# A Short Guide to Green's Mill
## and How it all Works

## A WORKING MILL

A windmill is, in essence, a simple machine, capturing the power of the wind to turn the millstones and grind grain to flour. Yet there is more to a mill than this, particularly a large tower mill such as Green's Mill. Although the power source - the wind - is free it is greatly variable, not only in strength but also in direction. The windmill must be able to work in the lighter breezes and yet be able to mill safely in a near gale. Or with a wind that gusts one moment and dies away the next and which can rapidly change direction, too. The supply of grain to the millstones must be regulated according to the speed at which the mill is working, as must the gap between the stones. The miller needs to be able to start and stop the mill, hoist sacks up the mill, clean the grain and store it.

The windmill is an integrated system of many different mechanisms. Some of these, such as the bevel gears, have been employed for perhaps two thousand years or more, first being used in the watermills that preceded windmills. Others, such as the fantail that keeps the sails facing into the wind, are more recent. The evolution of windmills is a tribute to the cunning and innovation of countless millers and millwrights who strove to make their mills grind grain to flour more efficiently and safely.

Green's Mill is a fine example of a 19th century tower windmill. Although extensively restored, the materials and methods used by the millwrights are very much those that were used in the original construction of the mill over two hundred years ago.

## OUTSIDE THE MILL

Green's Mill stands on a ridge overlooking the Trent Valley. It is an excellent site for a windmill, being exposed to the winds from all directions. Indeed, there was a post mill on this site before Green's Mill was built here in 1807 and at least two more post mills further up Windmill Lane.

Windmills were often built on hills or on slopes. This helped ensure that the mill was free from the turbulence caused by the wind blowing over houses, trees, hedges or rough ground. Also, the wind blows faster as it passes over a hill, giving greater power to the windmill.

Around the millyard the buildings housing the Science Centre are on the same plan as the original granaries, stables and outbuildings that once served the mill. Only the mill foreman's cottage has not been replaced. This was built onto the east side of the mill where there is now a flat paved area. You can still see the faint line of the cottage roof on the mill below the gallery, as you can the limewash on what, although now the outside of the mill, was once on the inside wall of the cottage.

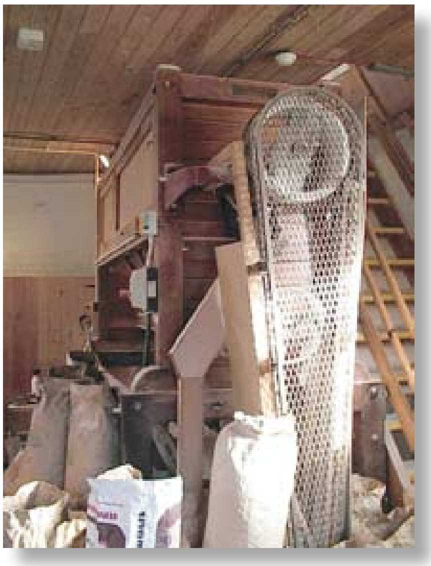
Green’s Mill is a brick tower windmill with two cloth covered ’common’ sails and two shuttered ’spring’ sails. The ’ogee’, or onion shaped, cap is typical of the tower mills of the East Midlands and East Anglia. At the back of the cap is the fantail that drives the cap around on top of the tower as the wind changes direction. The wooden gallery at the first floor level allows the miller to attend to the sails.

There are three doors in the ground floor of the mill. The door nearest the top of the millyard is now the main entrance. The door to the left is used when sacks of grain are unloaded into the mill. The third door once led directly from the mill foreman’s cottage into the mill.

## GROUND FLOOR

The ground floor of the mill has the largest area of all the floors in the mill and is used for the storage of grain waiting to be milled and sacks or bags flour ready for sale in our shop.

### THE FLOUR DRESSER



The large piece of machinery on this floor is the flour dresser. Essentially this is a large sieve that separates the 100% wholemeal flour into its different parts; fine white flour, coarser flour and the bran.
Flour is fed, via a hopper on the floor above, into the rotating horizontal drum in the dresser. The flour moves along the drum and is beaten against cloth mesh sieves by rotating beaters. The first mesh is of a very fine weave and only allows the finest particles of flour to drop through and down the canvas sleeve into a sack. This produces a fine, white flour. The next sieve is of a coarser weave to separate out the ‘middlings’. These are the larger particles of flour or 'semolina' and the smaller flakes of bran. The larger flakes of bran are then left to fall into the last sack.

### THE SACK HOIST

The chain hanging down from the ceiling is the sack hoist. Grain is delivered in 25kg sacks and the power of the wind is used to lift them to the upper floors of the mill. The sack hoist is a continuous chain that goes up through the mill to the cap. There it passes over a drive wheel and then comes all the way down again. Each floor has a pair of trap doors through which it passes.

Short chain ’tails’, each with a ring on the end, are attached along the length of the chain. The miller’s assistant makes a loop in the end of the chain and tightens it around the neck of a sack. Then the miller, on an upper floor of the mill, pulls on the rope hanging down through the mill next to the chain. This engages the sack hoist drive at the top of the mill. Providing that the sails are turning, the sack will be lifted up the mill, pushing open the trap doors as it passes through each floor.

Once the sack has passed, the trap doors fall shut again. When the sack reaches the floor where it is wanted the miller lets go of the rope and the sack drops gently onto the now closed trap door. The miller takes the chain loop off the sack and is ready to bring up the next. The trap doors also stop the miller - or visitors - falling through the sack hoist hole.

### FOLLOWING THE GRAIN

It is easier to understand the workings of a windmill if we start at the top. The grain, once it has been lifted up on the sack hoist, comes down through the various parts of the mill by gravity. Likewise, the power of the wind turning the sails is transmitted down through the mill to turn the millstones. So our tour continues on the Grain Cleaner Floor at the top of the mill.

## THE CAP AND DUST FLOOR

You can see the machinery in the cap from the stairs on the Grain Cleaner Floor.

The machinery in the cap is the most complicated part of the windmill. It does three quite separate things; firstly, when the sails are turned by the wind the upright shaft turns with them and this drives the millstones three floors below. Secondly the whole of the cap, bearing the sails and all the machinery that you see in the cap, turns on top of the tower as the wind changes direction, rather like a huge weather vane. Finally, there is the drive to the sack hoist. Let us take each part in turn.

### THE WINDSHAFT

Have a look out of the windows to see which way the sails are facing. The sails are attached to one end of the windshaft, the grey painted cast iron axle that spans the cap. The forward end of the windshaft is supported by a half bearing on the weather beam, part of the huge oak cap frame that supports the cap and windshaft (and hence the fantail and sails). This supports the weight of the sails.

The back end of the windshaft fits in a thrust bearing on the tail beam, the rear part of the cap frame. This takes the force of the wind blowing onto the sails. If the sails are turned by the wind then the windshaft must also turn.

### THE BRAKE WHEEL

Just behind the weather beam, on the forward end of the windshaft and turning with it, is the huge oak brake wheel. Bolted around its edge are cast iron gear teeth. These mesh with the teeth of the wallower, the smaller gear wheel around the top of the upright shaft.

Around the outside of the brake wheel is the brake band. One end of this steel band is bolted to the cap frame. The other end of the band is fixed to one end of a cast iron brake lever that the miller can raise or lower by means of the brake rope. This hangs from the cap outside of the tower down to the gallery. When the miller raises the lever the brake band is slackened off and the sails may turn. When he lowers it, the band tightens around the brake wheel, bringing the mill to a stop.

As the brake wheel turns so does the wallower on the upright shaft. They form a bevel gear; the difference in the size of the two gears means that for every turn of the horizontal windshaft, the vertical upright shaft turns about two and a half times. Although the teeth on the brake wheel are made of cast iron, those of the wallower are hard beech wood that, over a number of years, will wear out whereas the cast iron teeth will not. It is then a simple matter to replace the worn wooden cogs with new ones previously cut in the workshop. If the teeth of both wheels were of iron they would wear at the same rate; eventually both sets of castings would need to be replaced, an expensive repair.

Another advantage of having wooden teeth is that should something jam the millstones or put undue strain on the shafts the cogs will break, preventing further damage to the shafts or sails.

## THE UPRIGHT SHAFT

This shaft is in three sections; the upper part is of oak, the two lower sections are cast iron. On the top of the shaft, above the wallower, is an iron cap that locates in a bearing on the spindle beam, the central beam of the cap frame. This beam is secured to the side timbers of the cap frame by wooden wedges. By knocking these wedges in or out the beam can be moved forwards or back or to one side or the other. This allows the shaft to be positioned exactly in the centre of the circle of the top of the tower, ensuring that the brakewheel and wallower are always engaged whichever way the sails happen to be facing.

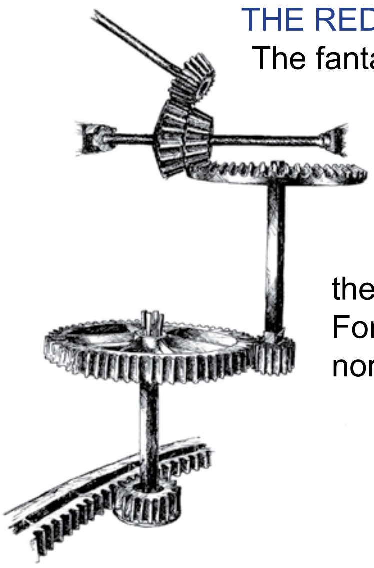
## THE TURNING GEAR: THE FANTAIL

The cap turns on top of the tower to keep the sails facing into the wind. In the smaller wooden post mills that preceded tower mills such as Green's Mill this had to be done by hand. In stormy weather the miller pushed the body of the mill round whenever the wind changed direction, day or night. This was quite a burden on the miller and would have been difficult, if not impossible, with a large tower mill.

To overcome this problem, in 1745 Edmund Lee patented the fantail. This is the eight-bladed device at the back of the cap. If the wind is blowing face-on to the sails then it is edge-on to the fantail blades and they do not turn. When the wind changes direction it will blow more sideways-on to the fantail and will cause it to turn. The fantail, driving through a gear mechanism inside the cap, causes the cap of the mill to turn until the sails are facing into the wind again.

## THE CURB

Around the top of the brickwork of the tower is a cast iron ring or curb. The cap frame sits upon this curb and slides around on it. There are no ball or roller bearings between the frame and the curb. Instead rounded iron blocks are fixed to the underside of the frame where it crosses the curb. This 'dead curb' is kept well greased. Around the inside face of the curb are gear teeth.



## THE REDUCTION GEAR

The fantail blades, turning at the back of the cap, turn a shaft that runs down to a gear box that is above the cap frame inside the rear of the cap. It is difficult to see the gear box as there is a wooden platform below it giving the miller access to the gearing when the cap needs to be turned around by hand. The gear box greatly reduces the drive from the fantail blades; the fantail needs to turn 51 times for just one turn of the final pinion that engages with the teeth around the inside of the curb. For the cap to turn through half a complete revolution, e.g. from facing north to facing south, the fantail needs to turn 544 times.

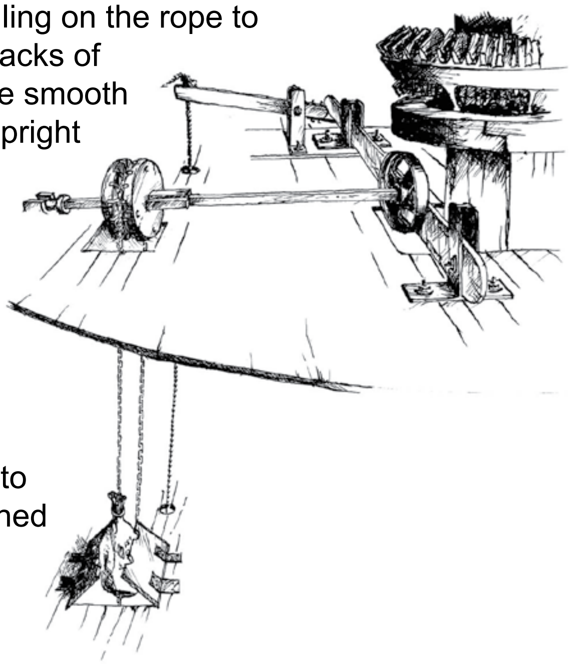
## THE CAP

As the cap frame merely rests upon the curb there is a tendency for it to slip sideways off the tower when the fantail drives it around. To prevent this there are 12 centring wheels, each about 30cms in diameter, fixed to the underside of the cap frame and locating just inside the curb.

The cap itself is constructed from oak ribs rising up from the cap frame to give the cap its ’ogee’, ’reverse-S’ or onion shape. Cladding the ribs are a double layer of pine boards. They extend down below - and outside of - the top of the brickwork of the tower to prevent rain and birds from getting in. At the back of the cap is a small door to allow the miller to get out onto the fantail frame to oil the gears.

## THE SACK HOIST DRIVE

On the ground floor it was explained how the miller, by pulling on the rope to engage the drive to the sack hoist, was able to bring the sacks of grain up the mill. When he pulls the rope a lever lifts up the smooth iron wheel that is level with the dust floor just next to the upright shaft. The wheel comes into contact with the wooden ring attached to the underside of the wallower. If the sails - and hence the wallower - are turning, then this iron wheel is turned, too. It is fixed to one end of a shaft that runs above the dust floor to the drive wheel over which the sack hoist chains pass. This wheel has V-shaped steel bars set into it to grip the chain between the links.



The sack hoist is driven by a smooth iron wheel coming into contact with a smooth wooden ring, rather than using toothed gears. By using a friction wheel the drive slips a little at first, reducing the strain on the machinery and allowing a smooth start. It is, in effect, a clutch.

# THE GRAIN CLEANER FLOOR

The large machine taking up much of the space on this floor is a grain cleaner. Although this one was probably made in the 1930s, Green’s Mill had a similar machine during at least the latter part of its first working life. Unlike the earlier one in this mill, our grain cleaner is driven by an electric motor.

Grain bought straight from the farm has in it bits of straw and leaves, whole ears of corn, grains with the chaff still on them, chaff and dust. This is fed into the hopper at the top of the grain cleaner (with some difficulty due to the floor beam immediately above it). When the cleaner is operating, the grain is fed from the bottom of the hopper onto the sloping  perforated metal screen. This is a sieve on the top of a large box that is shaken rapidly to and fro. The larger unwanted material stays on the sieve, falling off the end into a sack at the side of the cleaner.

Below this sieve are two more that remove small particles such as weed seeds. The grain, chaff and dust then pass through an up-draught of air from a fan in the cleaner. The chaff and dust are blown out into the expansion chamber at the back of the machine whilst the clean grain drops down a chute into sacks on the floor below.

The wooden sleeve around the lower part of the shaft allows sacks to be stacked right up to the shaft without coming into contact with it as it turns.

## THE BIN FLOOR

The sacks of grain only go up to the floor above if the grain needs to be cleaned. Usually they brought up as far as this floor. The sacks are opened and the grain is tipped into the wooden bins that act as reservoirs, feeding grain down to the millstones on the floor below. Each bin holds around half a tonne of grain.
The grain in the bins can be conditioned here; brought to the correct moisture content for it to mill properly. Sometimes it is too dry and the hard, brittle grains shatter into fragments rather than milling into fine flour. This gives the flour a coarse, gritty feel. The moisture content can be measured and the appropriate amount of water added as the sacks are emptied into the bin. The lid is put on and left for a couple of days whilst the grain adjusts to the correct moisture content.

The bottom of each bin is funnel shaped, leading the grain to a wooden chute and down to the millstones.

## THE STONE FLOOR

This is the heart of the mill for here the grain is ground into flour.

### THE GREAT SPUR WHEEL

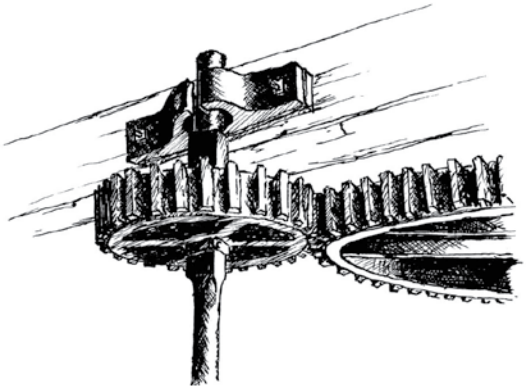
In the centre of the floor between the two millstones is the third and final part of the upright shaft. The weight of the shaft is taken on a bearing on a beam below the floor. This bearing is encased in the wooden box at the bottom of the shaft to keep out dust and dirt.

The huge gear wheel on the upright shaft is the great spur wheel. As the brakewheel (on the windshaft) and the wallower (on the upright shaft) are always in gear, whenever the sails are turning, so the great spur wheel turns as well. The spur wheel may then engage with the much smaller stone nuts, each of which is fixed to the top of the quant that will then drive a set of millstones.

There may be times when the miller wants to turn the sails but not the millstones, for example when only operating the sack hoist. Or, as is more common in the mill today, only one set of stones is required to be milling. Thus, there must be a way of disengaging the spur wheel and the stone nut. This is done (with the mill at rest) by lifting up part of the bearing on the beam above the quant. This allows the stone nut to be pulled away from the spur wheel. The loose part of the bearing can then be slipped back into place, the ring attached to it slipping over the top of the quant to prevent it falling right over.

The spur wheel is made of four cast iron sections bolted together and keyed to the upright shaft. You can see the wooden pattern used to cast the sections on display inside the Centre. A wire safety cage encloses the spur wheel for the headroom on this floor is less than it originally was. The length of the cast iron columns (not original to the mill) on the meal floor below, determined where the stone floor was rebuilt.

## THE STONE NUTS AND THE QUANT



The stone nuts, the gear wheels driven by the cast iron great spur wheel, have beech wood teeth set into an iron ring. Thus this gear is very much like the brakewheel and wallower in having iron teeth driving wood. Also, the considerable difference in diameter of the two gears again results in a gearing up, the stones revolving much faster than the upright shaft. The overall ratio from the sails to the stones is 1:8.3. In practice, if the sails are turning 12 times every minute (which is a reasonably brisk milling speed) the stones will be turning at 100 times per minute.

The bottom end of the quant is fork shaped and fits into the mace that carries an iron bar, the rhynd, across the eye of the upper or runner stone. Thus as the quant is turned, the runner stone is driven around.

## THE STONE FURNITURE

Above and around the stones is the stone furniture. The grain, in the bins above, drops down the wooden chute into the hopper, the box above the millstones. Wooden sliders in the chutes can be pushed in to stop the flow of grain.

The hopper is supported by the frame known as the horse, presumably because it has four legs and large amounts of grain go through it (old miller's joke).

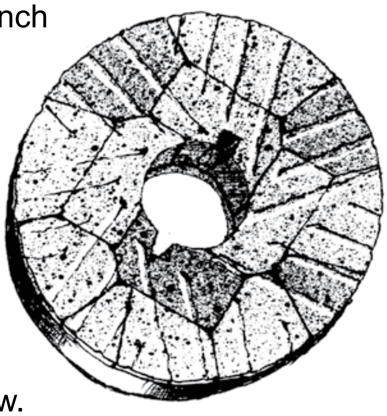
Below the hopper the shoe slopes down towards the eye of the stone. But the slope is not sufficiently steep for the grain to slide down and off the end unless it is agitated. This is done by the lower end of the quant which is square in section. As it turns, driving the millstone, the corners act as cams and strike the oak block on the end of the shoe. This joggles the grain into the eye of the stone. The end of the quant that does this is known as the damsel. The block is held against the damsel by a rope connected to a wooden leaf spring; a piece of ash that has been split along its length and bolted to the wooden tun around the stones.

The arrangement of damsel and shoe is very elegant for it allows both manual and automatic control of the flow of grain. A windmill never runs at a constant speed for the wind itself is inconstant. As the mill speeds up in the gusts, the quant turns faster and more grain is joggled off the end of the shoe. Likewise, as the mill slows, the flow of grain slows and even stops completely if the mill comes to rest. Thus the flow of grain is matched to the speed of the mill.

But the miller, working on the floor below, may decide that there is not enough grain going through, whatever the wind speed. By slackening off the rope that supports the end of the shoe, he can increase the slope of the shoe; the flow of grain increases. And likewise, if too much grain is going in and the stones are beginning to clog, tightening the rope reduces the slope of the shoe and thus the flow of grain.

### THE MILLSTONES

In the 19th century Green's Mill had three pairs of stones. Two were French 'burr' stones whilst the third pair were Derbyshire gritstone or 'greys'. This was a common arrangement with the high quality - but expensive - French stones producing fine flour for bread making and the cheaper, local Derbyshire stones used for animal feed. The mill was restored with two pairs of French stones.



The grain, driven between the upper, turning runner stone and the lower, fixed bedstone, is cut and crushed into fine flour. Emerging from around the edge of the stones it is contained by the wooden tun and then drops down a hole into a chute and into the sacks on the floor below.

## THE MEAL FLOOR

This is the floor where you will usually find the miller when the mill is at work. Here he has control over many of the parts of the mill. He can go onto the gallery to make adjustments to the sails and to get to the brake rope to stop and start the mill. As we have seen he can adjust the flow of grain into the stones by adjusting the rope supporting the the shoe. You can see it coming down from the stones above, next to the meal chute.

Flour drops into a sack strapped to the bottom of the meal chute. When the sack is full the sliding door at the lower end of the chute is closed so that the sack can be exchanged for an empty one without the flour falling onto the floor. The flour is then weighed out into sacks for bakeries on the sack scales or into smaller bags on the weighing bench.

### THE TENTERING GEAR AND THE GOVERNOR

The miller needs to be able to adjust the gap between the stones to control the fineness of the flour produced. If the flour is too coarse the upper or runner stone must be lowered slightly, bringing the stones closer together. If the stones are too close the flour may be too fine. There is also a risk of damage to the stones if they are allowed to touch and, at worst, the stones may cause sparks and set the mill on fire. The device that controls the gap between the stones is the tentering gear.

Above the meal floor you can see the two bedstones, supported by two huge oak beams and the cast iron columns beneath them. Beneath each pair of stones is a solid cast iron beam, the bridge tree. This supports the stone spindle that passes up through the bedstone, supporting the runner stone and turning with it.

One end of the bridge tree is hinged and the other may be raised or lowered by the tentering screw, the T-shaped handle of which comes down to within the miller's reach. By turning the handle the bridge tree and spindle - and hence the runner stone - may be raised or lowered.

The flow of grain into the stones varies with the speed of the mill; as it runs faster, so more grain passes through the stones. This tends to force the stones a little further apart, making the flour coarser. If no other means was available on gusty days the miller would be continually adjusting the gap, feeling the flour between finger and thumb to assess its fineness and turning the tentering screw accordingly.

In the late 18th century the governor was first used to control the tentering automatically. This is the device with the two heavy iron balls between the two bridge trees. The governor is turned by a gear wheel on the very bottom of the upright shaft; hence its speed is determined by the speed of the mill. It is connected to one end of the steelyard that is a lever with the pivot near the tentering screw.

As the mill speeds up the balls fly outwards and upwards, lifting the ends of the two steelyards (one for each pair of stones). As this end of the steelyard rises, the further end lowers the bridge tree, just as the tentering screw does. Once again the runner stone is brought down, closing the gap and bringing the flour back to the required fineness. Conversely, when the mill slows down the runner stone rises to prevent the grain being ground too fine or the stones touching. When the steelyard is correctly adjusted the mill will produce a constant fineness of flour, regardless of the speed of the stones.

## THE SAILS

There are two doors from the meal floor onto the gallery so that the miller can adjust the sails and operate the brake from the gallery around the outside of the mill. It would be dangerous to step out onto the gallery where the turning sails come past at head height; with two doors there is always a safe door away from the sails.

Unlike in a watermill, the miller in a windmill has no control over the power source. For the mill to work as often as is possible it must be able to catch enough energy from the lighter breezes to be able to turn the stones. It must also be able to regulate its speed as the wind speed changes in the gusts so that it runs neither too slow nor too fast. The mill needs to be able to keep working in strong winds and if the wind becomes too strong the miller must be able to stop the mill for fear it may run too fast and risk destruction.

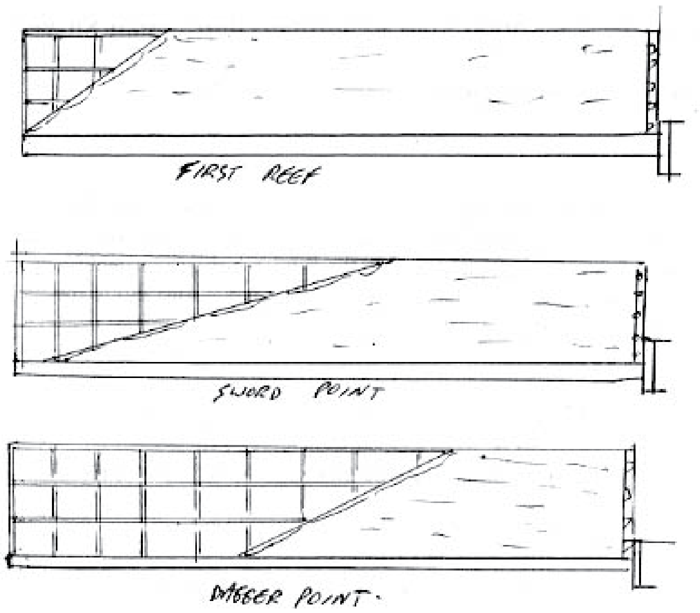
In other words, the mill must be able to work at an efficient and safe speed over the widest possible range of wind speeds. Various types of sails and regulating devices have been devised to do this, some of which you can see on Green's Mill. The mill has two sorts of sails; one pair of common sails with canvas cloths, the other pair spring sails with shutters. This is the arrangement that it had in the 19th century.

## THE STOCKS

The sails themselves are the wooden frameworks bearing the canvas or the shutters. They are bolted to the two stocks, two huge timbers passing through the poll end or canister of the windshaft where it emerges from the front of the cap. Each stock is held in the canister by wooden wedges and by two stock clamps bolted to the stocks and clasping the canister.

## COMMON SAILS

These are the oldest type of windmill sail; canvas is spread upon the wooden framework to catch the wind. When the mill is not at work or if the wind is sufficiently strong for the mill to work with only the spring sails, the canvas is furled up tightly along the front edge of the sail.




To set the sails ready for milling the brake in the cap is released by pulling on the brake rope that hangs down from the back of the cap. The sails may then be turned by pulling on the end of a sail with a hooked sail pole, bringing the end of the sail within reach of the gallery. The canvas cloth is untied and unfurled. It is then spread over the sail by means of ropes, the pointing lines, attached to its edges. Metal rings fixed to the top end of the cloth run on an iron bar, allowing it to be pulled across like a curtain on a rail.

In stronger winds only part of the sail need be covered with canvas thus reducing the area of the sail. The pointing lines are used to tie off the cloths so that three-quarters, a half or just a quarter of the sail catches the wind.

## THE SPRING SAILS

Whilst the common sails are very powerful and gain a lot of energy from the wind they do have a disadvantage. If the strength of the wind increases and the miller finds that the mill is beginning to run too fast he has to reduce the amount of canvas set. But to do this he has to stop the mill using the friction brake in the cap. Should the wind increase very rapidly the mill might begin to turn so rapidly that the brake cannot stop it. Out of control, machinery might become damaged and at worst the sails may disintegrate, destroying much of the mill as they do so.

Thus a means of self-regulation is required to reduce sail area as the wind strengthens and in 1772 the spring sail was invented. The canvas shutters on each sail are linked together rather like a venetian blind. When the mill is not at work all the shutters are open and the wind blows through them. To set the sail the shutters are held closed by a large spring - hence their name. When the pressure of the wind becomes strong enough the shutters are forced open, the wind blows through them and the mill loses power. When the wind drops the spring closes the shutters and the mill maintains speed. If the mill runs too fast in the gusts then the miller can reduce the tension on the spring and the shutters will open sooner.

Whilst the spring sails do give a measure of regulation they are not ideal. Firstly, they are not as powerful as the common sails. The shutters do allow some of the wind to pass through them even when they are closed. Hence Green's mill has the compromise of the power of the common sails and the regulation of the mill speed that the spring sails give. Secondly, to adjust the spring the miller still has to stop the mill and so there is still a risk of the mill running away in very high winds.

Around the time that Green's Mill was built the Patent sail was invented to overcome these problems. In this type of sail the tension on the shutters is provided by weights hanging down the back of the tower and connected to them by a complicated system of levers. The weights and hence the tension on the shutters can be adjusted whilst the mill is still turning. Green's Mill never had Patent sails but you can see a splendid example at North Leverton windmill in the north of Nottinghamshire.

## THE MILLSTONES

Green's Mill had the common arrangement of two pairs of French burr stones and one pair of Derbyshire greys. Before they can be used for milling, the working faces must be dressed or cut into grooves or furrows with the flat lands between them. You can see these on the spare French and Derbyshire stones.

## FRENCH 'BURR' STONES

These stones are excellent for milling fine flour as they are very hard, enabling them to be dressed very accurately and to keep a sharp cutting edge on the furrows. They are made from a very hard quartz once quarried near Paris, France. The cost of transporting them made them quite expensive.

This stone cannot usually be obtained in pieces large enough for a millstone to be made in one piece. Instead, sections are fitted together and bound with iron bands. Rather like fitting the tyre to a cartwheel, the bands were first expanded by heating them, slipped around the stone and allowed to cool, shrinking to a very tight fit as they did so.

The millstones wear with use and have to be re-dressed occasionally during a lifetime of many years and thousands of tonnes of milling. When this happens the iron bands have to be knocked down to expose more of the stone. Eventually the first band can be knocked down no further and it is removed and the stone can then wear down to the second band.

As well as allowing for wear, the thickness of a millstone is there to give weight to the upper or runner stone to allow it to bear down on the grain as it is milled. Eventually the runner will become too thin and it can then be turned over and used as a bedstone until it is too thin to be used at all. If the French stones were solid quartz, expensive stone would be thrown out. To avoid this they are made of two layers; the working side of quartz and a backing of plaster or cement. Thus the quartz may be worn down to perhaps only an inch or so thick yet the cement will give the stone strength and weight.

## DERBYSHIRE STONES

Unlike the French stones these are each made from a single piece of stone. They are made of Millstone grit, a kind of coarse sandstone, quarried in the Peak District (Derbyshire, Nottinghamshire, Staffordshire and South Yorkshire). About 2,000 millstones, in various stages of completion, are still scattered about there, evidence perhaps of the rapid decline of milling by stone once roller mills were introduced.

Although the individual grains of sand in the gritstone are hard they are not strongly bonded together and the stone wears rapidly, losing the sharp cutting edge to the furrows and making them unsuitable for milling fine flour. However, they are adequate for the crushing or coarse milling of animal feed such as barley, oats or peas: certainly the pigs have never complained.

## THE ACTION OF THE MILLSTONES

The first hand mills were just two blocks of stone; one large and flat and the other shaped to fit the hand. Grain, placed on the lower stone, was crushed as the upper stone was pushed back and forth over it. This was hard work and inefficient as the grains kept falling over the edge before they could be ground into fine flour.

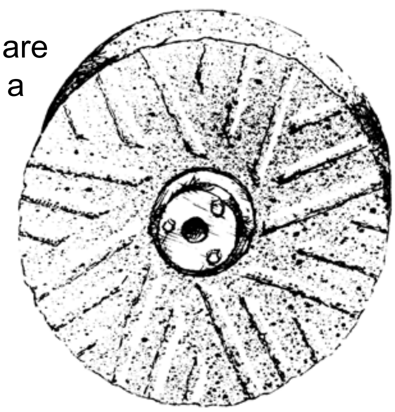
An improved kind of hand mill had the bottom stone shaped into a slope and hollowed out a little. This stopped the grain falling off the edges and helped to collect the flour. Although this made the milling a little more efficient it was still hard work.

A tremendous improvement in hand milling was made in Roman times: instead of the push-pull action of the saddle stone, two circular stones were used where the top one, of some weight, was turned around by a wooden handle. In this rotary grindstone - or ‘quern’ - the top of the upper stone was hollowed out to make a kind of hopper to hold the grain. The grain passed through a hole in the bottom of the ’hopper’ and had to pass outwards between the two stones. Thus it was ground into flour that would no longer have whole or only partly milled grains in it.

This is exactly the process at work in the windmill although with some refinements; the hopper is now a box above the runner stone, the flow of grain is controlled by the arrangement of the shoe and the damsel rather than by the size of the hole or ’eye’ of the stone, the gap between the stones is more easily regulated to adjust the fineness of the flour and the working surfaces of the millstones have furrows to provide more efficient grinding of the grain. And, of course, the power source is no longer the miller.

## FURROWS AND LANDS

The furrows do not radiate outwards from the centre of the millstone. Rather, they are more or less at a tangent to the eye of the stone. They are arranged in groups known as harps or quarters, each of that consists of a master furrow that runs from the eye of the stone to the outer edge and a variable number, perhaps three or four or five, secondary furrows.



The sharp leading edges of the lands, passing over the corresponding edges in the other stone, act rather like the blades in a pair of scissors, shearing or cutting the grains into fragments. The flat surfaces of the lands, roughened with small parallel grooves called stitching, then pass across each other, grinding the fragments into still finer flour.

The angle of the furrows is such that as they sweep across each other the grain and flour is forced outwards towards the edge of the stones.

### DRESSING THE STONES

The runner stone must be lifted and turned over, exposing the working surface of each stone. The stone spindle is screwed up to enlarge the gap between the stones so that wooden wedges may be driven between the two stones. When the gap is large enough a sling can be passed under the runner and through the eye to allow the stone to be hoisted up with a block and tackle slung from a large eye-bolt in the beam above. The stone may then be turned over as it is lowered to the floor.

The first task when dressing a millstone, either for the first time or to sharpen a worn stone, is to ensure that the surface is absolutely flat. This is done using the staff, a thick wooden bar one side of that is planed flat. A mixture of iron oxide and water or some similar thick coloured paste is spread upon the the flat face of the staff and this is then laid upon the surface of the stone and rotated over it. Any high spots will be shown up by the paste. They can then be chipped away with the mill bill. This tool is rather like a small pick-axe with a hardened steel held in a wooden handle called a helve or thrift.

Before it can be used to check the stones the staff itself has to be checked to ensure that it is itself flat and undistorted. It is laid on the proof, a cast steel bar that has one face machined flat to provide an absolute standard of 'flatness'. Again a layer of paste will show up any high spots or distortions in the staff that may then be planed off. The proof and staff are kept in a wooden case in the mill when not in use.

Having reduced any high spots on the stones the miller can then ensure that the furrows are sufficiently deep and that the cutting edges are sharp. Small parallel grooves, about sixteen to the inch, are then chipped into the lands, a process known as stitching or cracking.

The mill bills were of necessity very hard to be able to cut the French stones and small pieces often flew off and embedded themselves in the backs of the miller's hands. Itinerant stone dressers could indicate their experience by holding out their hands and 'showing their metal'. Modern mill bills are tipped with tungsten carbide so that nowadays this rarely happens.

## AT THE END OF THE DAY

When the day's milling is done, the miller disengages the stone nuts from the great spur wheel. He can then turn the sails to bring each one in turn down to the gallery. The shutters on the spring sails are opened to allow the wind to blow through. The canvas on the common sails is tightly rolled up and tied off along the length of the sail. The sails are then turned a little further until they are in the diagonal position, like a StAndrew's cross, and the brake applied. In this position the strain on the sails is equalised and the rain tends to run off the ends of the sails and fall clear of the gallery.

Inside the cap two huge timbers are pushed through the brake wheel and wedged in place to ensure that the sails cannot turn, even in the highest wind. The brake rope is pulled up into the cap out of the weather and coiled around two cleats.

After tidying up the miller sweeps up any spilt grain or flour to discourage vermin. Then, with a glance to ensure that the fantail is working and the sails are facing into the wind, his day's work is done.

## MILLING TERMS IN A TOWER WINDMILL

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|---|---|
| Back stays | wooden strengthening struts at the back of the sails. |
| Bay | space between two sail bars, with shutters in. |
| Bed stone | the lower, fixed millstone of a pair. |
| Bell alarm | device to alert the miller when the supply of grain runs low. |
| Bill | hardened steel chisel used to dress the millstones. |
| Bin | wooden container for storing grain. |
| Bin floor | floor of the mill with grain bins. |
| Brake | steel friction band around brake wheel to stop the mill. |
| Brake lever | cast iron lever that raises or lowers brake band. |
| Brake rope | rope to raise or lower brake lever and so control the brake. |
| Brake wheel | large gear wheel in cap, engages with wallower. |
| Bridge tree | hinged beam that supports stone spindle. |
| Burr stone | see French stones. |
| Canister | see Poll end. |
| Cap | wooden dome that turns upon top of tower according to the direction of the wind. |
| Cap circle | wooden frame around base of cap to support ribs. |
| Cap frame | horizontal frame that rests on the curb on top of the tower and supports the cap and sails. |
| Centre beam | see Spindle beam. |
| Centring wheels | see Guide sheaves. |
| Cloths | canvas cloths that are spread on common sails. |
| Cock head | top of the stone spindle, supports the runner stone. |
| Common sails | sails having canvas cloths to catch the wind. |
| Cracking | see Stitching |
| Curb | cast iron ring on top of tower, supports the cap frame. |
| Dagger point | third reef in sail cloth with about one quarter of the sail spread. |
| Damsel | square section of rotating quant that joggles the shoe. |
| Derbyshire stones | gritstone millstones, used for grinding animal feed. Also known as Greys or Peak stones. |
| Dressing | a) recutting the lands and furrows on a millstone, |
| | b) separating fine flour from coarser particles and bran. |
| Dust floor | floor of the mill just below the cap, with brake wheel, windshaft, etc. |
| Eye | hole in centre of runner stone into which the grain falls. |
| Fantail | wind driven device on back of cap to turn sails into the wind. |

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| First reef | first reduction in area of cloth on a common sail, with about three quarters of cloth spread. |
| French stones | hard quartz millstones for producing fine flour. Also known as Burr stones. |
| Full sail | all cloth unfurled on common sail (see First reef, Sword point, Dagger point). |
| Furrows | grooves cut into the working face of a millstone. |
| Gallery | wooden walkway around tower to give access to sails. Also known as the reefing stage. |
| Glutbox | bearing on top of quant that allows stone nut to be taken out of gear. |
| Governor | device for automatically regulating the gap between millstones according to speed of the mill. |
| Great spur wheel | gear wheel on bottom of upright shaft, engages with stone nuts. |
| Grey stones | see Derbyshire stones. |
| Grist | grain or mixture of grains ready for milling. |
| Guide sheaves | wheels on underside of cap frame to keep cap located centrally on curb of the tower. |
| Helve | see Thrift. |
| Hemlath | long wooden bar, the trailing edge of a sail. |
| Horse | wooden frame above millstones, supporting hopper and shoe. |
| Lands | flat areas of millstones between furrows where fine grinding of flour takes place. |
| Mace | bar between lower end of quant and the stone spindle - drives the runner stone. |
| Meal chute | wooden or canvas chute down which meal - or flour - falls into sacks. |
| Neck bearing | journal bearing on front end of windshaft. |
| Overdriven | millstones driven round by a quant above the stones. |
| Patent sail | self-regulating sail with system of weights and levers to adjust the shutters. |
| Peak stones | see Derbyshire stones. |
| Pointing lines | ropes to adjust amount of cloth set on a common sail. |
| Poll end | cast iron box on end of windshaft through which sail stocks pass. |
| Proof | cast steel bar, used to check flatness of staff. |
| Quant | cast iron shaft, with stone nut on its upper end, that turns the runner stone. |
| Runner stone | upper, turning millstone of a pair. |
| Sack hoist | device for lifting sacks of grain up the mill on a chain. |
| Sail bar | wooden bars running across the width of the sail. |
| Shades | see Shutters. |

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| Sheaves | see Guide sheaves. |
| Sheers | side timbers of cap frame, running from front of cap to the rear and forming the fantail platform. |
| Shoe | sloping trough that receives grain from the hopper and drops it into the eye of the runner stone. |
| Shutters | painted canvas boards in the spring sails that may be opened or closed to catch the wind. Also known as shades. |
| Spindle beam | centre cross beam of cap frame, carries bearing for top of upright shaft. |
| Spring sails | self-regulating sails with a spring to control and adjust the shutters. |
| Staff | wooden bar used to check flatness of millstones. |
| Steelyard | lever connecting governor to bridge tree. |
| Stitching | small grooves cut in the lands of a millstone. |
| Stocks | large timbers passing through the poll end to which sails are bolted. |
| Stock clamps | strengthening timbers clasping stocks to poll end. |
| Stone floor | floor of mill with millstones. |
| Stone nut | gear wheel on top of quant, driven by great spur wheel. |
| Stone spindle | shaft on top of which runner stone revolves. |
| Sword point | second reef in common sail, about half the sail cloth spread. |
| Tail beam | horizontal member at rear of cap frame, carries thrust bearing for end of windshaft. |
| Tail bearing | thrust bearing for end of windshaft. |
| Tail-winded | with the wind blowing onto the back of the sails. |
| Tentering gear | mechanism for adjusting and regulating gap between millstones. |
| Thrift | wooden handle for mill bill. Also known as Helve. |
| Tun | wooden casing around millstones to contain flour as it emerges from millstones. Also known as Vat. |
| Underdriven | with millstones driven round from underneath. |
| Vat | see Tun. |
| Wallower | gear wheel at top of upright shaft, driven by brake wheel. |
| Weather | twist along length of a sail, rather like a propellor. |
| Weather beam | front member of cap frame, carries neck bearing for windshaft. |
| Whip | principal longitudinal timber of a sail. |
| Windshaft | cast iron axle carrying sails and the brake wheel. |