Powder Processing

Ingredient preparation.

How a black powder plant prepares the ingredients will be determined by several factors. Both sulfur and potassium nitrate may be purchased in a high state of purity and as a finely divided powder. It is necessary to screen these materials to remove any foreign matter that might prove dangerous in a batch of powder being worked in a wheel mill. This might also include passing the material over a magnet to pick up any bits of ferrous metal that might be present in the powdered ingredient.

The method used to prepare the charcoal varies from one powder producer to another.

In the Du Pont method the charcoal is purchased as a fine powder but is then mixed with the sulfur. These two combined ingredients are then subjected to ball-milling for several hours to reduce their particle size prior to wheel-milling. This ball-milling of the sulfur and charcoal together was also used by ICI powder plants.

Charcoal.

The S/A Pernambuco Powder Factory, producer of Elephant brand black powder, prepares their charcoal from Imbauba wood. The Imbauba tree being a type of palm tree.

Figure 15. Removing bark

In 1999 the S/A Pernambuco Powder began to remove the bark from their Imbauba wood prior to the charring of the wood. The bark is manually stripped from the wood and a thin, hard skin found covering a central opening in the wood is removed.

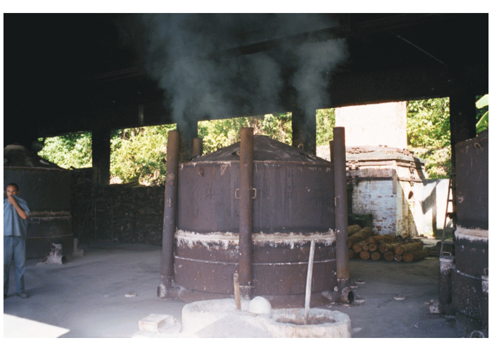

Figure 16. Charring vessel

The wood is then charred to a specified fixed carbon content in metal cylinders that are heat by a fire in a compartment beneath the charring cylinder.

Storage.

The original Du Pont black powder plant near Wilmington, DE stored raw materials in a stone building that was divided into three sections. The original Du Pont black powder plant has been partially restored and preserved by Hagley Museum And Library. Each door leads into a section of the storage building.

Figure 17. Ingredient storage, Hagley

Bags of powdered sulfur in a storage shed at the S/A Pernambuco Powder Factory near Recife, Brazil.

Figure 18.

Screening potassium nitrate at the S/A Pernambuco Powder Factory.

Figure 19.

<u>Wheel mill batch preparation.</u>

Figure 20. Mill batch storage

The proportions of ingredients used in a batch of powder to be run in a wheel mill will be specified on a batch sheet. The ingredients are portioned, or weighed out, and placed into bags for storage prior to being used to lay up a batch of powder in a wheel mill. These bagged ingredients are stored in a building while waiting transfer to a wheel mill.

This is the storage building used to store portioned ingredients at the S/A Pernambuco Powder Factory prior to being transported to a wheel mill.

The track in front of the building carries push carts used to transport the materials to the various wheel mills.

Figure 21. Wheel mill batch cart

Ingredients portioned for wheel mill batches are then moved to the wheel mills on carts pushed by hand.

Photographed in front of a wheel mill house at Hagley Museum And Library.

Wheel-milling.

The function of the wheel mill is to reduce the particle size of the three ingredients while bringing the particles into an intimate contact with each other. The following particle size graph will show the difference in charcoal particle size between a slow burning fireworks powder and a fast burning sporting type powder.

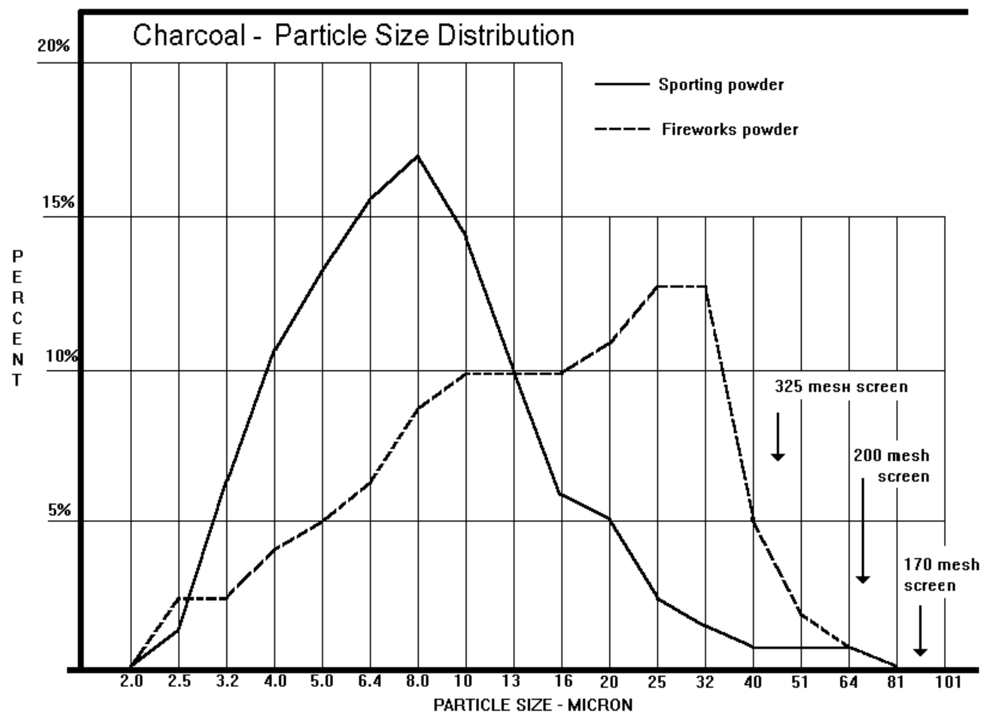

Figure 22. Charcoal particle size comparison

To better address the topic of wheel mills and their function in the black powder manufacturing process it will be necessary to describe building construction, methods of powering the mills and various wheel mill designs.

Stamping mills were once used to manufacture black powder but were largely replaced by wheel mills by the mid-19th century. Being of little more than historical interest, they will not be covered in this work.

A pair of wheel mill houses at Hagley Museum And Library known as the Birkenhead Mills.

A water wheel located between the two buildings supplied powder to each mill.

Figure 23. Birkenhead Mills, Hagley Museum And Library

The author standing in front of one of the wheel mill buildings at the Hagley Museum And Library. This should give some idea as to how massive these buildings are. The stone is granite that was quarried from a hillside behind the mill building.

The wheel mills used in these buildings were under driven mills. The lower compartment housed the drive gears while the mill was mounted in the larger area above the lower compartment. This building had been designed to house an “8 ton” wheel mill.

Figure 24. Front view of a mill house.

Figure 25. Details of lower compartment.

Looking into the lower compartment of one of the wheel mill houses. The arched opening on the right allowed a drive shaft to enter the compartment. The piece of pipe in the middle of the floor acted as a foot bearing for the lower end of the center drive shaft that extended down from the wheel mill above. The center shaft carried a large ring gear that was driven by a pinion gear on the end of the drive shaft entering through the arched opening.

The ceiling of the compartment forms the floor of the mill room above. Steel "I" beams have arched brick work in between each beam.

Figure 26. Wheel mill servicing bridge.

Each pair of wheel mill buildings has a bridgework built level with the wheel mill rooms. This bridge carries wooden rails over which the hand carts travel in servicing each mill during the charging and emptying of each mill.

The wheel mill buildings are constructed with 3 very thick stone walls. The roof is light and simply rests in supports. During mild weather the front of the building facing the creek were simply left open. A lightly constructed wall would be held onto the front of the building with metal brackets during cold weather months.

Figure 27. Details of roof construction.

Roofs are attached to the building only lightly. Steel "I" beams support lengths of angle iron into which pieces of wood are laid. Galvanized sheet metal is then lightly nailed to the wood strips. In the event of a wheel mill explosion the roof is easily blown free of the building.

Powering the mills.

Figure 28. Water wheel and water flow gates.

One of the older means of driving wheel mills is by the use of a water wheel. Here we see a water wheel between the two Birkenhead Mills at the Hagley Museum And Library. The mill race is seen in the lower left corner with a sluice gate that controls the water flowing to the water wheel. A second gate at the water wheel controls the speed of the water wheel which in turn controls the speed of the wheel mills.

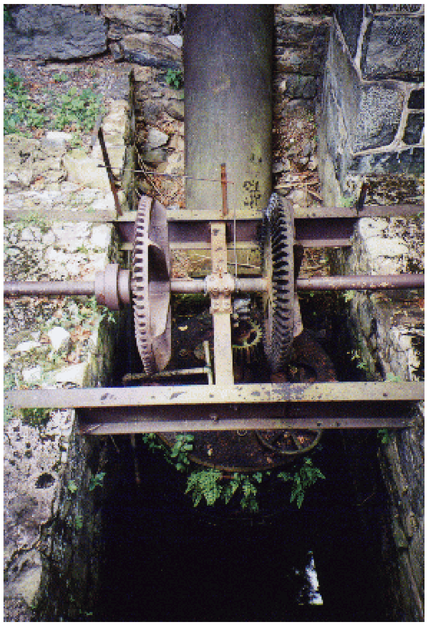

Fig. 29. Water turbine drive.

By the mid-19th century, water turbines began to rapidly replace the older wooden water wheels.

A 36 inch diameter pipe, seen in the rear, carries water from a control valve, and directs it at an angle into the turbine housed in the wooden tub. The turbine shaft has a top mounted gear. The large ring gears slide on their shafts and may be moved to engage the turbine mounted gear to drive the shaft that extends, to the right and left, into the lower compartment of the wheel mill house.

Figure 30. Water turbine rotor.

One of the turbines on display in one of the wheel mill buildings at the Hagley Museum And Library. The angled vanes in the center section catch the water as it flows into the wooden tub from the 36 inch supply pipe.

Figure 31. Drive shaft from turbine.

A view of one of the drive shafts where it enters into the lower chamber of a wheel mill building.

Fig. 32. Overhead drive mill.

This is a 5 ton wheel mill at the S/A Pernambuco Powder Factory in Brazil. The S/A Pernambuco Powder Factory manufactures Elephant brand black powder.

This is a suspended edge runner mill with the drive gears over the wheel mill. An electric motor is mounted outside of the mill building with a drive shaft entering the wall behind a gear box mounted on top of the wheel mill.

<u>Wheel mill design.</u>

The basic design of wheel mills had evolved over a period of roughly 100 years. Designs changed to improve the productivity of the wheel mills and then finally the safe operation of these mills.

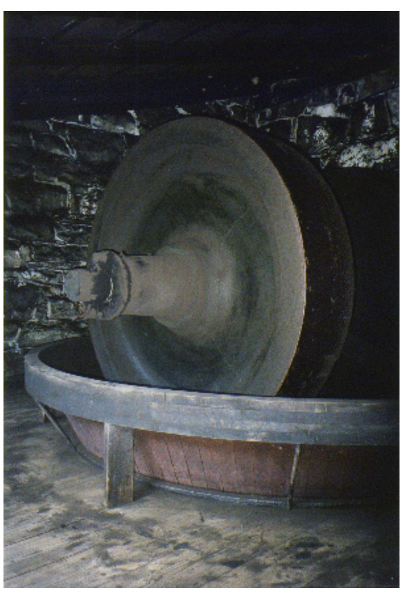

Figure 33. An 8 ton mill.

This is an 8 ton wheel mill that was restored and on display at the Hagley Museum And Library. This mill represents late 19th century technology in black powder manufacture. Each wheel weighs about 8 tons. This type of mill would run on a 600 pound charge of blasting powder while faster burn rate powder would call for lower batch weights. The mill runs at about 8 to 9 revolutions per minute.

The two wheels do not follow the same path in the mill pan. The wheels are slightly staggered to allow one wheel to run close to the outside edge of the mill pan while the other wheel runs close to the inside curb where the drive shaft comes up through the bed pan from the compartment below. Compared to mill designs where both wheels follow the same path, the staggered wheel design is supposed to give a more intensive mixing and grinding action.

Figure 34. Wheel mill pan details.

By today's standards the mill bed pan design with the 8 ton mill is rather unique. There is a thick steel bed plate attached to the floor. The plate has an outer ridge that retains wooden slats, or staves, that form the sloping sides of the pan. These are anchored to a wooden curbing that runs around the top of the slats. In the event of an explosion the cost of replacing the mill pan is far less than the cost of replacing cast steel pans.

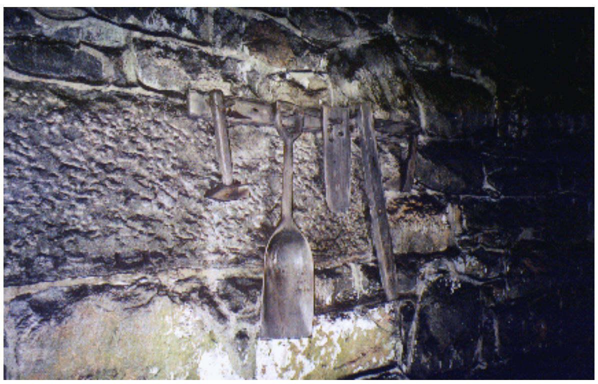

Figure 35. Wheel mill tools.

The wheel mill display at the Hagley Museum And Library also includes examples of the tools that were used to service the mill during the charging and emptying of the mill pan. The tools are made of wood while the hammer has a brass or bronze head and the spud on the far end of the rack appears to be brass or bronze.

Figure 36. Cast mill pan.

This is a 5 ton wheel mill salvaged from an idled ICI black powder plant in Australia. This is another wheel mill driven from below. The pair of wheels and central drive shaft sits behind the pan in the photo.

With these cast mill pans the pan must be well supported to prevent flexing should a batch of powder blow up in the mill. If not firmly supported the pans will sometimes crack or shatter should the batch being milled explode.

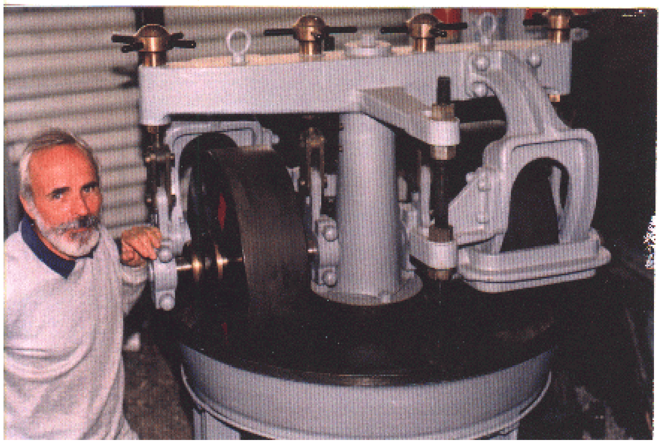

Figure 37. Small wheel mill

Wheel mills had been constructed in a variety of sizes. This small wheel mill is mounted on a stand with the drive motor and gearing arranged within the stand.

This particular wheel mill dates to the first decade of the 19th century and was recently restored by Ron Grosvenor, Tamworth, NSW, Australia.

This design is known as a suspended edge runner mill since the wheels are supported from above.

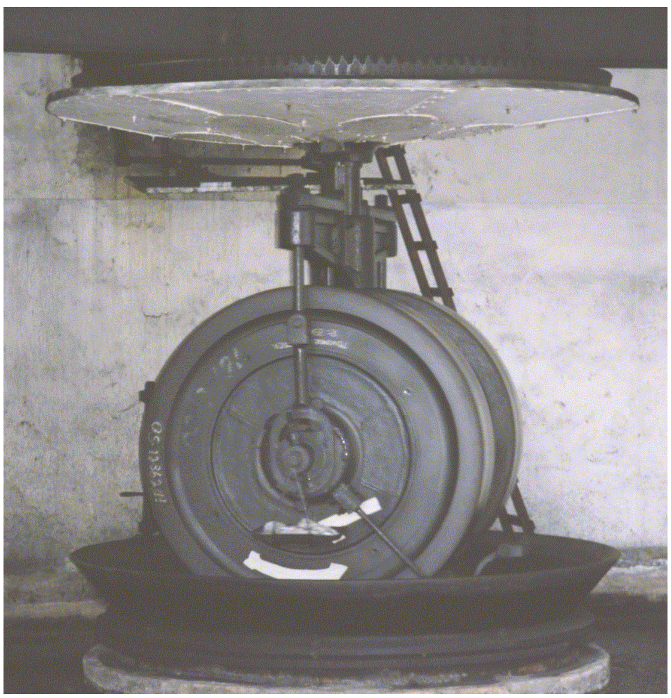

Figure 38. Wheel suspension rods.

This is one of the 5.5 ton wheel mills in use at the S/A Pernambuco Powder Factory, Recife, Brazil. Here we see the supporting rods on the ends of the wheel's axle. The thin rod that extends to the left of support bearing holds one of the ploughs used to push the powder into the path of each wheel.

The large ring gear that drives the mill is seen above the mill. Note the pan covering the underside of the gear that prevents foreign objects from falling into the mill pan where they could cause an explosion of the batch being worked in the mill.

The conversion to suspended edge runner mills in England and Europe during the first quarter of the 20th century resulted in a dramatic decline in the number of wheel mill explosions in the industry. The wheel suspension system insures that the heavy wheels will not drop onto the mill pan should there be no powder under a wheel.

<u>Wheel mill function.</u>

The wheel mill accomplishes a number of things within the batch of powder being worked. Wheel milling will reduce the particle size of the ingredients, disperse these particles uniformly throughout the mass and bring the particles of charcoal, sulfur and potassium nitrate into an intimate contact.

Figure 22 shows the differences in charcoal particle size between a powder type that is worked for only a short time in the wheel mill versus one that is worked for the longest period of time in the mill. This graph gives some idea of the effect of wheel milling times on ingredient particle size reduction.

When a batch of black powder is placed in the pan of the wheel mill the wheel mill operator will add water to the batch. Roughly 10% of the batch weight. This wetting of the batch is often described as being a safety measure. That is true but is only part of the reason for wetting the batch during the milling cycle.

The wheel mill is a mulling machine. To be more exact, a paste muller. The two wheels are traveling a circle in the pan. In forcing the wheels to run in a circle, rather than in a straight path, they "scrub" on anything they are riding on. The action is as if you placed the palm of your hand on a flat surface and gave your hand a twist. The wheels impart a smearing action. While running over the powder they apply a great deal of shearing action to the powder under the wheels. With the great weight of the wheels it is a pressure smearing of the batch being worked.

The wheels ride on the batch while the batch is in a paste form. The pressure/smearing action of the wheels causes considerable friction within the pasty mass of powder. To an extent, the water acts as an internal lubricant within the mass in addition to some cooling of the mass through evaporation of the water. Potassium nitrate crystals are reduced in size through their rubbing together as the wheel smears the mass under pressure. The potassium nitrate crystals in turn act as a grinding medium in reducing the size of the charcoal and sulfur particles.

The texture, or viscosity, of the batch of powder is important in this reduction in ingredient particle size. An excessive amount of water will allow the mass to flow freely under the wheels which reduces the grinding action. Too little water and the mass will not be fluid enough to allow particle size reduction to take place.

It has been said that black powder is an "intimate mixture" of the 3 ingredients. If crude methods are used to make black powder the resulting powder will lack the degree of "intimacy" required to promote a rapid burn rate. Crude methods produce rather slow burning powder.

Both charcoal and sulfur exhibit hydrophobic behavior. In finely powdered form, they hate water. Both are difficult to wet out in water.

A simple experiment will show this hydrophobic behavior. Take a large glass test tube and half fill it with distilled water. Add finely powdered charcoal or sulfur. With a glass stirring rod or stainless steel spatula try to force the powder beneath the surface of the water in the test tube. You will see the particles cling together in masses while surrounding the mass with a large bubble of air. The particles simply do not disperse into the water, let alone as individual particles.

Place a rubber stopper into the mouth of the test tube. A rubber stopper with a piece of thin tubing through it. Hook that up to a vacuum pump and slowly remove the air from the test tube. As air is being removed you will see the particles being to sink through the surface film on the water and disperse in the water as individual particles as they sink to the bottom of the test tube.

Milling powder requires the use of water. As the particles of sulfur are worked in the batch they will initially be covered in a thin film of air or form aggregations of particles encapsulated in a small air bubble. The combination of pressure and smearing, imparted by the wheel, will strip away this air encapsulation and allow the particles to be distributed throughout the mass as individual particles that are in actual physical contact with each other or the crystals of potassium nitrate.

Various methods have been tried to incorporate some form of a wetting agent into the batch to reduce milling times. In Col. George. W. Rains, "History Of The Confederate Powder Works, he describes a method of batch pre-treatment where it is subjected to steam in a closed cylinder prior to the batch being laid up in the mill pan. This was supposed to reduce wheel milling times without sacrificing finished powder burn rates. In writings on fireworks one will see an alcohol being used as a wetting agent. This is far too dangerous to carry out in large wheel mill batches. One powder company, during the 20th century, added water-soluble HPMC (hydroxypropylmethylcellulose), as a wetting agent, to the water used to wet the batch in the wheel mill.

These wetting agents would reduce the surface tension of the water in a effort to eliminate the air encapsulation of the charcoal and sulfur particles. Generally, the wetting agents were either too dangerous to work with on a large scale or were objectionable in the finished powder.

In general, the longer the powder is milled, the faster the finished powder will burn.

Following the wheel-milling step, the powder then goes on to the powder press.