running repairs.

Milling Gunpowder

Gunpowder, once known as Blackpowder, had been traditionally manufactured using an Edge Runner Mill, sometimes called a Muller Mill. These were notoriously dangerous. They were operated remotely, but contained a large batch of gunpowder. When an accident occurred, the mill house was devastated leading to heavy casualties in the surrounding area. The Edge Runner Mill consisted of two very heavy iron wheels, connected by an axle, that were rotated in a circular iron pan. There was a small gap between the wheels and the base of the pan. The pan contained the gunpowder mix, dampened with a little water. The massive weight of the wheels crushed and mixed the ingredient grains, thus milling and mixing them into a damp powder.

The modern choice of mill is the Fluid Energy Mill - commonly known as a Microniser. Rather than having a large quantity of gunpowder in a batch, as with the Edge Runner Mill, the process was continuous, so the dwell time in the Microniser mill is far shorter. This was described as the 'little and often approach'.

The general idea behind the microniser is to blast compressed air through nozzles, producing high velocity jets, into a chamber into which the gunpowder is fed. The impact of grains of gunpowder ingredients hitting the wall of the chamber, and colliding with themselves, smashed them into fine particles. There are two basic designs of microniser: the ‘Loop’ type, suitable for large outputs, in which the material re-circulated, and the ‘Plate’ type, which is a single pass method and is suitable for lower outputs - even very small ones are obtainable for use on a ‘laboratory scale' (50 mm diameter).

In the 1970's, a large 'loop' gunpowder facility had been constructed in Indiana in the United States, however this had been mothballed. Another plant was built in Norway and had proved operationally successful. Unfortunately, two maintenance men had been killed in separate explosions whilst working near the plant. Ironically, it was not the microniser that caused the explosion, but poor general housekeeping. Boxes of micronised gunpowder had been stacked outside the plant, instead of being taken to a magazine. Two lives were lost, so the operation was deemed unsafe and production terminated.

For the proposed experimental work at Waltham Abbey, Chris purchased a small Plate Microniser of 100 mm in diameter. This had an ideal throughput of 100 grams per minute, bearing in mind that the explosive limit on the facility was just 10 pounds (4.5 kg). The plate microniser was shaped as an enclosed disc and constructed of stainless steel. It had a circular recess inside, into which a solid metal ring was seated. The ring had numerous angular nozzles drilled around it. Compressed air was blasted into the outer circular ring, resulting in high velocity jets in the inner chamber that formed a powerful vortex. The ingredients were blasted into this inner chamber, again using compressed air. Here the grinding process took place.

An additional characteristic of the microniser was that the rotational flow of material in the vortex of the inner chamber acted as a particle size separator. The heavier grains remained trapped inside the chamber, flung to the walls for further milling, whilst the finer particles were entrained in the exiting compressed air, via a central outlet. The micronised product fell into a removable container below, whilst the spent air escaped above through a large, tall, cloth filter bag. A small amount of superfine particles settled on the surface of the bag and were removed as ‘waste’ afterwards.

Safety Aspects

I heard I was to be part of the team, probably because I had some previous experience with micronisers. Later that day I visited the Powdermill Club for the usual refreshments. At the bar was Bob McGuigan who looked at me and started chuckling, and said, “I hear you’ll be working on the gunpowder job. You know the two most dangerous explosives operations are gunpowder and nitroglycerine?” He thought it was most amusing! However, I think this was Bob’s way of saying ‘be careful’. Or probably it was more than likely that he didn’t want to lose a regular from the club bar! Whichever way, I never cease to wonder at the speed at which news travelled on the 'Waltham Abbey grapevine'. It was like greased lightning - super speed broadband, eat your heart out!

The building used for the experimental work was a ‘remote controlled facility’ on Process Research Section and was locally known as the ‘10lb Facility’. It consisted of two explosives cells separated by a small service bay set in the middle, where electrical ancillary electrical equipment could be isolated. The area was mounded. On the other side of the mound was the control room.

Considerable safety aspects associated with the gunpowder work were addressed before starting and are summarised as follows;

Smooth Walls

The concrete walls of the explosives cells were puckered with round crevices, left from bubbles in the original concrete mix. Here, gunpowder dust could very easily have settled. So the walls were screeded smooth and painted. Smooth walls are an essential starting point in any dusty process, and the microniser produced a very fine dust - something like ‘talcum powder' and even finer.

Electrical Earthing

All equipment was bonded to earth to remove static. Many plant items needed sturdy support, especially the heavy hydraulic press, the rotating cone blenders and a solid base to attach the microniser to. Hence I used heavy steel work benches; the surfaces and edges of the benches were clad in brass sheet and earthed. Significant static is generated in the tall microniser dust bag by the exiting decompressed air, so the filter bag was earthed by hanging numerous ribbons of conducting plastic around its circumference, each suspended from a brass earthed disc attached to the ceiling.

Humidity of Air in the Cells

Humid air prevents the build-up of static. Static charge is generated by process plant and by people moving about. To counteract this hazard, a very fine mist spray was blown high up into the cell, using filtered compressed air, and this quickly raised the relative humidity to a satisfactory level of 80%.

Clothing

Clothing manufactured from manmade polymer fibres generate considerable static electricity and hence produces sparks, so is clearly dangerous when handling gunpowder. Remember those original nylon shirts way back in the distant past, that hung to the body like cling film on a very dry day?

We managed to acquire some antistatic cotton overalls that were used by RAF personnel when refuelling aircraft - very smart! These, in conjunction with antistatic shoes, fitted the bill. The floors were also damped down to complete the draining of static. Finally each person entering the cell would touch the earthed benches to rid themselves of any static charge.

One of our industrials, who was a large strong man, wore the standard white antistatic rubber boots that were absolutely shapeless, so he wrote on each boot with a permanent marker: a large L for left and a large R for right. It gave him some clue as to which foot to put in them. I remember we had some visitors to the establishment who glanced at the boots with glazed looks on their faces, but were too polite to say anything. I think they got the impression that us lot at Waltham Abbey were a right load of 'loons' - but of course we weren't. Far from it - I think!

Power for Driving the Plant

Electricity was banned from the cells. The only exception was the building's integral lighting that was dust-proof. All plant items were driven by compressed air motors and the exhaust air was piped outside the building to remove any trace of lubricating oil. Copper tubing replaced all the old nylon tubing for piping compressed air and this was earthed. The copper oven, needed for drying the 'gunpowder biscuits', was heated by a warm water jacket. The warm water supply came from an electrical unit outside the explosives cell in the service bay.

Hand Tools

Non-sparking hand tools were needed to avoid 'sparks' that could evidently be caused using steel. As in the old days of gunpowder, I chose phosphor bronze, but getting my hands on them proved difficult. Apparently, at the time, North Sea oil was booming and there was an insatiable demand for non-sparking tools by the oil companies!

Gunpowder Charcoal

Two of the ingredients needed for the gunpowder process: Potassium Nitrate and Sulphur, were readily available at the purity required. Obtaining a suitable Charcoal was an entirely different story - as one would have expected. Barbeque charcoal was definitely off the menu. Gunpowder charcoal needed a specific carbon content with the balance consisting of residues of tar. The choice of wood was critical. Dogwood, alder and willow charcoals were traditionally used in gunpowder manufacture.

We obtained a copy of a wonderful book from the Waltham Abbey site library, that I believe was called 'The Manufacture of Gunpowder'. This old account described the production of gunpowder at Waltham Abbey in the 1800's. It was written by a Captain Smith. He described the plant and process he used at the time in considerable detail. He clearly had a wide practical knowledge and experience of gunpowder. He described how he manufactured gunpowders made with different charcoals, prepared from dogwood, alder and willow woods. He then made charges using each gunpowder of exactly the same weight. They were fired in a cannon and the distance the cannon ball landed from the firing position was measured. The dogwood charcoal gunpowder reached the greatest distance, proving it to be the most powerful gunpowder and, thus, dogwood the best wood for manufacturing gunpowder. This was because gunpowder made from dogwood charcoal was the fastest burning.

Dogwood probably got its name from its use in making 'dogs', which were wooden skewers used for cooking meat. Dogwood is also known as Alder Buckthorn, but its true botanical name is Frangula Alnus. Confused? So were we at the time!

Chris discovered that a National Trust wetland at Wicken Fen, in Cambridgeshire, was the best candidate for sourcing dogwood. Dogwood is a pretty insignificant bushy tree that is very difficult to identify by the layman, but for the skilled staff of the National Trust there was no problem. We paid a visit to Wicken Fen on a beautiful sunny day. The local staff were helpful and took us on a walk through the fens where dogwood is found - I thought, "Am I actually being paid for this?" The day was successful, as they agreed to supply us with 'bundles of dogwood, one inch diameter', which was the size we asked for.

Charcoal Manufacturing Plant

The next step was to manufacture dogwood charcoal on a pilot plant scale for the micronising work. Constructing a plant in-house was not feasible, as it was felt that some direct experience was needed. As a result, Chris and I visited a small manufacturer of barbeque charcoal in Worksop. Here we were met by the managing director, who was a dapper little man in a black suit and white shirt - I felt sure he had a bowler hat and umbrella in his cupboard! He and his production engineer were the only management staff. They took us on a tour of their charcoal plant. They said they used any wood available to make their charcoal, including old fence posts and waste wood. They described how nails and the like could be found in the charcoal and also stones that had become embedded in the bark. Of course their charcoal was totally unsuitable for gunpowder! They agreed to design and produce a charcoal pilot plant for us and these two knowledgeable characters, with charcoal running through their veins, produced just the pilot plant we needed.

The charcoal plant arrived at Waltham Abbey and was housed in an empty building, next to the south site canteen (N513). It was about 6' high, 4' wide and 6' long and mounted on sturdy legs. A door at the front gave access to nine bins, each 12" square and 18" high. Here the dogwood would be placed and converted to charcoal. It was electrically heated.

I had a temperature controller fitted to ramp the temperature up at a suitable rate to drive off residual moisture present in the wood (100 degrees C), then raise it to the carbonising temperature, where it was held steady over a period of time (280 degrees C). The temperature controller was of the 'rotating cam' type, popular at the time. So once the aluminium cam was cut to produce a specific heating cycle, this could be repeated exactly for all subsequent charcoal batches.

The dogwood sticks were debarked before carbonizing, as it was an ‘inferior material‘, and it could also contain grit. The charcoal plant was, in effect, a retort, where the wood went through a process of destructive distillation. The distillate, of gaseous tarry products, was carried away in a pipe to the outside of the building and burned off. These tarry wastes were, to say the least, nasty, so I thought burning them off completely was the best solution - after all it was next door to the canteen!

Thus we successfully produced one inch sticks of dogwood charcoal. These sticks then needed to be crunched up and mechanically milled and sieved, to produce a consistent grain size ready for feeding into the microniser. We purchased a dedicated plant for this purpose from a company called Alpine; the plant was installed adjacent to the charcoal plant. I remember it was around Christmas time, so I went off on leave. When I got back, the boys from the tea club informed me that the Alpine rep had called and had left me a bottle of whisky. I asked where the whisky was and they said, “Oh, we drank it!”. Ah well, I never was that fond of whisky, much preferred a glass of gin.

Mike Evans

To be continued.

The Last of the Powder Men! Part Two

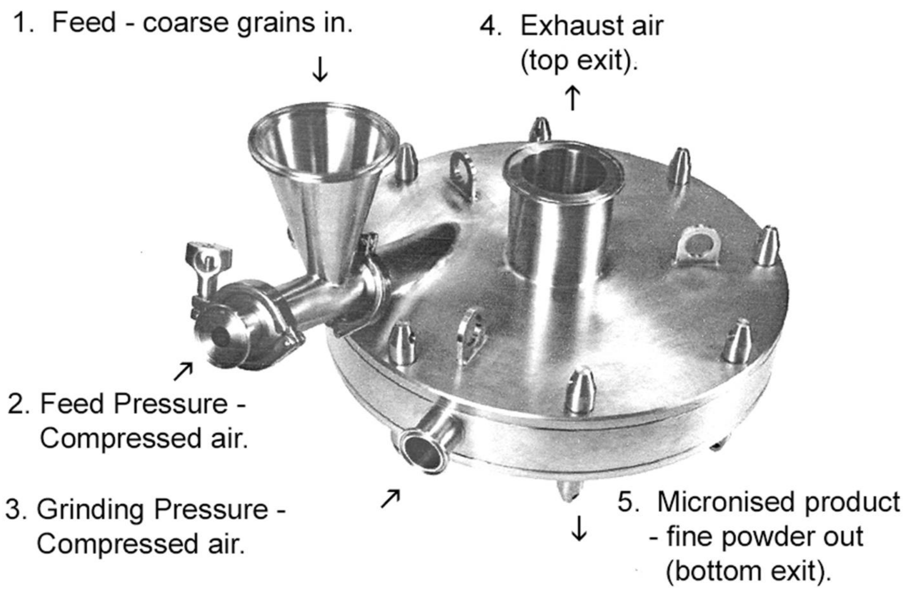
The Main Steps in the Preparation of the Experimental Gunpowders.

There were many steps in the manufacture of the gunpowder samples. An outline of the path I selected, from some experimental ‘initial trials’, is as follows;

1. INGREDIENTS - Charcoal, Sulphur and Potassium Nitrate.
2. PREMILLING and SIEVING - crunch up each ingredient separately and sieve to size.
3. MICRONISING - mill each ingredient separately using the microniser.
4. PREBLENDING - weigh and mix a batch of the three dry ingredients in a rotating stainless steel blender (up to 4 kg)
5. WATER ADDITION - transfer a small batch of the dry micronised mix to a small brass rotating blender. Add water over a period of time.
6. HYDRAULIC PRESS - press the damp powder into ‘gunpowder biscuits’.
7. OVEN DRYING - dry the damp consolidated gunpowder biscuits in the oven.
8. HYDRAULIC PRESS - break the hard dry biscuits between matched toothed brass platens to produce gunpowder grains.
9. POLISHING - polish off the rough edges of the grains in a rotating blender to give a smoother, easy flowing, material.
10. SIEVING - sieve the gunpowder grains to the required specification.

Experimental Process and Plant Notes: The Nitty-Gritty.

The aim of the work, using our experimental plant items and processing method, was to produce gunpowder samples for quality evaluation.



Microniser

Fine Milling Using the Microniser - Selecting the Method:

The US and the Norwegian micronising plants produced gunpowder on a fairly large production scale. Our requirement at Waltham Abbey was far less and pilot plant quantities fitted the bill. I did some early tests on the microniser and milled the three ingredients individually to see what, in general, would happen. I was most interested in checking the static electricity generated around the tall dust collection bag - as we didn't want a dust explosion!

Micronising the charcoal gave some crackling noises and a similar level of noise was experienced with the potassium nitrate. The sulphur was the last to be tried. I did expect more static noise, compared with the other ingredients, and I certainly got it - the static crackling was bordering on the 'horrendous'! The good news was that there was no dust explosion, proving that our antistatic measures worked well.

It was pretty clear that if I mixed the three ingredients together to produce a 'pre-gunpowder mix', the static level should drop, as the conducting charcoal would help dissipate the charge. Adding water to the mill, as in the US and Norwegian plants, would also help remove static. However, with our small microniser, the addition of another inlet port to feed water, or steam, posed problems. The basic microniser design would be altered, with unknown consequences, and it would also be difficult to meter a water feed against very high pressure compressed air. There were far too many complications - and there was no guarantee that it would work. Another possibility was to dampen the premix with water and feed this into the mill. My previous experience of micronisers showed that damp feeds often led to 'bridging' in the feed hopper, effectively stopping the feed altogether. Small micronisers have narrow bore inlet ports that can block very easily. For expediency, I decided to micronise the ingredients separately and later mix them together with water to form a damp powder. The mixing task was carried out using a cone blender. So, for our requirements, this route of gunpowder manufacture was the preferred choice.

Microniser Control - Producing the Required Particle Size:

A range of particle sizes from the microniser can be achieved by varying the power to the mill. This was quite simply done by adjusting the compressed air pressure to the microniser grinding chamber. In this way a number of samples, with a broad range of ingredient particle sizes, for the experimental work, were achieved.

The gunpowders made from these materials had correspondingly different burn rates. The burn rate was measured using a test known as the 'Lead Fuse Burn Time'. This was carried out at the Royal Ordinance Factory at Chorley. By plotting the microniser 'Compressed Air Pressure' versus 'Burn Rate', we obtained a graph and hence we were able to produce 'tailor made' gunpowders.

Producing the Gunpowder grains:

Hydraulic Pressing: As previously mentioned, weighed amounts of the damp powder were pressed between brass platens in the hydraulic press. In this way flat, biscuit sized, cakes of consolidated gunpowder were made. These were then dried to produce 'hard biscuits'.

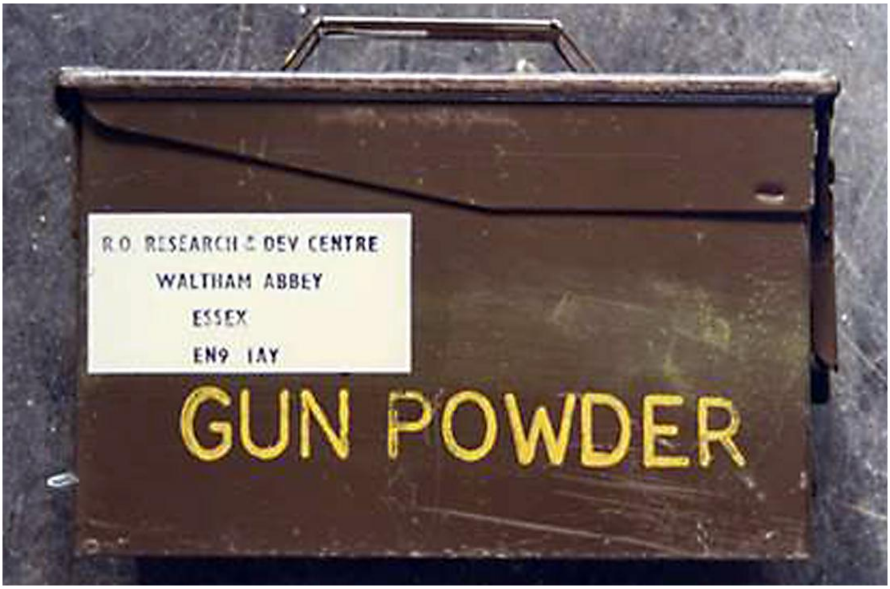
It was interesting to note that it took a higher pressure to consolidate the micronised gunpowder, compared with that from the traditional edge runner mill. The reason was simply because the edge runner mill produced a wider range of particle sizes, whereas the microniser had a built-in classification effect, similar to a cyclone separator, and gave a more uniform particle size. The traditional gunpowder packed down more easily, because the finest particles filled the voids between the larger particles (known as close packing) so, for a given density, the micronised gunpowder needed rather more force to compress it.

Granulation of the Dried Gunpowder Biscuits:

Chris and I visited ROF Chorley, where a lot of redundant gunpowder plant remained after its production ceased there. We were invited to take whatever we wanted and we selected an old gunpowder 'roller crushing' mill, made of phosphor bronze. Chunks of gunpowder cake were dropped between grooved rollers, where it was 'pinched' and shattered. The milled fragments fell below.

The rollers had 'teethed grooves' along their length that had been machined down to a smooth finish - very similar to car gear teeth -

but, of course, they extended along the length of the two foot rollers. Unfortunately, as the roller crushers were intended for production scale work, they were far too big for our needs. To overcome this problem, I got our machine shop to copy the profile of the rollers' teeth, and then manufacture two flat 'matching platens' to fit into our hydraulic press. These brass 'flattened platens', with a similar profile to the old gunpowder crushing roller mill, successfully produced a gunpowder grain size suitable for our needs.



The Finished Product

The Final Results.

Our micronised gunpowder samples were tested by the quality department at Chorley and they proved to be highly successful. They were tested against an MOD gunpowder specification that included the all important Lead Fuse Burn Time test. The Burn Time of our micronised gunpowder fell exactly at the centre of the permitted burn time limits of the specification - exactly what we had aimed for.

At a follow up meeting at Fort Halsted, we were asked if we could 'possibly' make a gunpowder with a specific 'burn time', that suited their own particular requirement. So we returned to Waltham Abbey to produce this 'tailor made' gunpowder. Once again, the gunpowder sample was sent off for Burn Time test evaluation and the result was spot on target.

Thus it was clearly proved that gunpowder, milled using a Microniser, easily matched that produced by the old traditional Edge Runner mill. Also, by adjustment of the micronising pressure, the burn time characteristics required could be accurately achieved.

So finally, it can be said that the last gunpowder produced at Waltham Abbey was in the early 1980's. This signalled the end of a long line of gunpowder makers, the 'Black Powder men', whose reign extended way back to the 1600's - we were the last! I cast my mind back to one very dark winter's morning, when a particularly heavy fog fell across the Lea Valley. I stood in the murky mist near the gunpowder building and I saw some hazy apparition of two medieval monks, draped in cloaks and hoods, slowly approaching through the woods. I thought, "Is this a ghostly visitation of the souls of the past masters of the evil blackpowder - eager to improve their wicked art?" Well I was wrong, it was just two scientists wearing duffle coats with their hoods up! Some things never change!

Mike Evans