THE MIDLAND WIND AND WATER MILLS GROUP

This Journal is published by the Midland Wind and Water Mills Group, which is concerned with the study of the history and technology of mills and, in principle, with their preservation and restoration. Its area is the region loosely defined as the Midlands, especially the central counties of Staffordshire, Shropshire, Worcestershire, and Warwickshire.

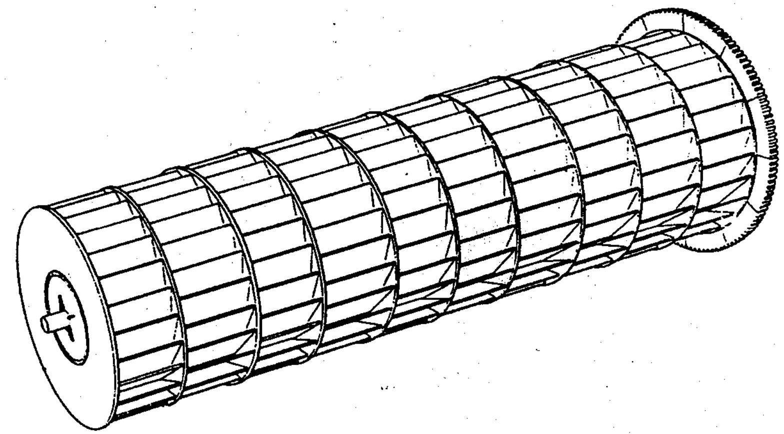
The group holds monthly meetings, with talks and discussions, during the winter, and arranges mill tours and open days during the spring and summer. Members periodically receive a Newsletter and the Journal.

For further particulars, please contact:

Mrs. M.Tucker,
26, Twatling Road,
Barnt Green,
Birmingham, B45 8HT

Wind and Water Mills

Number 13



The Midland Wind and Water Mills Group

Wind and Water Mills is the journal of the Midland Wind and Water Mills Group and is therefore naturally concerned with the mills of the Midlands, but it is not intended to be narrowly parochial. Interesting and important articles relating to mill matters in other parts of Britain and the world will be included whenever available. In general, articles by members will have priority for publication, but submissions by non-members will be willingly included.

Cover illustration. The wooden waterwheel in the West Mill at Belper in 1811 as described in *Rees's Cyclopaedia*, drawn by Mr P.Proudlove for *Wind and Water Mills*. (See pages 2 to 13)

ISSN 0260-504X

Publisher: The Midland Wind and Water Mills Group.

Editor: Mr.A.Bonson,
14, Falmouth Road,
Congleton,
Cheshire.
CW12 3BH.

Wind and Water Mills

The Occasional Journal of the Midland Wind and Water Mills Group

Number 13

1994

Contents

The Water Works at Strutt's Mills at Belper and the First Suspension Waterwheel.

by Alan Gifford.

In the 1790s Jedediah Strutt, who had been in partnership with Richard Arkwright until 1781, was extending his cotton manufactory business which was situated at Derby, Milford, and especially at Belper on the River Derwent. The works at Belper were the centre of this commercial enterprise, where the building of a new mill, called West Mill, started in about 1792. In spite of the death of Jedediah Strutt in 1795 the business continued to expand under his son William, eventually having six mills with eleven waterwheels at Belper.

Apart from the size of the business, the Belper cotton mills were important for the role they played in the development of 'fire-proof' mill construction, and because the West Mill was the site of the first suspension waterwheel. Fortunately details of the complex water works and the suspension waterwheel were recorded for posterity in *Rees's Cyclopaedia,* published in 1811, under the entry for 'Water'. After minor editing to render the text easier to understand by today's reader this description is as follows:-

> 'The cotton works of Messrs. Strutt at Belper, Derbyshire, are on a large scale and the most complete we have ever seen, with extensive dams and waterworks (see Figure 1). The mills are turned by the water of the river Derwent, which is very subject to flooding. The great weir is semicircular, built in very substantial masonary, and has a large pool of water immediately below it, in to which all the water falls.
>
> On one side of the weir are three sluices, each 20 feet wide, which are opened up in floods and allow the water to flow sideways into the large lower pool. On the opposite side of the weir is another such sluice some 32 feet wide. The water is held in the lower pool by the restriction caused by running through the arches of the river bridge. The main fall of water is broken up by dropping into the water of the pool, beneath the great semicircular weir.
>
> The water is drawn off from the mill dam above the weir and passes through three sluices, each 20 feet wide, and is then distributed by different channels to the mills, which are situated at the side of the river, and quite secure from all floods. There are six large water wheels; one of which is 40 feet in width and which is specially mentioned because of the ingenuity of its construction and another, built in iron and made in two 15 feet wide sections, is also described. All are

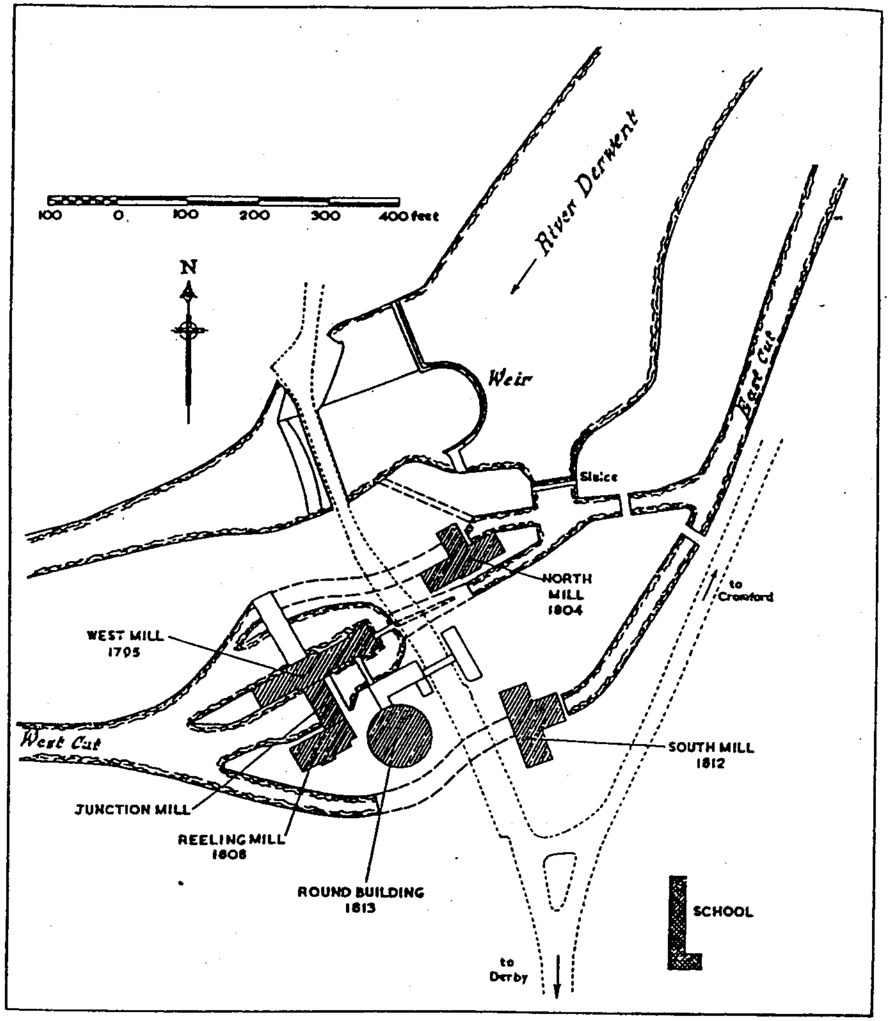


Figure 1. Plan of Strutt's Cotton Mills at Belper.

breast wheels, with the iron works made by Messrs Walker of Rotherham, in Yorkshire, and represent very good specimens of water works.

A part section of one of the wheels is shown in Figure 2. The wheel is very wide and to support the shuttles (or sluice gates), A and B, a strong grating of cast iron is fixed on top of the breast and the gates are fitted at the back of the grating E, so they can slide up and down against it, the loading caused by the water being carried by the grating. The lower gate is moved by means of long screws, a, which have bevelled wheels, b, at the upper end to turn them, through a connection to controls inside the mill building. The upper gate, B, is drawn up and down by racks and pinions, c, which are turned by a winch, or handle. The bars of the grating, E, are placed one above the other, like shelves, but they are not horizontal; they are inclined such that the upper surfaces of all the bars form tangents to an imaginary circle one third the diameter of the water wheel. These bars are not more than half an inch thick and the spaces between them are about 2.5 inches. The bars are of considerable breadth, the object of them being to lead the water, with a proper slope, from the lower shuttle, A, so as to flow directly onto the floats of the water wheel in a controlled manner.

This arrangement allows the gate to be placed at such a distance from the wheel which allows upright bars of cast iron to be placed between the wheel and the gates, against which the gates bear, and which prevents them from bending towards the wheel, which the great weight of water involved would otherwise cause to happen. These upright bars are very firmly fixed in the stone works of the breast at their lower ends, and the upper ends are fastened to a large transverse timber, D, which is supported at its ends in the side walls. This has a truss framing built on the inlet side, like the framing of a roof, to prevent it from bending in towards the wheel. The upright bars are 5 feet apart and support the gates in two places in the middle of their length, as well as at both ends. Large rollers are fitted to the gates where it bears against these bars, to reduce friction, which would otherwise be very high.

The upper gate is 2.5 feet high and 15 feet long with the lower gate 5 feet high and the same length, so that it exposes 75 square feet of surface to the pressure of the water. Taking the centre of pressure as being at two thirds of the depth, or three and a third feet, we find the pressure equal to that depth of water is acting on the whole surface, that is the

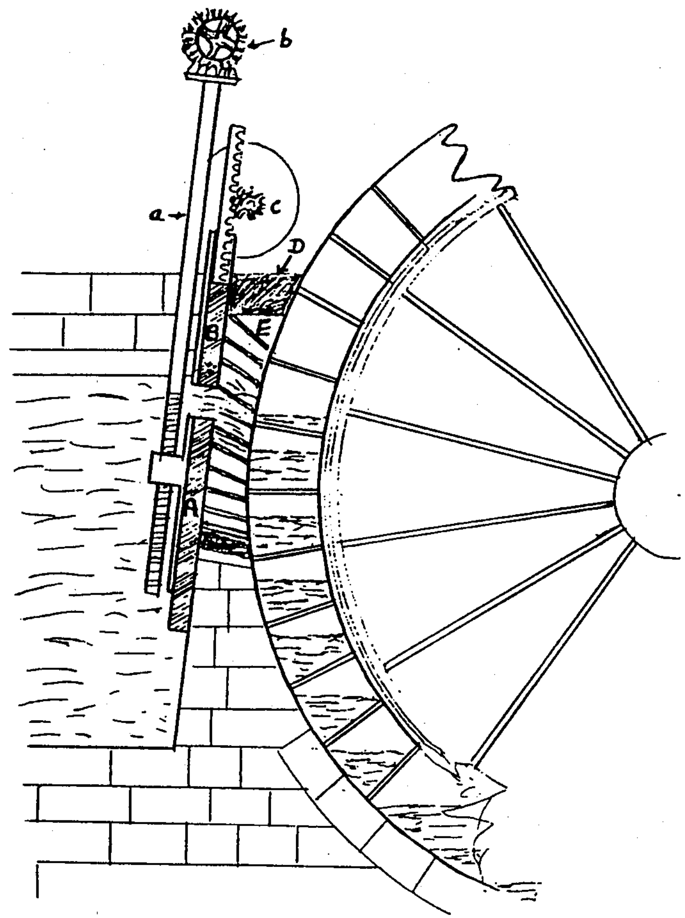


Figure 2. The Sluice Gate for the Iron Waterwheel, West Mill, Belper.

weight of three and a third cubic feet of water, or 208 lbs, bears on each square foot of surface, a total of 15,600 lbs - nearly seven tons, on the lower gate alone! But when taking the two sluice gates together the surface involved is 122 square feet with a mean pressure of 312 lbs upon each square foot, or 16 tons on the whole structure!

These careful arrangements appear to be essential when the size of the water works are considered. The wheel is 21.5 feet in diameter and 15 feet wide and the fall of water is 14 feet when it is at mean height. The wheel has 40 float boards, each pointing to the centre, and is made of cast iron. There are two wheels each of the size noted, which are arranged in line with each other and they are only separated by a wall which supports the central bearings. They work together as one wheel and the separation into two is to avoid the difficulty of making one wheel of such a great width as 30 feet. This is not impossible however since there is a wheel in the same factory which is 40 feet wide, but made in wood, not iron, and constructed in a most unusual manner, described later.

These large breast wheels (see Figure 3) are worth further description. The rims of the wheels are made of cast iron and the float boards are included between the rims in the manner of an overshot wheel, but the arms are only made of small round wrought iron rods, which are very light, and which have very little strength to resist bending. Since they are all tied in from the centre, the rim cannot deviate from its truly circular form and to maintain the wheel laterally oblique bars are extended from the hubs at each end of the axle which are connected to the circular rim, in the middle of its 15 feet breadth.

It is plain that the axle in such constructions does little but to support the weight of the wheel itself, for though these arms are sufficiently strong for that purpose they have little strength as levers to transmit the forces of the circular motion from the rim of the wheel to the axle. The power is therefore transmitted in a much better way than through the axle - it is achieved by a ring of cogs screwed to the circular rim of the wheel which drives a small pinion gear which conveys the power and motion to the mill through a shaft. There is another similar ring of cogs at the other side of the wheel which drive a pinion fixed on the same shaft. By this means nearly all the strain is taken from the axle of the wheel, since the pinion is placed on the descending side of the wheel and the weight of the water acting on the float boards is thereby immediately transmitted to the pinion gears through the great strength of

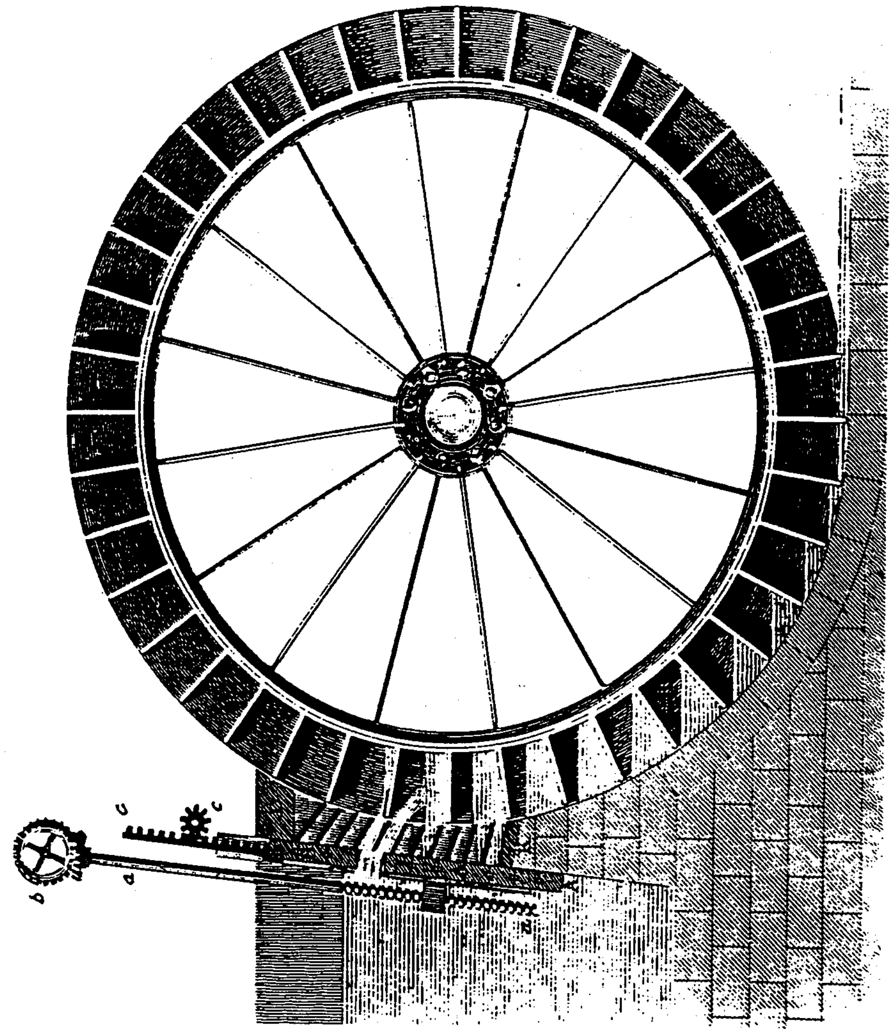


Figure 3. The Iron Suspension Waterwheel, West Mill, Belper.

the rims of the wheel.'

The invention of the suspension waterwheel is usually credited by modern commentators to T.C.Hewes, a Manchester engineer, who installed the iron waterwheel in the West Mill at Belper for Messrs.Strutt, as described above, some time just prior to 1811. However this suspension type of waterweel was not installed when the West Mill was built in 1795. Certainly in 1802 the West Mill had two wooden waterwheels which were described by Britton & Brayley as follows:-

> 'The principle (main) building of these mills is 200 feet long, 30 feet wide and six storeys high and is considered to be fire proof. The two water wheels which work the machinery in this building are remarkable as well for their magnitude, as for their singularity of construction; one being upward of forty feet long and eighteen feet in diameter: and the other forty eight feet long and twelve feet diameter. As it was impossible to obtain timber sufficiently large to form the axles or shafts of these wheels in the usual mode of structure they are made circular and hollow, of a great number of pieces and hooped like a cask: one of the shafts is between five and six feet diameter and the other between eight and nine.'

If, as suspected, these wheels transmitted power via their axles, the barrel-like construction would be a serious weakness due to the torque developed in the shafts. Obviously, by 1811 these waterwheels had been replaced, but it is somewhat strange that Hewes's wheel appeared immediately in a fully developed form (later in the Century the famous millwright William Fairbairn could only make minor improvements to the design in order to help the installation and maintenance of suspension waterwheels). However the entry in *Rees's Cyclopaedia* is concluded by describing another waterwheel in the West Mill (see Figures 4 & 5) as follows:-

> 'At Messrs Strutts works there is also a very powerful breast wheel, made with an extraordinary width of 40 feet and it deserves attention for its unusual manner of construction. The diameter is only 12.5 feet and it is made without an axle, or rather the axle is hollow and is so large that the float boards are fixed directly to it. It is made like a large cask, 48 feet long, composed of 32 staves, each of six thicknesses, which are bound together by hoops, like an ordinary cask or barrel.
>
> It is 5 feet at one end, 6 feet in diameter at the other and in the middle is some 7 feet 2 inches. The small end is made up solid for 3 feet in length and the gudgeon is fixed into this solid part. The larger end is solid for 4 feet from the end and on this a large cog wheel is fixed to transmit the power and motion to the mill machinery. This gear wheel is 14 feet in

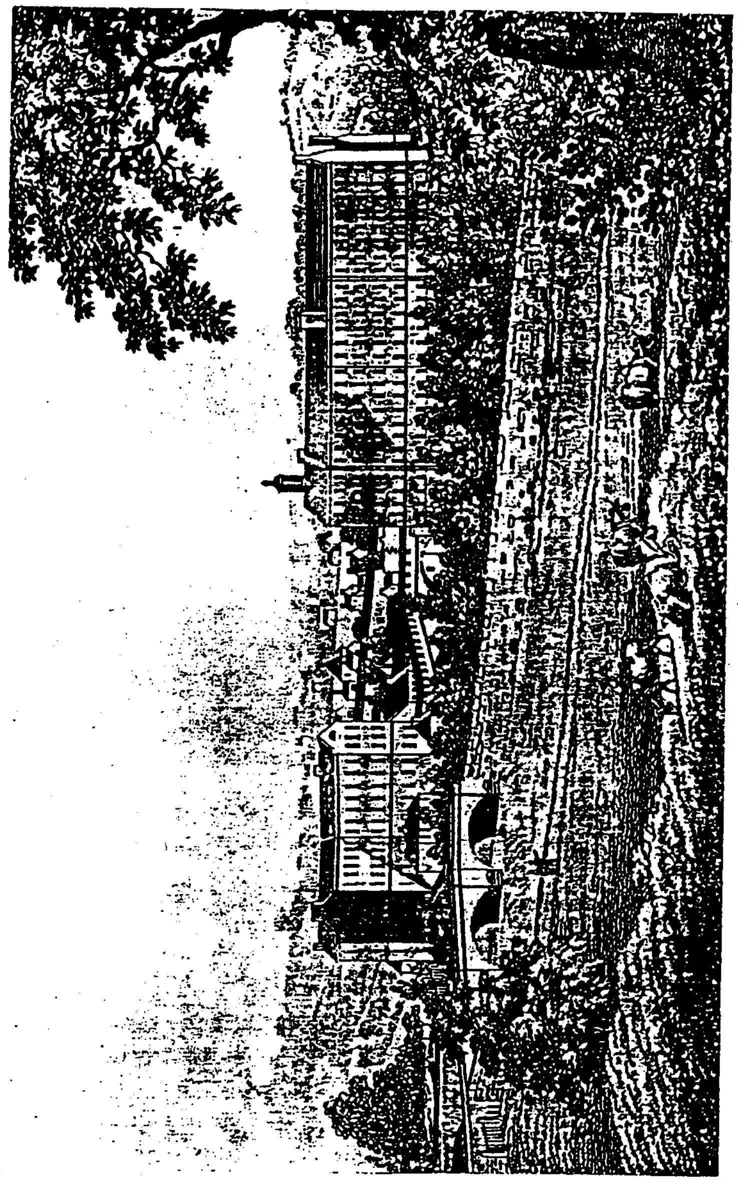


Figure 4. Belper North and West Mills. (Reproduced from *A New Historical and Descriptive View of Derbyshire*, 1811)

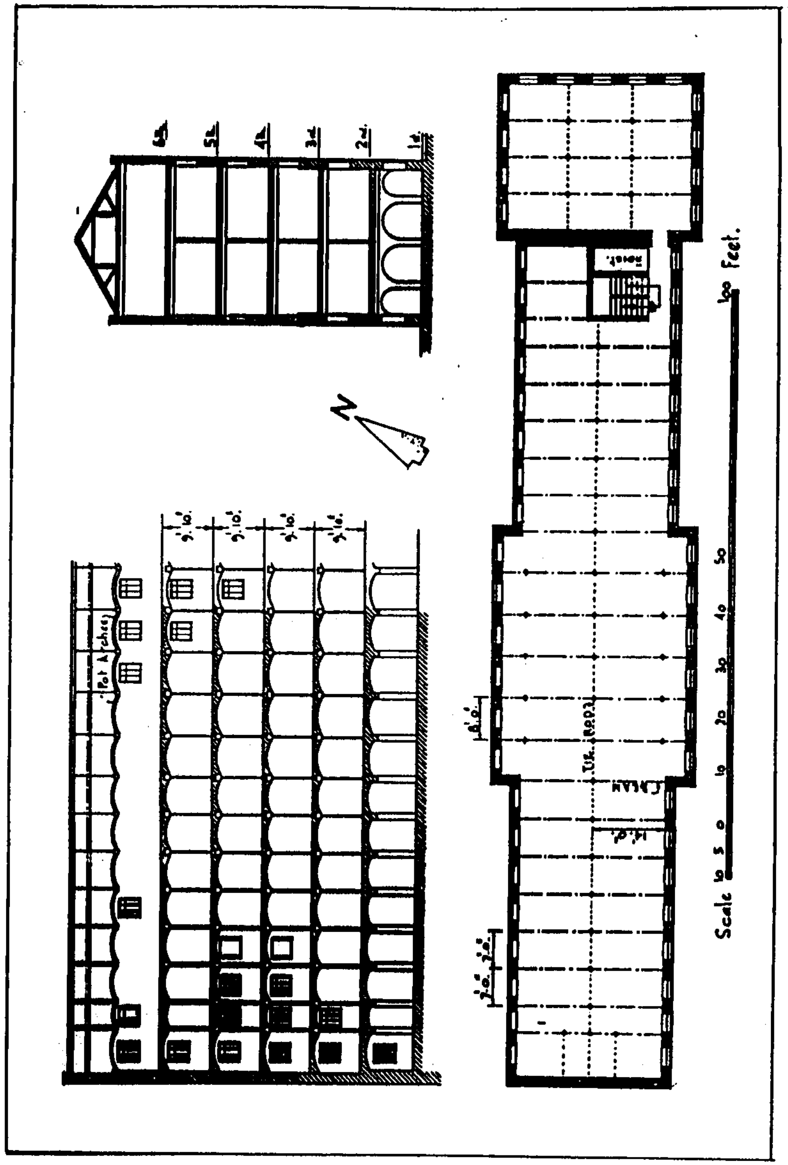


Figure 5. Belper West Mill, 1795

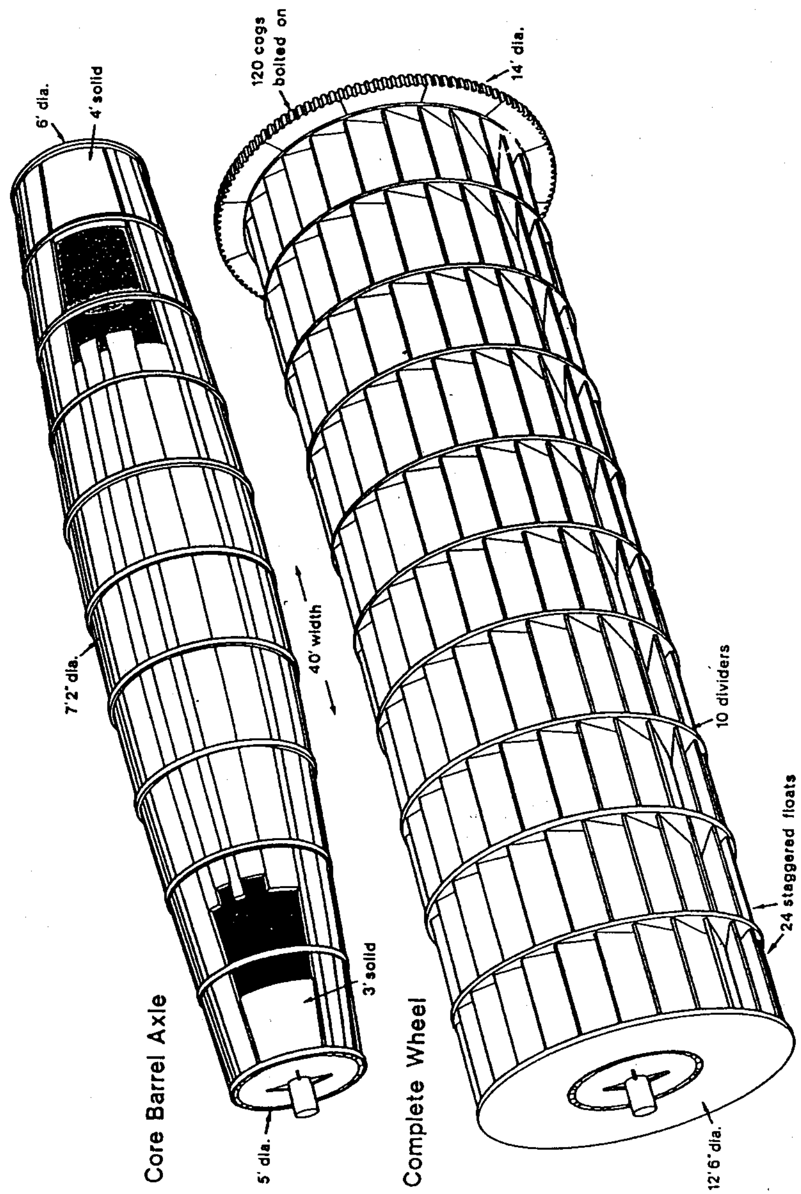


Figure 6. Strutt's Breastshot Wooden Waterwheel, West Mill, Belper. (Drawn by P.Proudlove)

diameter and has 120 cogs whilst the water wheel itself is only 12.5 feet to the outside of the floats. The floats are supported by 10 circular rings which are fixed to the outside of the axle (or cask) at four feet distance from each other, and the float boards are then fixed between these rings.

Twenty four floats are arranged in each circle, but the floats in adjacent spaces are not in line with each other because if the water were to strike upon the whole length of float board at once it would give a significant shock to the water wheel and cause the water wheel to work irregularly. As a result the floats between all the rings are placed midway to the intervals between the floats in the adjoining spaces, by which means the water acts on the floats in rapid succession, so the effect of the shock of water impact on any one float is much more limited.

The float boards clear the central barrel or axle by 2 inches in order to allow the air to escape. The float boards in the middle are 2 feet 4 inches deep and at the ends are deeper. This wheel has two shuttles, one above the other, like the breast wheel described earlier which are of the same dimensions, for the wheel is in the same mill, but is arranged to work when the tail water rises in time of flood to such height as would prevent the other wheel from working.'

This waterwheel has been overlooked due to comment concentrating on Hewes's iron wheel, which was illustrated in the *Cyclopaedia*. However the drawing (see Figure 6), which has recently been produced from Rees's description, shows that this wooden waterwheel had rim gearing and hence would have had the properties of a suspension waterwheel. The construction of the shaft with the gear end thicker and more heavily reinforced would seem to indicate that its builders still expected the shaft to have to withstand the torque generated. However it would be immediately obvious, in operation, that this was not the case. Therefore, it may be reasonable to assume that this waterwheel was an evolutionary step on the way from the original barrel shafted waterwheels to the design of Hewes's iron suspension waterwheel.

Although a cotton mill owner, William Strutt was a very respected analyst and mathematician whose work on stresses in iron beams used in mill construction is highly regarded (he later became a Fellow of the Royal Society). Certainly it was the view of William Fairbairn that the discovery of the suspension waterwheel was attributed to Strutt, but this seems to have been overlooked in later times as meaning that Strutt was merely the owner who paid for it. In the light of the above evidence it appears that Hewes was not the inventor of the suspension waterwheel but that Strutt was the first to realise the possibilities of this type of waterwheel and that Hewes was only carrying out Strutt's instructions.

Bibliography.

Britton,J. and Brayley,E.W., *The Beauties of England and Wales*, London, 1802, Vol 3.

'Water', *Rees's Cyclopaedia*, Vol 38, London, 1819.

Davies,D.P., *A New Historical and Descriptive View of Derbyshire*, Belper,1811

Glover,S., *The History & Gazetteer of the County of Derby*, Vol 2, Derby, 1833.

Fairbairn,W. *Treatise on Mills & Millwork*, London, 1863.

Johnson,H. and Skempton,A.W., 'William Strutts Cotton Mills, 1793-1812', *Journal of the Newcomen Society*, Vol 30. 1957.

Fitton,R.S. & Wadsworth,A.P., *The Strutts and the Arkwrights*, Manchester University Press, 1958.

Reynolds,T.S., *Stronger than a Hundred Men, the History of the Vertical Waterwheel*, John Hopkins University Press, 1983

Acknowledgement.

The author would like to express his thanks to Mr.P.Proudlove, a technical illustrator, for providing the visual interpretation of Rees's text describing the wooden waterwheel in the West Mill, Belper; and to Tony Bonson and Barry Job of the Midland Wind & Water Mills Group for their constructive comments in preparing this article.

Drying Kiln Clay Tiles.

By Barry Job.

One of the most important operations before milling is to dry any damp grain so that it can be milled without clogging the millstone surfaces or sieves. The moisture content of the grain must be lowered to between 12% and 18% or, in the case of oats, to such a point that the husks became brittle and could be readily split off.(1) Thus the drying kiln was a common addition to many watermills (although apparently not to windmills) and might be expected to be more numerous in wetter regions.

Some early kilns were reputedly circular in plan but the survivals are square or rectangular. They are of two storeys, the lower floor containing the furnace. Fuel depended upon what was available, but varied from oat husks and chaff to wood, coal, coke or anthracite. Heat, smoke and fumes passed up and outwards along brick formed channels to emerge through the floor of the second storey. Floor construction had to be fireproof and generally consisted of cast iron joists on which were laid clay tiles or cast iron plates. Of course these were perforated, so that grain, spread over the floor to a depth of 4 to 6 inches, could be dried. The smoke then left the kiln through the roof ventilator or, in many cases, found its way out through the roof as best it could. The grain was regularly turned whilst being dried, the miller used a large wooden shovel for this task which must have been unpleasant, if not hazardous, in the smokey environment. Once dried the grain was bagged or led off through spouts for milling.

The iron plates were said to be preferable to the clay tiles as they retained the heat better and were probably more durable but clay tiles are more varied and it is these which will be considered here. Their function determines their general form. For ease of laying they are generally square and of a reasonable size (usually 12 inches square). They must be strong enough to support the weight of the miller and the grain and are typically 2 inches thick. They must present a flat upper surface for shovelling, perforated by many holes to let the smoke through. To save weight and prevent blockage the perforations lead through to a series of larger holes coming up from below. To provide an element of self-cleaning the perforations and larger holes should be tapered, becoming wider downwards.

It might therefore be assumed that all kiln tiles would conform to a standard design. In general they do, but only a small number of tiles were required at any mill. The kiln at Coton Mill, for example, is ten feet by eleven feet and therefore required 110 tiles. This generally precluded them from being made by a major manufacturer (indeed I have never noticed a manufacturer's mark on a tile although I understand that they do exist). Thus they would usually have been made locally as the construction or refurbishment of a kiln dictated. After the

one-off production run the tile mould would no doubt have been thrown away so that any batch of tiles will exhibit detail differences to those from another production run.

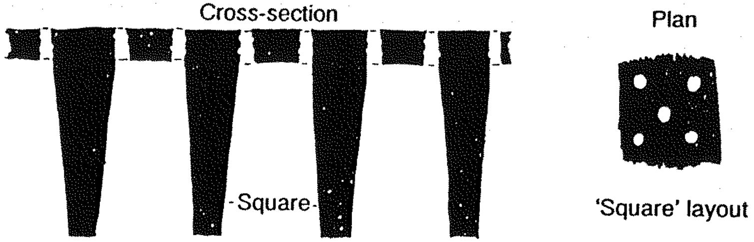
We might presume that the typical mould consisted of a square wooden box with wooden blocks fixed in to produce the large holes. As mentioned earlier these should be tapered, which would also assist the release of the clay from the mould, these might have been easier to make if they were square in plan. The layout of the blocks within the mould box could be either with their edges parallel to the box edges ('square layout') or parallel to the box diagonals ('diamond layout'). It might be assumed that the former is the easiest to construct. The perforated holes should be reasonably large in size and number and could be produced in the mould by fixing metal spikes (again preferably tapered) into the ends of the blocks. But this would make it difficult to form the flat upper surface of the tile; usually achieved by drawing a wire or board across the top of the mould box. Therefore the perforated holes should preferably be put in later with a pronged device. Again if they are to be tapered upwards they must be put in from the underside. Thus the process would initially be similar to the hand production of bricks; a very soft clay body would be thrown and pressed into the prepared mould box, the top cut clean by sriking across the box top. The clay would be released from the mould, allowed to dry a little before the perforations were made from below, the top surface cleaned up and the tile was then fired.

A careful examination of any tile will indicate its method of production. For example if the perforated holes were made in the mould box they will possess a distinctive shape with a clean lead in, and they will exhibit a regular relationship to the large holes. If made later they will show clay distortion, which will also show if they were made from above or below, and some misalignment of the perforations with respect to the large holes might be expected.

Obviously the tile maker must make a number of decisions; the outer dimensions of the tile, the size and shape of the large holes, their layout, the number of perforations, and their size and shape. With all of these variables we might expect that detailed differences will exist. We will now go on to consider a random selection of seven different tiles which were to be found at only three mills; Coton Mill (SJ 977314) in Staffordshire, Lowcross Mill (SK 470504) in Cheshire, and Stainsby Mill (SK 456653) in Derbyshire to see if they conform to any standard pattern.

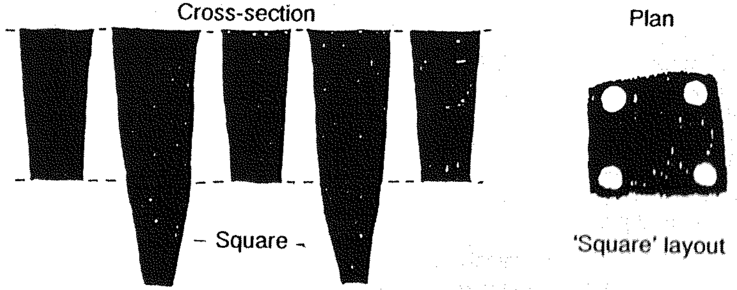
Commencing with Stainsby Mill (see Figure 1) we find a thin edged tile of some 6.5 inches by 7.5 inches, its small size allows a thin top surface with the perforations made in the mould. It is easily the most finely made of the seven tiles and during firing it has been salt glazed to render it less permeable. Interestingly the kiln at Stainsby has been rebuilt at some period with the clay tiles replaced by much larger cast iron plates thus requiring a much larger joist spacing.

Stainsby Mill.



Salt glazed, with a very thin edge, finely made tile.

Lowcross Mill 'A'.



Variable dimensions, crudely made tile.

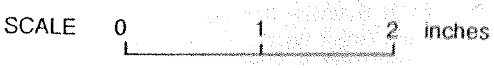


Figure 1. Clay Kiln Tiles, cross-section and plan.

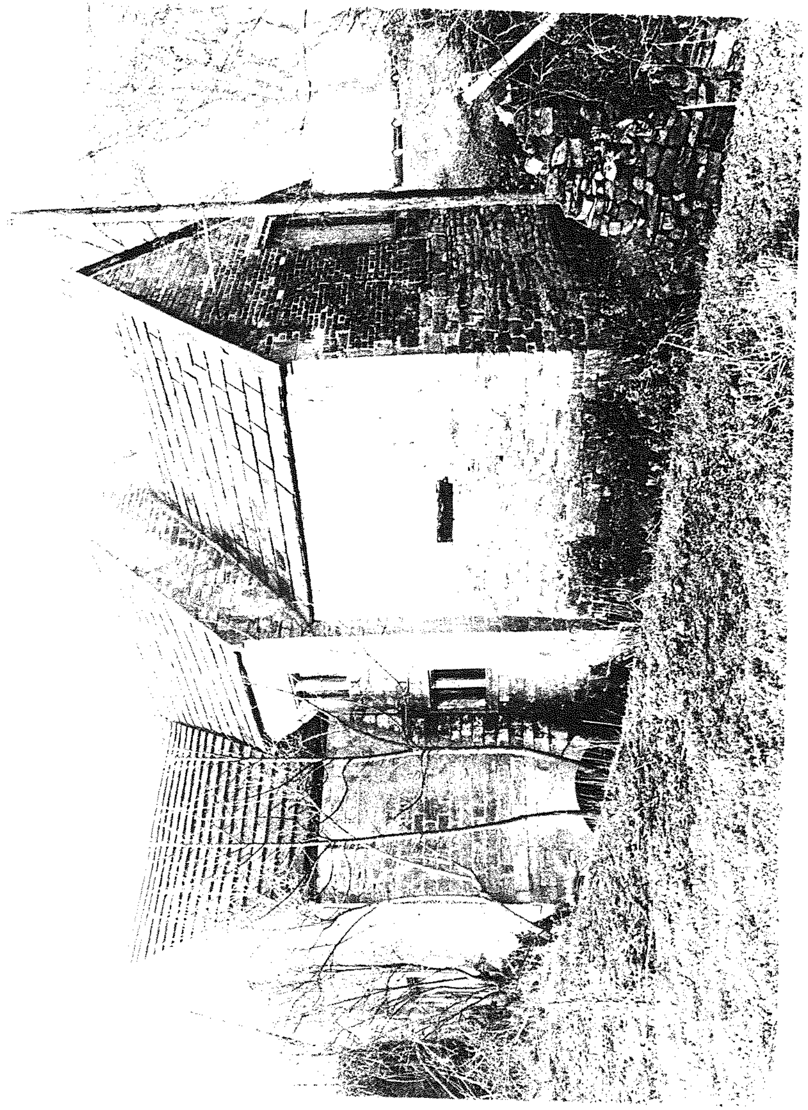


Plate 1. Stainsby or Hardwick Mill, 1991.

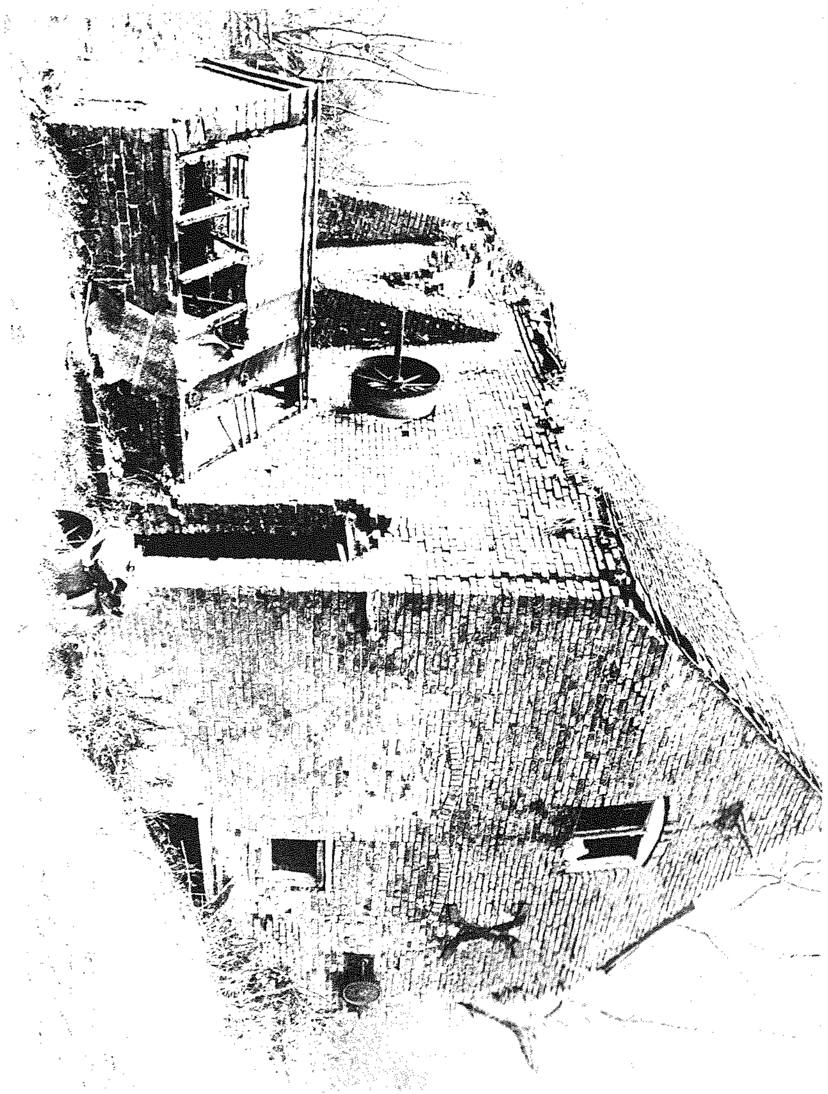
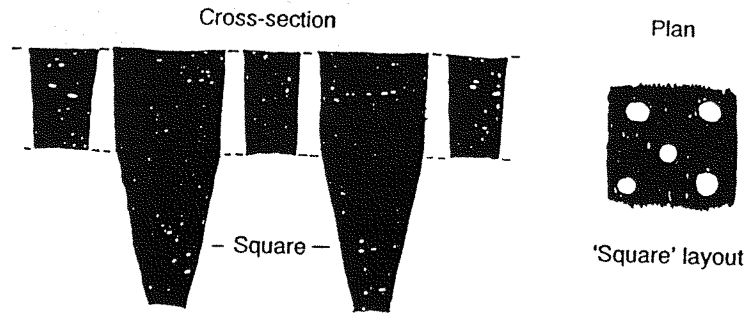


Plate 2. Coton Mill, 1986.

Lowcross Mill 'B'.



Lowcross Mill 'C'.

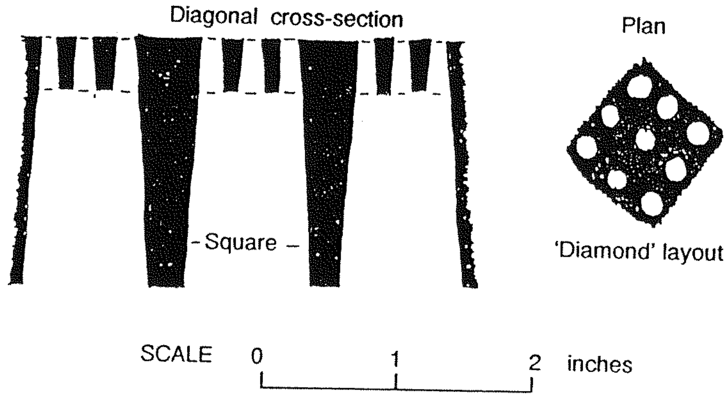


Figure 2. Clay Kiln Tiles, cross-section and plan.

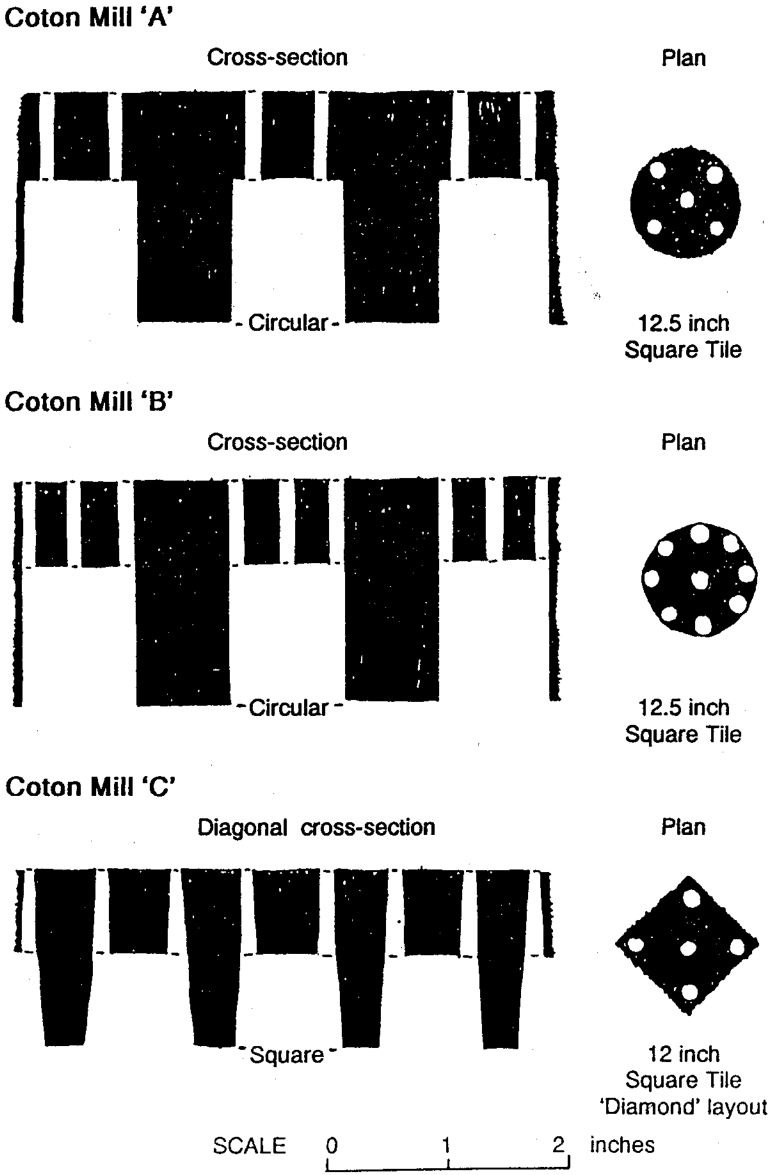


Figure 3. Clay Kiln Tiles, cross-section and plan.

At Lowcross at least three different tiles (see Figures 1 & 2) could be found suggesting a number of refurbishments of the kiln (how often was this necesssary?). The 'A' tile has slightly variable dimension and is quite crudely made. The thick upper surface is compensated by the pronounced taper on the perforations. Numbering only four per set these were made from below. The 'B' tile is also a substantial tile but now with a pronounced taper on the large holes, the perforations now appear to have been made in the mould. By contrast the 'C' tile is more finely made, it has a diamond layout, the upper surface is thin and the perforations, again probably made in the mould, now number nine per set.

Coton Mill (see Figure 3) similarly possessed at least three different tiles. The 'A' tile has variable dimensions and has circular non-tapering large holes with very smooth sides. Could these have been individually bored out? This would have been very laborious as there are 85 per tile and, therefore, 9350 in total for the kiln. The five non-tapering perforations were made later from above. The 'B' tile is identical, suggesting the same tile maker, except that the perforations now number nine per set. These were quite crudely put in from above with many perforations missed or duplicated. But these errors do not conform to a regular pattern; were these also put in individually? This would require 765 perforations per tile and 84150 in total for the kiln! The 'C' tile is quite different; it is less deep and reverts to square large holes although to a diamond layout. The five perforations per set were put in from below.

Thus if we consider what has been proposed as the 'ideal' tile, that is one easily made and effective in use, we are looking for a square tile of large physical dimensions, tapering square large holes to a square layout, with a large number of tapering perforations put in from below (see Tables 1 & 2 overleaf). Which of our seven tiles match these requirements? The answer is none of them! Of course each of the tiles examined would in reality perform in a satisfactory manner. Although most kiln tiles do at least possess tapering holes and perforations; illustrating the belief that these were preferable. But perhaps too much emphasis has been placed on this. Certainly an examination of any old tile will reveal blocked holes but whether tapering holes are in reality significantly less prone to this than non-tapering holes would require further study. Definitely ease of manufacture does not appear to have been a priority. But perhaps the final point to emphasise is that of the seven tiles randomly selected no two are the same! With so many variable factors, although sets of tiles are superficially the same, they are (like so many other things about mills) very individual when considered in detail.

Reference.

1. Watts, Martin. *Corn Milling*, Shire Publications, 1983.

Acknowledgement.

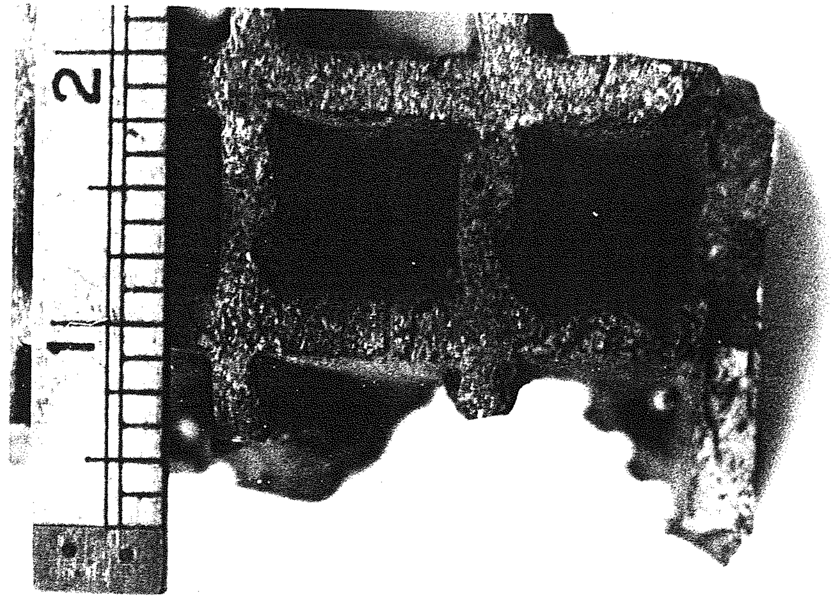
The author would like to express his thanks to Mr.Don Pass of the National Centre for Ceramic Design and Technology, Staffordshire University.

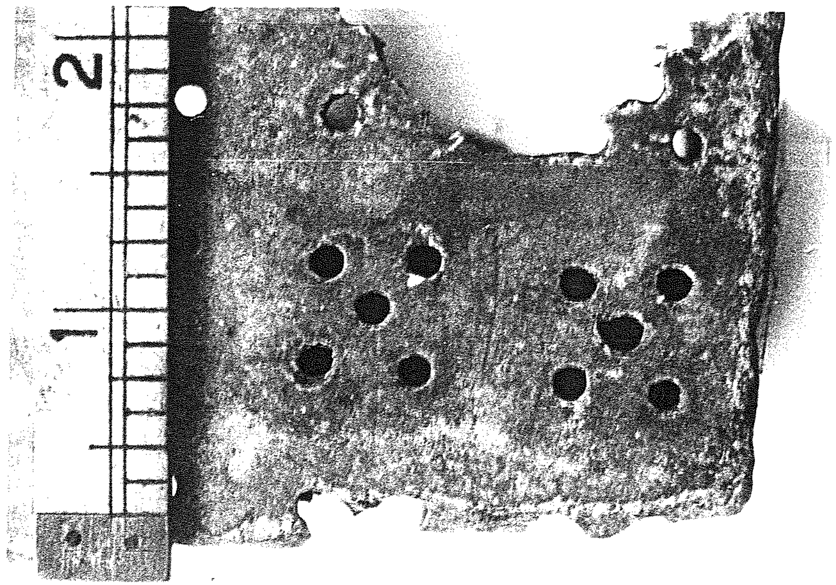
	Circular shape	Square shape	Diamond layout	Square layout	Tapered holes
'Ideal' Tile	-	YES	-	YES	YES
Stainsby Mill.	-	YES	-	YES	YES
Lowcross Mill 'A'	-	YES	-	YES	YES
Lowcross Mill 'B'	-	YES	-	YES	YES
Lowcross Mill 'C'	-	YES	YES	-	YES
Coton Mill 'A'	YES	-	-	YES	-
Coton Mill 'B'	YES	-	-	YES	-
Coton Mill 'C'	-	YES	YES	-	YES

Table 1. Kiln Tile Large Holes - shape and layout details.

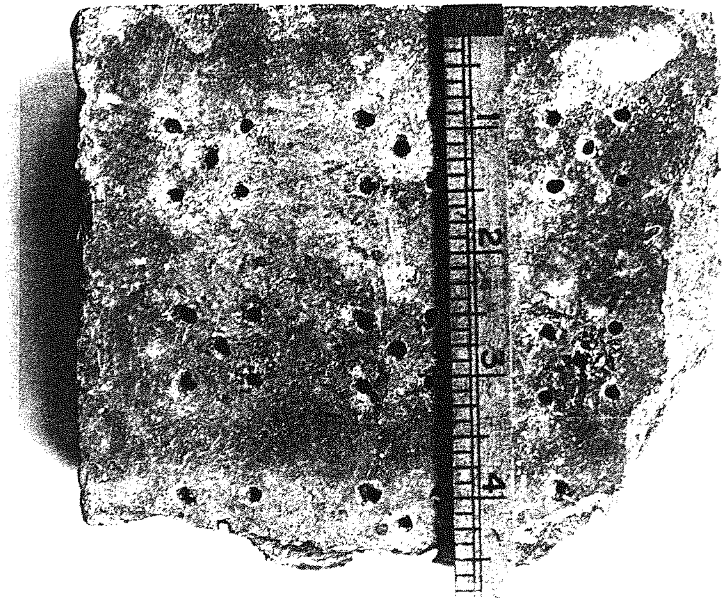
	Number of holes	Tapered holes	Made from above	Made from below	Made from a mould
'Ideal' Tile	5+	YES	-	YES	-
Stainsby Mill	5	YES	-	-	YES
Lowcross Mill 'A'	4	YES	-	YES	-
Lowcross Mill 'B'	5	YES	-	-	YES
Lowcross Mill 'C'	9	YES	-	-	YES
Coton Mill 'A'	5	-	YES	-	-
Coton Mill 'B'	9	-	YES	-	-
Coton Mill 'C'	5	YES	-	YES	-

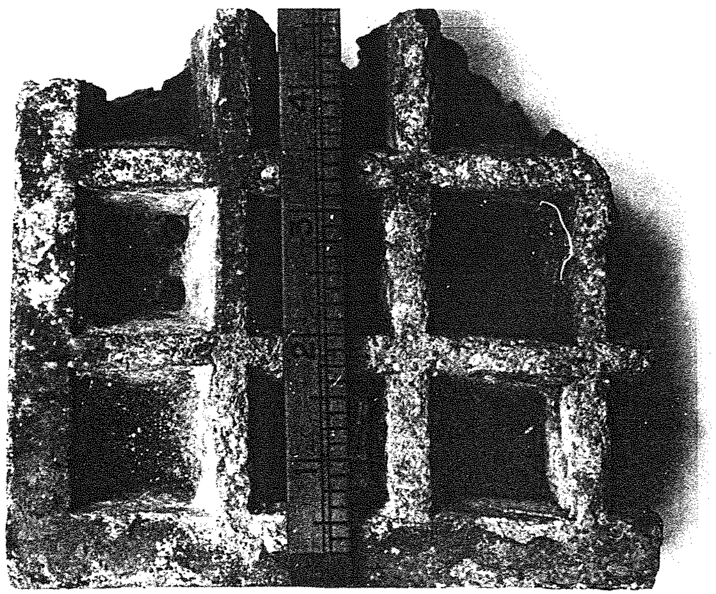
Table 2. Kiln Tile Perforated Holes - number and manufacture details.



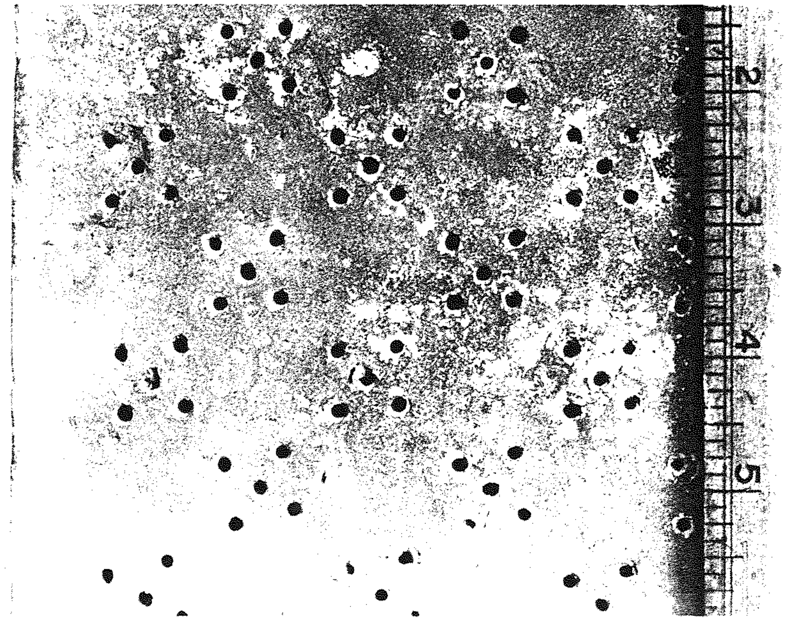


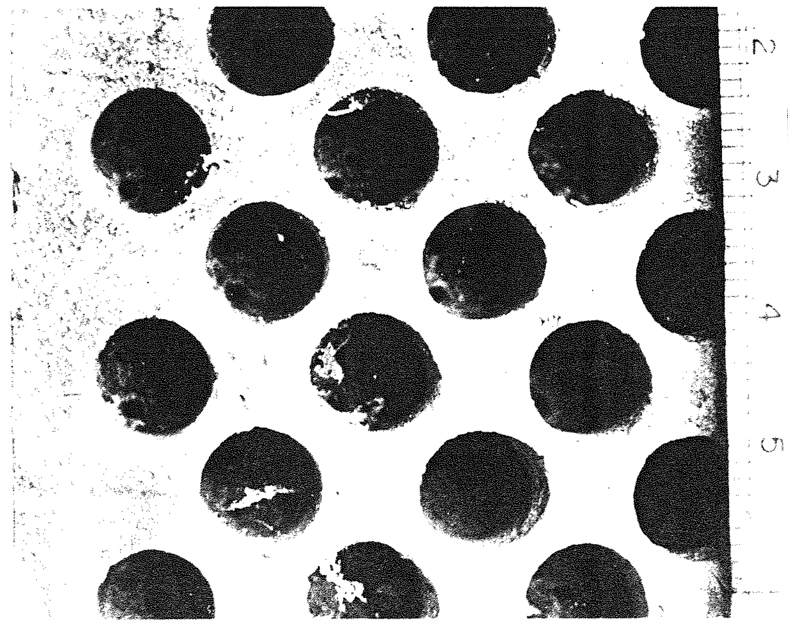
Plates 3 & 4. Stainsby Mill Kiln Tile. Top view (above). Underneath view (below).



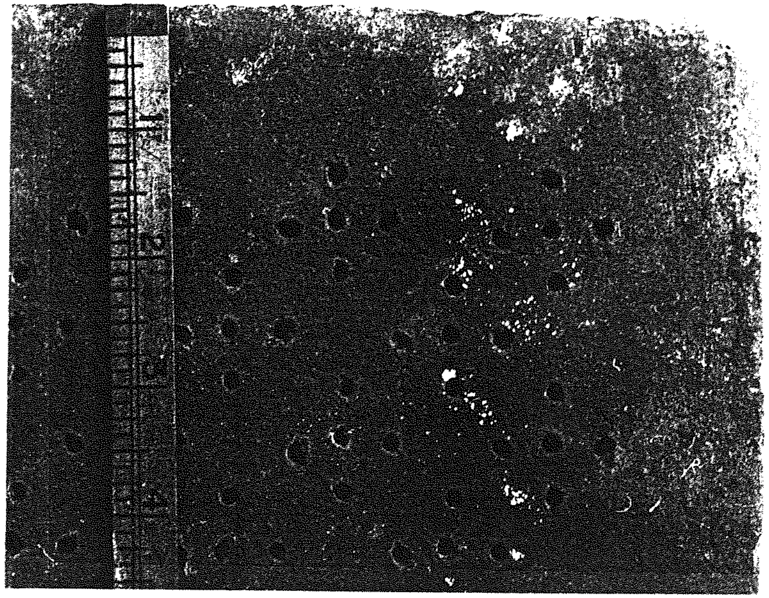


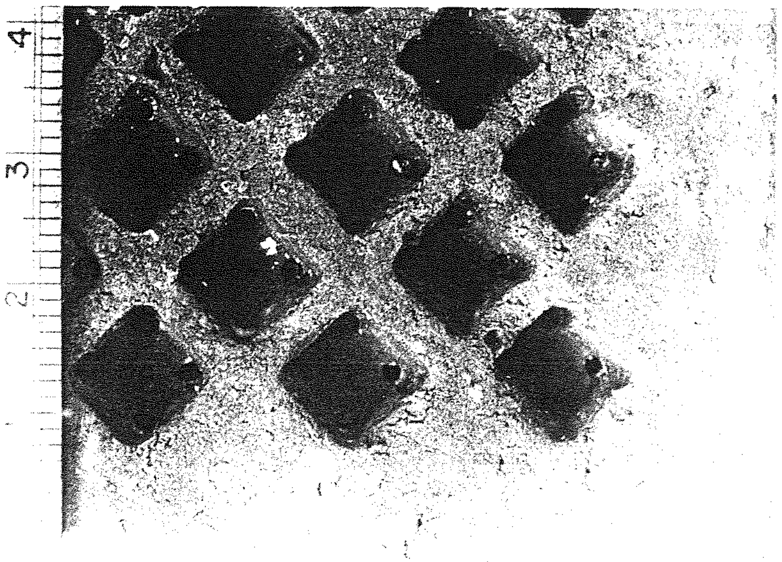
Plates 5 & 6. Lowcross Mill Kiln Tile type 'B'. Top view (above). Underneath view (below).





Plates 7 & 8. Coton Mill Kiln Tile type 'A', Top view (above). Underneath view (below).





Plates 9 & 10. Coton Mill Kiln Tile type 'C', Top view (above), Underneath view (below).

Nepali Watermills - An Update

By Roy Gregory

In January 1991 I had the opportunity to spend three weeks in Patan, a small town immediately to the south of Kathmandu. As my host would be occupied during much of the normal working day, I eagerly contemplated the prospect of some mill hunting in a hitherto uncharted area, molinologically speaking. My thoughts idly flitted through Needham**(1)** and I pondered the possibility of wind powered prayer wheels, lever hammer mills and even possibly the odd horizontal windmill. However, my flights of fancy were soon grounded when my attention was drawn to the articles of John Boucher on mills in Nepal**(2)** and Kashmir**(3)**; which shows that in fact the Nepalis make extensive use of horizontal water mills. Coupled with the research of Mike Harveson**(4)**, it became quite clear that there is a considerable region running from Persia in the west, along the southern slopes of the Himalayas, as far as eastern Nepal at least, where horizontal watermills are still in every day use. To give some idea of the number, it is estimated that there are some 50,000 horizontal mills in Nepal alone, a prospect which more than compensated for my chagrin following the realisation that Nepal was not to be virgin territory, molinologically speaking.

Paradoxically, one of the early facts which one encounters when visiting Nepal, classified by the UN as the fourth poorest country in the world, is that the so-called civilised western world has still a thing or two to learn. Since the opening up of Nepal in 1951, foreign governments have been falling over themselves to offer aid in the form of modernisation projects. Sadly in offering projects, western governments have paid insufficient attention to the knowledge and experience of the indigenous population, with the result, for example, that a road has been built at colossal cost which is hardly used and in some cases has simply disappeared due to landslides. Impressive though the Himalayas are, it must not be forgotten that they are one of the newer mountain ranges on the globe and as such are extremely unstable, a fact also evident from attempts to introduce large hydro-electric schemes. In one case a large dam was washed away when an upstream glacial dam burst its banks, taking with it twenty bridges, thirty houses, many cows and several people. Another problem is that many large hydro-electric schemes have failed to be self-financing; in other words, once the foreign government has built the project and returned home, the Nepali Government is faced with continually subsidising its on-going operation, using money it has not got **(5)**.

There is a certain arrogance in the view that the way to help underdeveloped nations is to throw western ideas at them. This was a major fault of the late medieval colonists and one might have expected modern governments to show a little circumspection. If the lesson was not learnt by the newcomers, it was quickly realised by the Nepalis themselves. For example, the

Kathmandu University Research Centre for Applied Science and Technology (RECAST) soon recognised that the traditional horizontal water wheel had served the scattered mountain communities well for (presumably) hundreds of years and a more practical way forward was to look at the possibility of improving the efficiency of indigenous proven machinery. RECAST eventually came up with a modular form of horizontal water mill, comprising two steel frames, one a hurst carrying the stones, hopper, etc, the other a simple frame carrying the waterwheel. The arrangement is quite flexible, the hurst can be mounted on top of the wheel frame and both fitted into an existing mill building, or they can be used separately - the hurst can be driven by a diesel engine or electric motor and the wheel frame can be used to drive other machinery, such as a small generator to light a few houses. The added subtlety of the design is that when dismantled, the unit is easily transportable by Sherpas to the remotest part of the country. This device, the Multiple Purpose Power Unit (MPPU), is illustrated and described in detail by John Boucher and it is not necessary to repeat the details here.

Once in the country, searching for watermills proved to be quite a slow process, due mainly to the fact that most had to be approached on foot. But once the building type became recognised, the give-away feature being the very characteristic plume of water emanating from a square opening in the base of the mill building, it was apparent that there are very large numbers still in existence, with a very high proportion still in daily use. A typical example of a traditional mill comprised a stone built structure with thatched roof, the outside dimensions being 6 feet 9 inches wide, 14 feet 4 inches long, 2 feet 8 inches to the eaves and 6 feet 3 inches to the roof ridge. It will be appreciated that an average Nepali is considerably shorter than the average Englishman but in any event Nepalis squat on their haunches when working, indeed frequently when not working, which accounts for the low roof of the buildings. The mill contained one pair of stones, mounted at floor level (see Plate 11), the runner being 22 inches in diameter, 3 inches thick at the rim, but the bedstone was some 6 inches greater in diameter. The millstones were all monolithic, made from the local sedimentary rock. Grain hoppers were traditionally inverted conical baskets but all those I saw were either of wood or steel, the latter variety being made from disused oil drums. At the tip of the hopper a small shoe was vibrated by wooden jogglers which rested on top of the runner stone. There were no vats, the flour was simply brushed up from around the stones.

The wheel comprised flat wooden paddles 13 inches long by 7 inches deep, mounted on a timber shaft 19 inches in diameter. Bridge trees were timber, some mounted in line with the flow of water, some transverse, and tentering was by means of a vertical pole with slots where it protruded through the stone floor, controlled by pegs or wedges. The footstep bearing was brass or similar alloy and held an iron pin set on the bottom of the upright shaft. The traditional leat was carried along on embankment, if the natural contours so required, with the final inlet via an open wooden trough inclined at an angle of around 60 degrees to the horizontal (see Plate 12). The usual head of water was around 10 to 12 feet.

I was unable to gain any firm information on the date of these mills. On one occasion my young guide said they were very old, about 20 years old. When I suggested he really meant 200 years old he assured me he meant 20.

The MPPUs tended to be installed in taller buildings, frequently on the stone foundation of an earlier mill, extended in brick and with a corrugated iron roof. All the MPPU mills had the final inlet enclosed in a pipe, a mini arubah.

Whereas a keen eye was needed to spot mills in the countryside, it was necessary to rely on one's ears in the larger towns, due to the fact that all these mills are simply fitted into an ordinary row of shops. Indeed one of the interesting features of Nepali architecture is that in the towns, the blocks of buildings all tended to look alike. The ground floor could be a dwelling, a shop, an office, a workshop, or indeed a mill. (One thing about mills is that whatever they look like, they nearly all emit the same noise). These mills were driven by electricity from comparatively successful hydro-electric schemes. I say comparatively because this power source appeared no less variable than water power, as witnessed by the occassional total and unannounced blackouts.

These town mills varied in size. They appeared to be more modern than the country mills, some had the MPPU hurst frame but there were an equal number fitted with cast iron vertical mills; in appearance similar to such mills found in England but in fact manufactured in India, a country with considerable influence in Nepal. In addition many mills were fitted up for oil extraction, also using machines imported from India. The oil extraction process involved first crushing the seed in a unit not unlike a Bamford oat roller, then heating it in an open pan, stirred mechanically. The final pressing was performed by a powered horizontal screw press, with the heated seed being placed in a conical hopper, the oil dripping into a bowl placed underneath and the cake extruded at one end. The cake was repeatedly put through the machine until no further oil could be extracted. Many mills had an additional item of equipment called simply a rice flattener. This comprised a heavy cast iron tub, with a flat bottom some 3 feet in diameter and sides about 6 inches to 9 inches high, in which a vertical cylinder rolled around the inner sides of the tub simply crushing rice. All the items of plant were belt driven from a floor mounted lay shaft, an arrangement which might raise the odd eyebrow from a Health and Safety Inspector, particularly having regard to the loose clothing worn by both miller and customer.

The commercial arrangement is one of customers bringing their own seed to be processed, and in the protracted oil extraction process, actually helping with the operation. This would no doubt speed up the process thereby reducing the cost to the customer. Whether payment was by toll or cash I was unable to ascertain.

One aspect of Nepal not widely appreciated is that a wide strip along its boundary with India is outside the Himalayas and comprises a now substantially de-forested jungle region, known as the Terrai. Here no fast streams are available to power watermills, nor have many of the villages been connected to mains electricity. The buildings are almost entirely of wood or bamboo and straw, including the mills. Again fairly modern, the mills were all driven by diesel engine, and their characteristic 'phut-phut' was again an aid to location.

But the Terrai contains a number of small traditional villages frequently little more than a dozen dwellings, where the economics of rural life do not even permit the use of diesel power. Here the ox still pulls the plough and cart; threshing is carried out by oxen trampling on the grain which is winnowed by placing it on a flat basket and tossing it in the air.

Milling was also back to basics. Here the women still use rotary hand querns, made I think of some form of concrete, in two hemispheres, with the bottom stone being placed on a small rope ring to hold it steady. Also in use were several foot lever pestles, for hulling rice, an operation requiring precise teamwork. One person, usually a young girl, stepped rhythmically on the lever, raising and dropping the pestle. Each time the pestle fell, a quantity of the rice was ejected out of the hole and the woman in charge of the operation immediately scooped it back in with her two hands. The process was conducted at quite a rapid pace, with little room for error in timing.

Whilst in the Terrai, I had the priviledge of being invited to tea with a local headmaster, where to my surprise I observed a quern under the eaves of the kitchen building. This was no humble item of equipment but designed for the more affluent families, having a decorative pattern chiselled into the upper surface. Apparently, the quality of flour available in the market is poor, being stale and containing impurities, and the discerning wives in the small town prefer to mill their own by hand. My tour of milling history was completed when my attention was drawn to a saddle quern used to grind spices.

Baktaphur, in the Kathmandu valley, produced one further surprise. Here I found a machine which has made a slight dent into the Indian dominance of the milling machinery market, in the form of a modern Chinese made rice mill. There were two items of plant, both powered by electricity, and both looking like what I can only describe as a steel four drawer filing cabinet. The rice was put in on the top and the treated rice came out onto the floor at the bottom, with the waste product ejected at one side. One machine seemed to be hulling rice, the other removing the germ. Unfortunately without an interpreter I was unable to find out anything further.

One final visit, in Kathmandu, was to the premises of the Kathmandu Metal Industry, again access was through an ordinary shop but the small courtyard at the rear had been roofed over and comprised the workshop where the MPPU was produced. Tucked away in one corner was a brand new MPPU hurst, resplendent in a coat of bright blue paint. The purchase price of the frame, complete, was about £100 but even at that figure most millers purchasing one would need a bank loan. But equally interestingly, the workshop contained several Pelton wheels in various stages of construction (see Plate 13), which I understood were to be used for micro-hydroelectric plants. They ranged in size from about 3 feet in diameter to very small examples around 12 inches in diameter. The cups were cast in brass, brass founding being a traditional

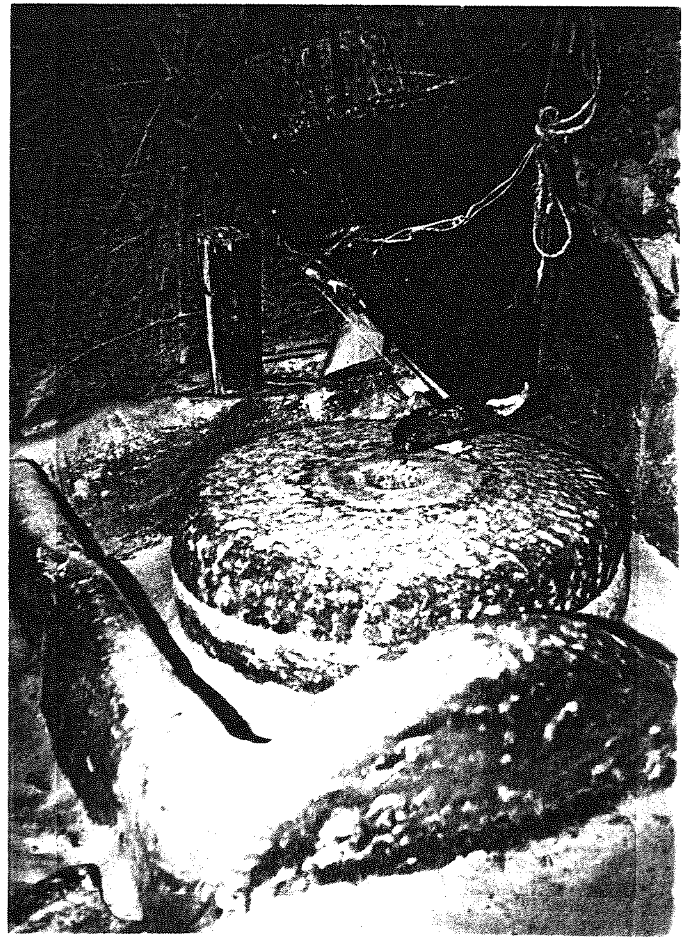


Plate 11. Watermill at Naubise showing stones, hopper and jogglers.

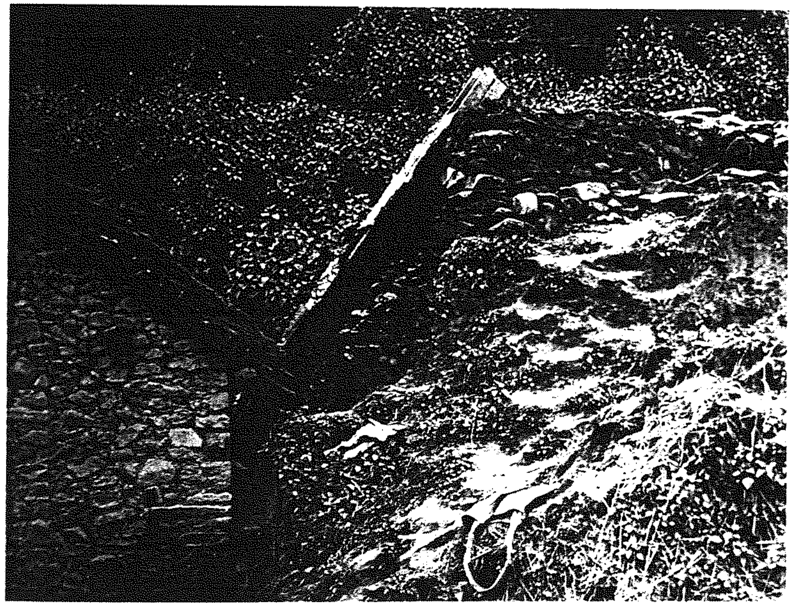
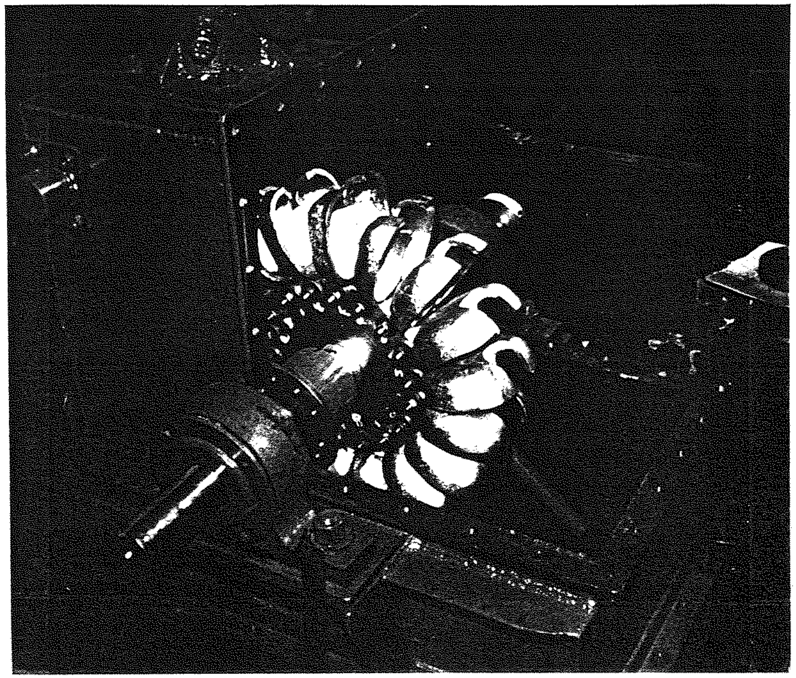


Plate 12. Watermill at Naubise, the leat and headrace trough.



Plates 13. Pelton wheel under construction at the workshops in Kathmandu.

industry in which the Nepalis have considerable experience, with brass being used for a wide range of objects from temple ornaments to household utensils and including the fascinating singing bowls used by Buddhist monks.

Finally, windpower. I saw no evidence of the early use of windmills, whatever may have happened during the eastward migration of windmills from Seistan into China, or vice versa. But at the RECAST site I saw one modern wind engine, being used to pump water and I understand a number are being used for this purpose in the eastern part of the country.

So, as I nestled back into my seat on the Nepali Airline Boeing 757, with the reassuring RR logo on the engine pod, I had a 17 hour flight home to reflect on what I had learnt. I had seen horizontal watermills still working satisfactorily; a type of mill which until Wilson published in 1960, was regarded as 'an example of .... a piece of mechanism..... of a type so archaic as to be almost wholly unknown beyond [Shetland]'**(6)**. These 'archaic' mills, modernised but fundamentally using the same principle, were providing a practical method of harnessing a freely available and environmentally friendly power source at a price the country could afford. Conversely, the attempted introduction of supposedly superior technology had still to prove its viability. Western Europe has moved on, but I could not help wondering whether people undertaking mill restoration projects in England could perhaps take heart from Nepal's experience.

References.

1. Needham,J., *Science and Civilisation in China,* **Vol 4**, Cambridge University Press, 1965.

2. Boucher,J.K.G., 'Watermill Research and Development in Nepal', *The Occasional Journal of the Midland Wind and Water Mills Group,* **No 5**, 1984.

3. Boucher,J.K.G., 'The Horizontal Mills in Hazara', *The Occasional Journal of the Midland Wind and Water Mills Group,* **No 4**, 1983.

4. Beazley,E. & Harveson,M., *Living with the Desert,* Aris & Philips Ltd., 1982.

5. Pye Smith,C., *Travels in Nepal,* Penguin, 1988.

6. Wilson,P.N., *Watermills with Horizontal Wheels,* Society for the Protection of Ancient Buildings, 1960.

See Also

Gimpel,J., 'How to light up the Himalayas', *Transactions of the International Molinological Society,* **No 4**, 1977.

Jones,D., 'Water Powered Lighting', *Transactions of the International Molinological Society,* **No 4**, 1977.

Proposals for Vertical Axis, Wind Powered Turbine Generators

By Kenneth M.Davies

The wind driven bladed wheel is not a new concept, and its application and adaptation have provided valuable service in many parts of the world. Contempary attempts to revive the wind principle have led to the construction of high-tower, horizontal axis (HA) and vertical axis (VA) wind driven turbines. The height of these machines has been influenced mainly by the fact that wind speed increases with height above ground level, and that the power available in the wind is proportional to the cube of the wind speed. The hub height is also influenced by the need for the large diameter of propellers necessary for the conversion of wind energy into rotation.

The protection and security of expensive generating machinery and controls requires that a more elaborate housing be needed than in the older, often rural structures. However, high-tower wind turbines are viewed by a great number of people, including environmental protection groups, as aesthetically undesirable. Despite these many objections, a vast amount of time and resources have been devoted to the design and development of high-tower turbines. Indeed, my own personal communications with 'responsible' bodies have left me in no doubt that "in a cost-effective wind turbine, the hub height should be maximised within design limits". Such attitudes and limiting criteria, coupled with some of the available literature seem to discourage further thought and work on alternative types of turbine in the provision of 'clean' energy. While the gospel of cost-effectiveness has its many clever and well-intentioned apostles, it is possible that people who are being slowly poisoned, suffocated or irradiated would be prepared to pay a little more for clean power.

Making Wind Turbine Structures Socially Acceptable.

The schemes proposed (see general arrangement drawings) are attempts to address some of the problems and objections by providing systems which, initially, are based on the size of an ordinary dwelling, and which can be housed in a structure whose appearance is likely to be more socially acceptable. The quasi-classical buildings with their circumferential walkways might possibly be sited on exposed seaside headlands or in country parks, and an extension of the idea might be embodied in pagodas or similar buildings, where turbine wheels could be positioned above each other. If there should be a noise penalty in the operation of this design of turbine, it may be that such sites and adaptations would be a more satisfactory option to that of the construction of quasi-classical 'follies'.

Position and Performance.

Although local topography influences the performance of all turbines, the location of high-tower units in remote areas results from the environmental concerns refered to earlier. A more practical concern must involve the attendant problems and costs associated with long power transmission lines to the intended user. It is envisaged that these problems would be reduced, as social acceptability would allow the siting of the proposed units nearer to communities. There is also the possibility of 'tailoring' the proposed units to suit local and topographical requirements, and with their less obtrusive appearance could be well sited on raised ground having a smooth approach.

There are many elevated sites in this country occupied by obsolescent or even derelict power stations, coal pit-heads, warehouses and factories, which have become during their working life environmentally tolerable, if not completely acceptable. The principles and basic designs of the schemes proposed could be made integral in some of the buildings on these sites, e.g. cooling towers, especially where some supply and distribution services still exist. It may also be worth considering the embodiment of these schemes into mock, or rebuilt farmhouses which are near to the top ends of sloping mountain valleys. It is however essential to be selective, so that no other structure is near enough to cause obstruction of, or turbulence in, the wind flow approaching the turbine installation. As a guide, the British Wind Energy Association suggests a clear approach distance of ten times the height up to the turbine wheel.

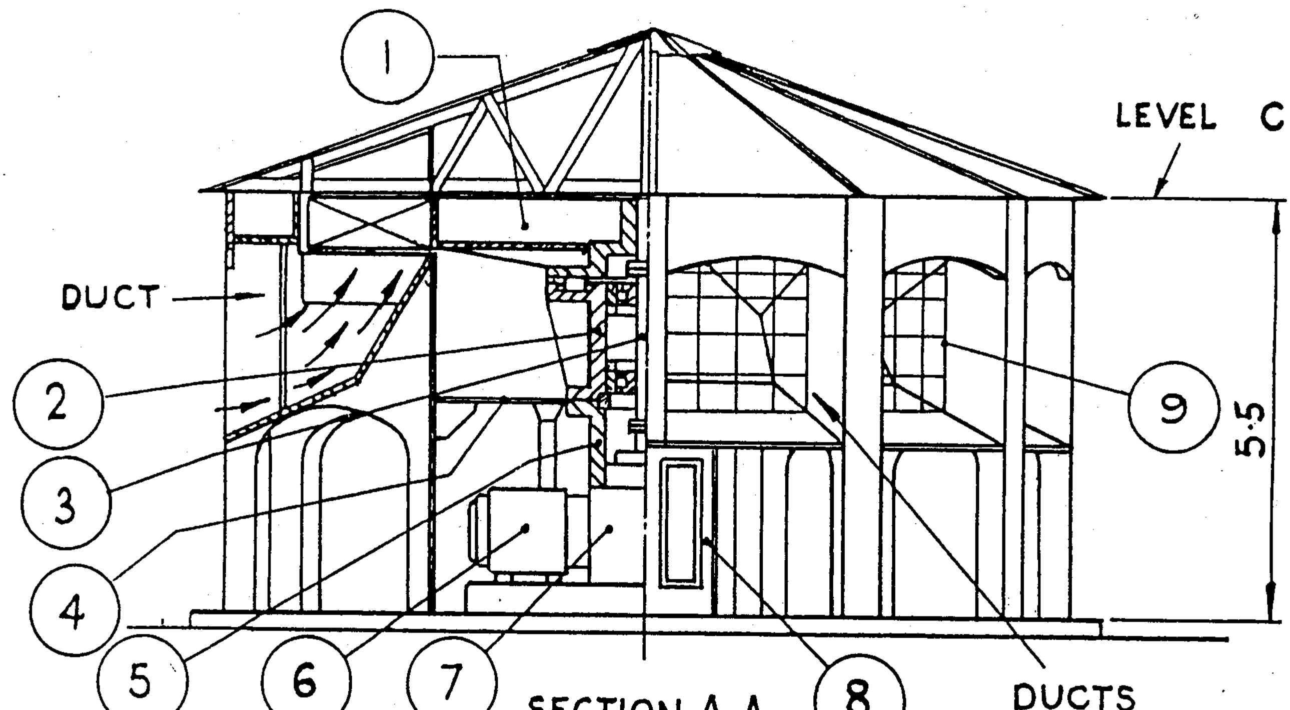
Benefits.

It may be reasoned that while the costs of gear boxes, generators and brakes etc., cannot vary greatly between the machines, the apparent cost effective advantage of the high tower machine compared with the proposed schemes is offset by the saving of material in the tower itself and the height (length) of the transmission shafting to low level.

The housings of the proposed low structures are less complicated than those in high tower units; where, in addition to the tower itself, the hub nacelle contains the framework necessary to carry the rotation, tilting and yawing mechanisms, and the attendant hoisting gear.

The foundations for the proposed units need not be as massive as those for the high towers, where there must be a considerable thrust leverage on the tower, pivoting about ground level.

Apart from the cost of erection, cost-effectiveness must also include the consideration of the cost of maintenance, and it may be fairly argued that the proposed units would be more accessible and require only simple scaffolding, platforms and mobile cranes for such maintenance and the fitting of any possible spare parts.



KEY.

1. Turbine wheel (Diameter across blade tips 9.0m.).
2. Split Shroud (Upper).
3. Rotor Shaft (3 part).
4. Maintenance platform.
5. Split shroud (lower).
6. Generator
7. Gearbox.
8. Access Doors - Double.
9. Grilles.

SCALE 1:100

Figure 1. Wind Generator - Scheme A, Elevation & Section A - A. (All dimensions in metres). Copyright © K.M.Davies 1-1-92.

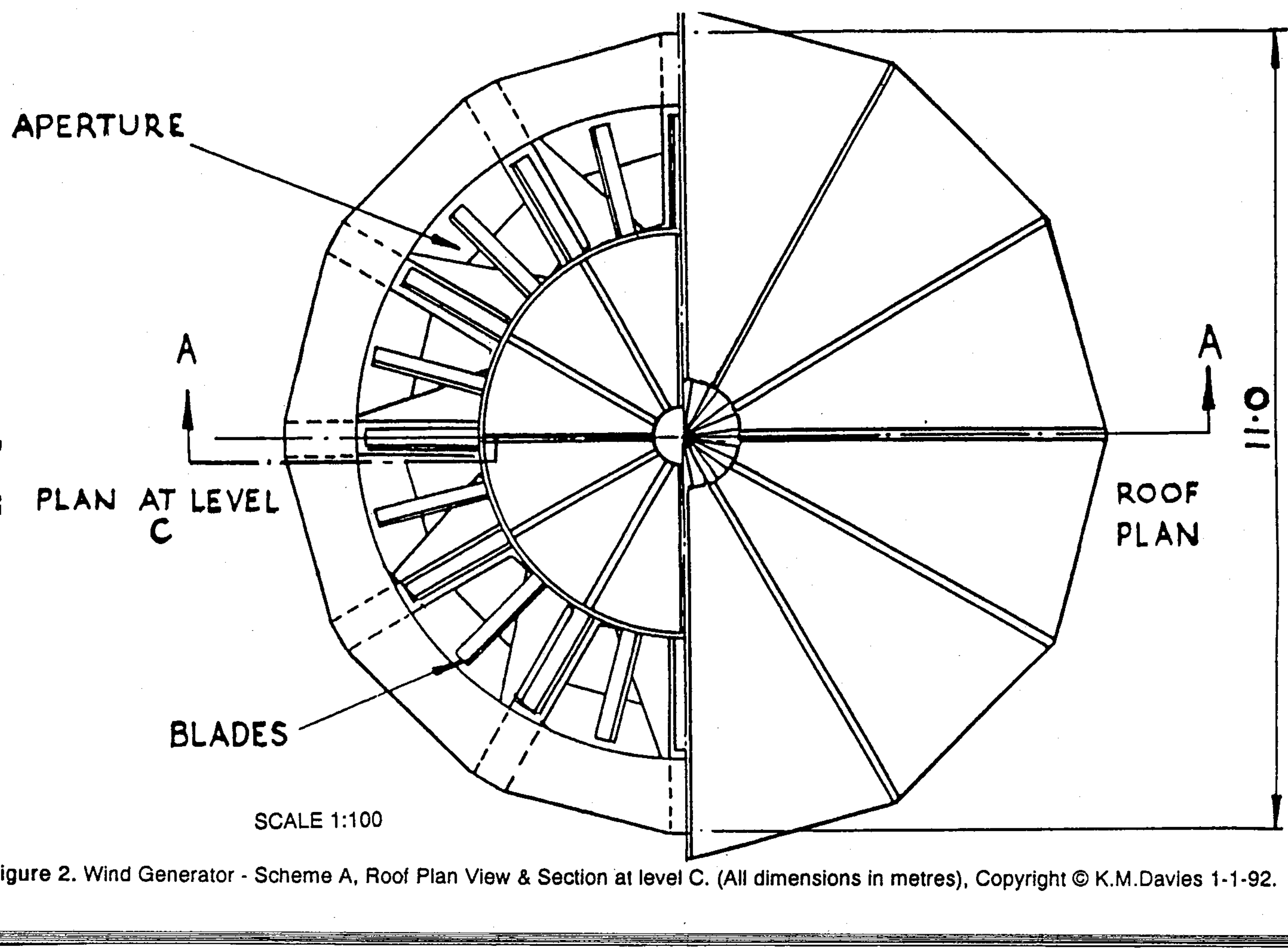
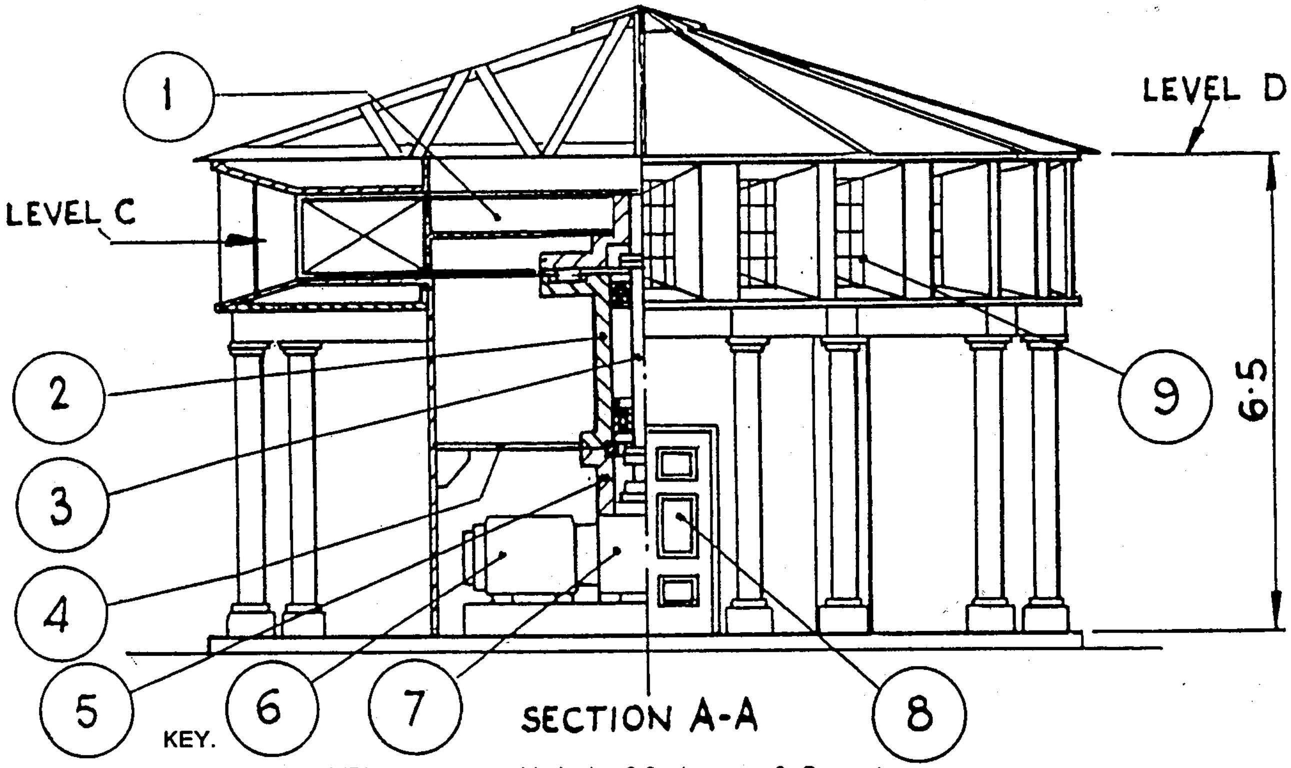


Figure 2. Wind Generator - Scheme A, Roof Plan View & Section at level C. (All dimensions in metres), Copyright © K.M.Davies 1-1-92.



KEY.

1. Turbine wheel (Diameter across blade tips 9.0m.).
2. Split Shroud (Upper).
3. Rotor Shaft (3 part).
4. Maintenance platform.
5. Split shroud (lower).
6. Generator
7. Gearbox.
8. Access Doors - Double.
9. Grilles.

SCALE 1:100

Figure 3. Wind Generator - Scheme B, Elevation & Section A - A. (All dimensions in metres). Copyright © K.M.Davies 1-1-92.

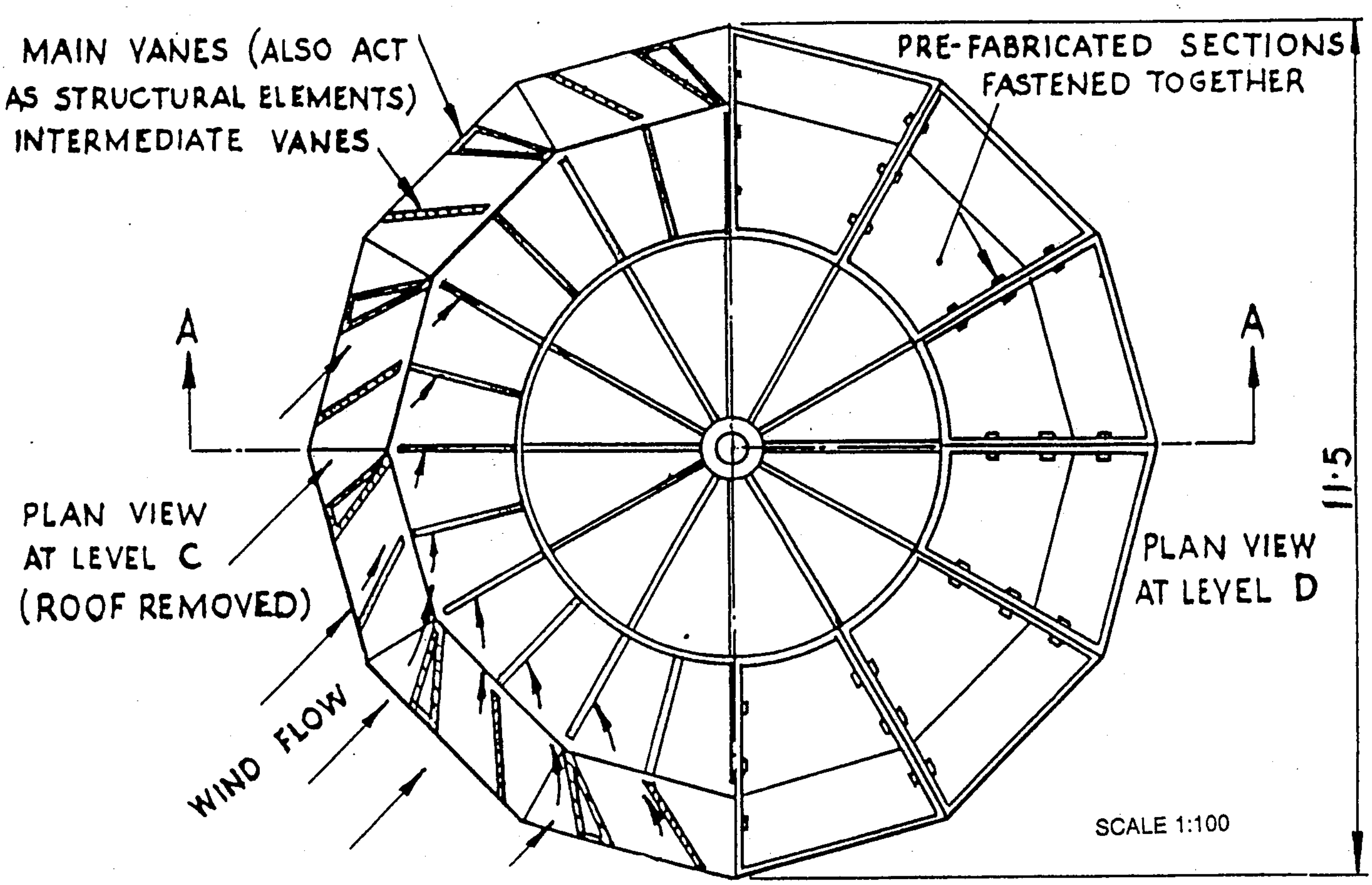


Figure 4. Wind Generator - Scheme B, Plan View at levels C & D, (All dimensions in metres), Copyright © K.M.Davies 1-1-92.

Basic Principle of Proposals.

The pictorial Schemes A and B show buildings roughly the size of a domestic dwelling, having a shaft whose length is small between turbine wheel and gearbox as compared with high-tower units.

In Scheme A (see Figures 1 and 2) the basic principle by which the turbine operates lies in the redirection of the windstream entering the large radius ducts - convergent faces in the ducts guiding the airstream upwards then sideways, whence it finally strikes the turbine blades. The sideways convergence directs the airstream to the 'weather' face of the blades irrespective of the general external wind direction. Scheme B (see Figures 3 and 4) shows another method of convergent ducting directing the windstream onto the blades independently of general wind direction. Thin, central blades within the ducts are intended to prevent the windstream acting against the advancing blades of the turbine.

Both Schemes A and B are for 'fixed' hub shrouds, with rotating wheel and shaft.

Further schemes deal with uprating the performance by using a double turbine wheel mounted on a hub 'shroud' arrangement which rotate on a stationary shaft. The double wheel - double row of blades is suggested because of possible problems accompanying the use of a single wheel with very large blades. The hub shrouds would have a large diameter, integral flange (disc) which would rotate within disc brakes mounted on top of the gearbox/generator unit. Additionally, the hub would have a concentrically mounted and keyed (primary) gear ring engaging a pinion (say 5:1 reduction) on the drive to the lower (secondary) gearbox (say 12:1 reduction).

Detail Design Considerations.

The following suggestions are made, but are not intended as an exhaustive list:

1. The turbine wheel could be in the form of a web made up of, say, 6 sectors, with the main weight disposed in the rim. The use of sectors would facilitate installation or replacement if damaged.

2. A circumferential track mounted on the main structure might be needed in the event of any sag in the rim of the turbine wheel.

3. If the wheel were made of a sectored web, and in order to avoid metallic corrosion at the shaft, it would be worth considering the use of high duty plastic or non-metallic material, possibly making use of plastic adhesives.

4. The material for the wheel must have adequate fatigue strength because of fluctuations of wind torque, possibly centrifugally induced enlargement of the wheel diameter, and the wide range of temperatures which could be experienced in different climates.

5. The blades could be constructed as (1) a solid sheet (2) a thinly covered framework, each built on to or around a spindle and having a buttress web on

the leeward face. The spindle end would locate into a boss moulded or fixed on the wheel rim. Circumferential rings could be fitted to minimise possible blade tip deflection.

6. A hub could be made in a number of different ways, depending on whether it rotates or remains stationary. Where the gear ring is fitted on the lower end of the hub, consideration could be given to the use of a thermo-setting material such as 'Tufnol' locating on the hub of 'structural' engineering thermo-plastic. The rings for the actual brake disc surfaces could be of alloy steel bonded to the hub disc flange.

7. Consideration could also be given to the use of plastic balls and rollers in plastic races, or in combination with stainless steel parts. This would minimise or remove corrosion problems, and with their claimed ability to function satisfactorily down to minus 40 degree Centigrade, breakdown and maintenance should be much reduced.

8. In the main structure, the plane surfaces of the duct sides might be made as smooth GRP(fibre glass) curved mouldings.

Editor's Note.

This article first appeared in 'Engineering Designer', the publication of the Institute of Engineering Designers, early in 1993. Since then the author has been awarded the Hornsby Cup by the Institute for the best article published by a member during 1993.

These proposals by Mr.Davies are not meant to provide an alternative to high tower, horizontal axis, wind turbines, but are put forward as a means of complementing the generating contribution of the high towers. To make progress with his ideas, calculations of likely costs and performance need to be derived and experimental confirmation of these calculations obtained by experimenting with a reasonably sized scale model (i.e. a quarter or one third scale perhaps). If any reader of this article is interested in providing practical help in this area, or has any comments on the designs, they are invited to contact the Editor who will pass their communications to Mr.Davies.

The Medical Condition of Makers of French Millstones.

By Thomas B.Peacock, M.D.

Adapted from *'The British and Foreign Medico-Chirugical Review'*, 1860.

In 1727 reference was made to the frequency of consumption among workmen employed at Waldshut, on the Rhine, in the excavation and cutting of millstones. In 1775 a form of disease prevalent among the men employed in cutting the grits or freestones of the neighbourhood of Etampes was described; and in 1799, attention was drawn to the frequency of consumption among the workpeople employed in Worcestershire in needle-pointing, stating that the disease was locally known as the 'grinders' rot'.

S· ;e these observations and the more casual notices of the frequency of consumption in stone-cutters, metal grinders, etc., the subject has attracted much attention; and the account given of the prevalence of pulmonary disease and the short duration of life among the stone masons of the neighbourhood of Edinburgh, and the similar reports as to the dry-grinders of Sheffield, have established the fact of the injurious influence of occupations in which the particles of stone or metal are thrown off, and, becoming diffused through the atmosphere of the shops, are inhaled by the workpeople.

In the following paper I propose briefly to draw attention to the prevalence of pulmonary disease in a class of workmen among whom it has not, so far as I am aware, been hitherto particularly noticed; I refer to the French millstone makers, or builders, as they, perhaps more properly, call themselves.

The stone which these men work is known in the trade as the 'French Burr'. It is imported into this country by way of Rouen and Havre, chiefly to London, Hull, and Liverpool, in which towns the shops for the manufacture of millstones are chiefly situated. During the war *[i.e. Napoleonic War - Ed]* when intercourse between France and England was cut off, the millstones employed so imperfectly fulfilled the requirements, that a prize was offered by the Society of Arts for the discovery of a substitute in this country; but without success, and since the peace the French stone has again been extensively imported.

The burr is a peculiarly hard kind of flint. It is known to French minerologists under the names of 'Silex Molaire' or 'Pierre meulière'; and is found in certain tertiary strata of lacustrine or fresh-water origin. It is situated in the Paris basin above the gypsum containing bones, and in strata of sand and sandstone. It occurs either in beds or in smaller masses, and the beds are sometimes so large as to admit of two or even three millstones being cut from the same piece, but never more. They are of no great thickness; are generally cellular, and the cells are irregular, and sometimes contain plates or fibres of silex. The stone is

more tenacious and less easily broken than gun-flint; it is slightly translucent, and is generally of a tarnished whitish, yellowish, or reddish colour. It is obtained in open quarries, and in removing it grooves are cut, into which wedges of iron or wood are driven, so as to break off portions of the required size. The best stones are obtained from La Ferté sous Jouarre on the Marne, to the east of Paris, where the trade has been carried on for some centuries. The stones which are of a bluish-white colour, and do not contain fossils are the best. The smaller portions are cut into carreaux, or quadrangular blocks, and are extensively exported to England and America.

Though the masses sufficiently large to form entire stones are occasionally brought to this country, it is usually in the form of the smaller blocks, measuring about fifteen or sixteen inches in length, ten or eleven in breadth, and six or seven in depth, that the burr is seen in the millstonemakers' yards. The stone is not only brought from La Ferté sous Jouarre, but also from the neighbourhood of Épernon, to the south-west of Paris, and it is said to exist extensively in other parts of France. The stones are of a yellowish brown colour, and are more or less thickly studded with small cellular or tubular spaces of irregular form, and lined by a yellowish powder. They are stated sometimes to contain fossil shells, - different quarries differing in this respect. The stones also vary in the degree of translucency.

From the 'carreaux', or blocks the millstones are manufactured in this country by cutting their surfaces into angular forms, so as to fit them together, cementing the portions with plaster of Paris, and binding the whole with strong bands of iron round the circumference; grooves, radiating from the central opening towards the circumference and about an inch and a half apart, are then cut on the grinding surfaces.

The rough working of the stones is effected by a steel chisel, 'the pritchell', which is struck by a metal hammer, and the surfaces are finished by picking with a double-pointed steel instrument fixed in a wooden handle - the 'bill and thrift'. As the burr is extremely hard, every stroke of the chisel is attended by a bright flash of light, and a cloud of dust and larger or smaller particles of stone, forming a sharp grit, are thrown off. Portions of the stone and of iron from the chisel, not unfrequently become embedded in the hands or face of the workmen, so that the backs of the hands of those who have been long at the trade are studded with small bluish spots, and occasionally the men sustain serious injuries to their eyes.

The men who were engaged in this work universally regard it as a very injurious occupation, and state that the burr is a much more dangerous stone to work than the Yorkshire or Derbyshire grit, the Scottish granite or the German basalt, which are also employed for the formation of millstones. The burr is only used for grinding wheat, and of cement stones, and for these purposes its extreme hardness is said especially to adapt it. The other stones are used for rice, barley, or beans.

A very intelligent young man, the foreman of one of the yards, who informed me that he had been bred to the trade, stated that he had known at least twenty persons die of chest affections, out of the small number, not, I believe, exeeding fifty, who are employed at the works in London. He also told me that the oldest workman he knew had only been in constant employment at the trade for thirteen years, and that all who work at it suffer sooner or later. One of the masters informed me, that those who are apprenticed to the trade, or take to it early in life, never live beyond forty years; and one of the foremen said they seldom do more than live out their time *[i.e. apprenticeship - Ed].* These statements are confirmed by my own observations during visits made to the yards in the spring of 1859; I found in three out of the four London shops, forty-one men at work, of whom twenty-three stated that they had been apprenticed to the trade, or had taken to it when they were not above twenty years of age. Of this number the average age was 24.1 years, and the ages of the five oldest workmen were 38,29,29,28, and 28. The average period during which they had worked at the trade was 8.9 years, and the three who had been longest engaged had been 18, 17, and 14.75 years. It also appears that it is common for the men to leave the millstone making and work for a time as millwrights or engineers, so that it is quite possible that some of the twenty three may not have been in constant work as millstone builders; but however this maybe, the age of the men was certainly very low, and their period of work short. The difference in these respects is indeed very remarkable between the men employed as millstone makers, and those who, in some of the same establishments, are engaged in wire-weaving, etc., for the formation of sifters for flour, for drying the pulp in the manufacture of paper, and for other purposes.

In one establishment I found nineteen men so engaged; of these thirteen informed me that they had been apprenticed to the trade, or had joined it at or before twenty years of age. Of this number the mean age was 35.84 years, and five of them had attained the ages of 71, 43, 42, 40, and 40. The mean period during which they had worked at the trade was 20.69 years, and eight of them had been engaged for 51, 32, 29, 25, 25, 24, 24, and 22 years. These men were certainly less healthy looking than the millstone-makers; but they stated that they enjoyed good health, and this was confirmed by the very small number who had received relief from the sick fund during the period of five years, of which the accounts were shown to me. The contrast between the different classes of workmen is the more striking, in that, as far as most circumstances are concerned, the metal weavers are in less favourable sanitary conditions than the millstone-makers; for their workshops are some of them underground and close; but I understand that they are steadier in their habits, and that their employment is more regular.

My attention was first attracted to the prevalence of pulmonary disease among the French millstone-makers by the number who applied to me at St. Thomas's and the Victoria Park Hospitals, and before I had made any enquiries at the shops which might bring the men more particularly under observation. I feel therefore convinced that the occupation is one which predisposes to pulmonary affections; but it is open to inquiry in what way it exercises an injurious influence - whether it be, as supposed by the men themselves, from the dust which they breathe, or from the influence of other

causes which rather operate by deteriorating their general health.

When I visited the shops during the spring, they were certainly dusty, though, from the dampness of the weather, it was said less so than usual. There can also be no doubt that the dust is extensively inhaled; for in a case the particulars of which will shortly be detailed, siliceous particles were found in consolidated portions of lung. It is evident that such particles lodged on the mucous membrane of the smaller bronchial tubes or in the cells of the lungs must be a serious source of irritation, tending in persons of healthy constitution to the production of chronic bronchitis and asthma, and in those inheriting a constitution predisposition to phthisis, to the development of tubercule.

Other causes doubtless conduce to the unhealthiness of the occupation. Thus, though, as a general remark, the workshops are sufficiently roomy and protected from the weather, in some cases they are very defective. In one yard, some of the men were at work in underground cellars, which, though freely open above, must be damp and unwholesome; and others occupied open sheds, where they must be much exposed to the weather. The want of general exercise is also objectionable. The men work at the stones standing up or leaning over them, and, except in their arms, use little muscular exertion, and their chests cannot be well expanded. It is probable that the powerful muscular exertion which is undergone by the wire weavers is one cause of their freedom from the affections which prove so fatal to the millstone-makers.

Some of the men also habitually take an amount of stimulus which must be very injurious. They state that their occupation is an exhausting one, and they in consequence drink a large quantity of beer. Four or five pints is, I believe, by no means an unusual quantity, and some take spirits also. One of the masters, a fine healthy-looking middle-aged man, who said that he had worked at the trade for many years, and had always enjoyed good health, ascribed his immunity from the usual effects to his temperate habits, and stated that if the men lived temperately they suffered much less. In his yard he allowed the workmen a pint of beer morning and afternoon, but interdicted all going to the public-house, or having beer brought upon the premises; and stated that his men were in consequence healthier than in other yards. This statement is confirmed by the fact, that though his shop is not far from St. Thomas's Hospital, and several of his men have applied to me for other ailments, I have seen no case of phthisis or chronic bronchitis among them.

So far as the ordinary necessities of life are concerned, millstone-makers are generally favourably placed. They earn good wages, being paid at the rate of 6d per hour, or 5s per day, or by piecework, at which they can earn still more. They are well clad, and live well. The occupation is also a tolerably certain one, but the men may occasionally be thrown out of work, and so suffer privation.

The causes which have been named do not therefore appear sufficient to explain the great tendency to pulmonary affections among the millstone-makers, apart from the injurious influence which is exercised by the gritty particles of silex which they inhale while at work. This is indeed, I believe, the main cause of their sufferings.

The following cases afford examples of lung disease in millstone-builders:-

CASE 1.

J.S., aged twenty-three, was admitted as an out-patient at St.Thomas's Hospital, on the 7th of October, 1858. He had been suffering for twelve months from an affection of the chest. He complained of a difficulty of breathing, pains in the chest, severe cough, and expectorating blood. He continued in work until the 3rd of March, 1859, when his declining strength having rendered him incapable of work he was admitted as an in-patient. He died three weeks later.

The post-mortem examination showed that the backs of the hands, especially in the neighbourhood of the knuckles, were thickly studded with spots, containing in their interior a small blackish-looking mass, which proved to be elongated angular fragments of stone or iron, varying from the size of a poppy seed downwards. The upper part of the left lung had numerous grey nodules which had a tendency to run together to form irregular patches of various sizes. Parts of the lower left lung were similarly affected. The right lung was very much reduced in size, compressed, and perfectly airless. It was studded thickly throughout with grey nodules; at the top it contained several cavities of considerable size, and the whole lung was filled with liquid. The bronchial tubes of both lungs were somewhat congested, and many of the bronchial glands were studded with noduless, and infiltrated with black pigment. The rest of the body was healthy.

CASE 2.

W.C., aged thirty-seven, applied as an outpatient at St.Thomas's Hospital on the 11th of November, 1858. He had had symptoms of affection of the chest for five years, very severely during each winter. He complained chiefly of difficulty of breathing, cough, and expectoration. The backs of his hands were covered with black spots, which he said were produced by the pieces of iron thrown off from the chisel in millstone-making. He continued to attend St.Thomas's Hospital till the spring of 1859; he presented the usual symptoms of chronic bronchitis and occasionally spat blood. In April he left me, feeling himself better, and I did not see him again till the 15th November, 1859 when I visited him at his home as he was very ill. He died one week later.

The post-mortem examination showed that both lungs were tuberculous, but the right one especially so, and the deposit at the top of the lungs was so copious as to render them solid. The tubercules existed in masses but the lower part of the left lung had merely here and there small tubercules which were especially superficial at the base of the lung. The bronchial glands were very large, hard, and of a deep black colour. Although the heart was flabby the rest of the body was healthy.

Parts of the lung tissue was further examined by ignition in the flame of a spirit-lamp. The white ash which remained dissolved to a great extent in hydrochloric acid, and partly with effervesence; but a portion was left which was

seen under the microscope to consist of small angular transparent granules, exactly resembling the finer portions of siliceous dust collected from one of the workshops. Parts of the lung tissue were also subjected to the action of fire and nitric acid, and a considerable quantity of gritty matter was found to remain, which had an amorphous aspect under the microscope, and was infered to be siliceous.

The cases which have been detailed do not appear materially to differ in their symptoms from similar forms of the disease originating under other circumstances, It is, however, possible that closer observation of other cases of disease in the same class of persons, may lead to the detection of some special facts by which they are characterised. It seems also probable that in persons who become phthisical from being exposed to local irritation from the inhalation of particles of stone or metal, the disease will be slower in its progress, and be preceded by more marked symptoms of faucial and laryngeal irritation, than under other circumstances.

So far as we know at present, the disease induced by this cause does not admit of any special treatment, but our attention must be mainly directed to prevention, and there can be no doubt that in this way much may be accomplished.

1. It would appear that much of the deleterious influence of French millstone-making may be obviated by not allowing persons to enter the trade until after they have attained their full growth and vigour of constitution. As I have before mentioned, one of the foremen said that when boys were apprenticed to the trade they scarcely do more than live out their time; and though this may be somewhat too strongly expressed, it appears to be mainly true, for one of the masters said that he had declined to take apprentices, from the number of persons whom he had known die of consumption when put to the trade early. On the other hand, all the information obtained tended to show that the work is much less injurious to those who take to it when more advanced in life. I found at work several middle-aged men who had been some years at the trade without suffering, and one man of fifty-four told me that he had taken to the work when thirty-four years of age, had continued at it for twenty years without suffering, and was then in good health.

2. The men should be cautioned to be careful to protect themselves against the usual causes of cold, by wearing suitable clothing, and especially to avoid all excess in the use of stimulants. Unfortunately, men engaged in trades which are known to be injurious are apt, partly perhaps from recklessness, but partly also from ignorance, to be dissipated in their habits; we are informed that such was the case with the millstone-makers of Waldshut, and with the needle pointers of Worcestershire; and the intemperance of the dry-grinders of Sheffield is notorious. The French millstone-makers have often told me that they require a large quantity of stimulating beverage, and that if a man is abstemious he dies sooner; and this is made the excuse for their taking a very immoderate amount of stimulus. There can be no doubt that the habits of intemperance very greatly aggravate the other evil influences to which they are exposed, and that were

they to live temperately, but well, they would suffer less, and live much longer. I cannot but think that representations of this kind would have much weight with the men; and I am informed that their habits have latterly improved, and with advantage to their general health.

3. Much may probably also be done to mitigate the injurious effects of the work by lessening the liability of the men to take cold from exposure to the weather, by reducing the quantity of dust thrown off and diffused in the atmosphere, and protecting the workmen against its inhalation. The workshops should be roomy and well ventilated, and should admit of being freely opened in dry and warm, and closed in damp and cold, weather. Working in underground cellars or in the open air are both objectionable. The men should be advised to work as much as possible in the upright position, instead of stooping over the stones, so as to expose themselves as little as possible to the inhalation of dust. The stones might, perhaps, be equally well worked wet instead of dry, and thus much less dust would be thrown off; and the only objection to this which I have heard stated is, that the tools would the sooner wear out. Lastly, they might avoid the inhalation of the dust by wearing respirators, either at all times, or when the shops are more particularly dusty.

Editor's Note.

In recent years there have been a number of articles published concerning millstones and millstone quarries, greatly increasing the amount of information available about these topics. The above article has been adapted for republishing so as to complement that information by giving an insight into the working conditions of the people involved in millstone manufacture and also an idea of the cost to them in terms of their health and life expectancy.

The Editor would like to thank Robin Clarke for discovering the article and suggesting that it should be republished.

Midland Wind and Water Mills Group Publications.

The following publications are available from:
Mr. B.Job,
Meadowside,
Clayton Road,
Newcastle-under-Lyme,
Staffordshire, ST5 3ET

The Journal of the Midland Wind and Water Mills Group.

A miscellany of articles on a variety of mill related topics. Each volume is between 48 and 64 pages, including photographs, maps, and drawings.

Numbers 3 - 10......£1.00 each + £0.40 postage.
Numbers 11 - 12.....£2.50 each + £0.40 postage.

Staffordshire Windmills.

By Barry Job.

76 pages, including 35 photographs plus line drawings and sketches.

£1.75 + £0.40 postage.

Some Watermills of South - West Shropshire.

By Gordon Tucker.

96 pages, including 48 photographs plus maps and line drawings.

Member's price. £3.95 + £0.45 postage.

Non-member's price. £5.00 + £0.45 postage.