THE MIDLAND WIND AND WATER MILLS GROUP

(affiliated to the Society for the Protection of Ancient Buildings)

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, Worcestershire and Warwickshire.

The Group, which functions as an autonomous society, holds monthly meetings, with talks and discussions, during the winter, and arranges several tours to mills during the spring and summer. Members periodically receive a Newsletter and the Journal, and can purchase other publications at preferential prices.

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Wind and Water Mills

The Occasional Journal of the Midland Wind and Water Mills Group

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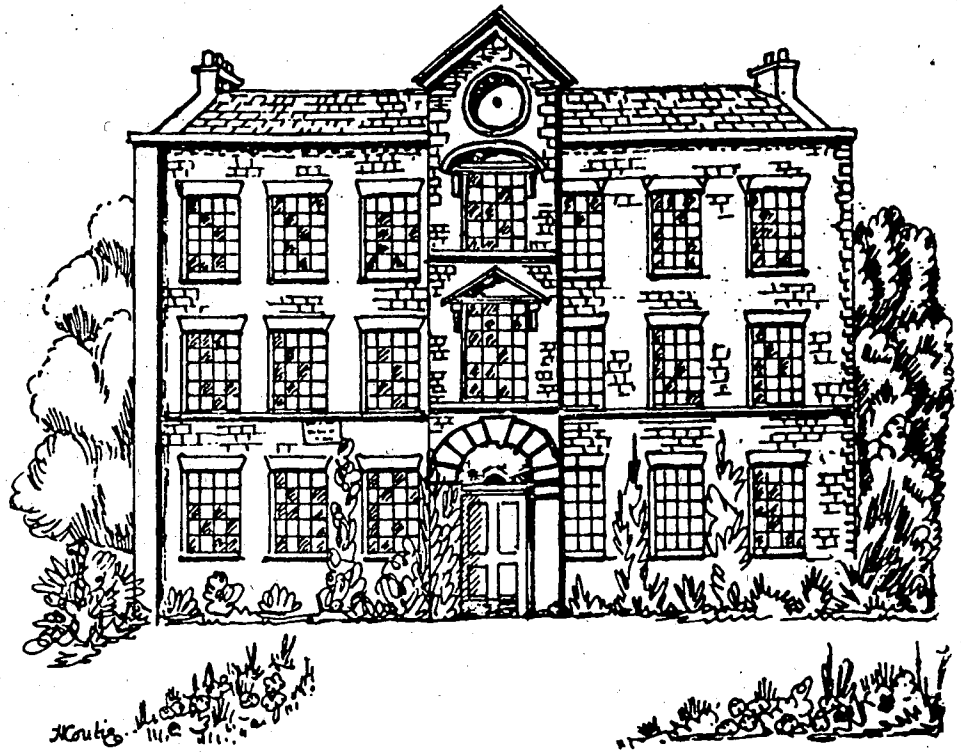
Number 8



Wind and Water Mills, although the journal of the Midland Windand Water Mills Group and therefore naturally concerned with the mills of the Midlands, 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, but submissions by others will be willingly considered.

A.B.
A.C.

Cover illustration, by Heather Coutie.
Crag Works Offices, Wildboarclough, Macclesfield,

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ISSN 0260-504X

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ERRATA

Page 13 plate 7. Change 'donkey wheel' to 'horse mill'

Page 17 para 2. Add 'at Worcester' after 'The stone furniture for the horse mill'

CRAG WORKS

by Tony Bonson

Crag Works, an impressive, stone-built water powered factory, were situated in the parish of Wildboarclough, Cheshire (SJ984688). They lay some five miles south west of Macclesfield, eight miles north of Leek, and six miles south east of Buxton. The site is in a steep sided valley, through which flows the Clough Brook, a tributary of the River Dane, that used to power the works. Although today the valley is quiet, secluded and remote, lying as it does, high in the Peak District close to the borders of Staffordshire, Derbyshire and Cheshire, once it was a veritable hive of industry with the works at Crag employing hundreds of people.

Much evidence exists concerning the operation of the works in its heyday, but the details of their founding, and the reason for their closure can only be inferred.

The origins of Crag Works are difficult to ascertain with any degree of accuracy. Current local tradition insists that the works were established as a water-powered paper mill by James Brindley during the period of his apprenticeship with Abraham Bennett, a millwright based at Gurnett, near Macclesfield.

The tale has been told often, down the years, of how the work at the paper mill was not going well. Consequently the young James Brindley set off one weekend to walk to Manchester, 30 miles away, to inspect for himself the recently built Smedley paper mills, so as to determine their construction details. He was successful in his intent, returning to work on the following Monday to put right the deficiencies in the design of the machinery.

This is the story that is now attached to Crag Works, unfortunately no evidence for this attachment can be found. The story was first told by Philips, in his book "Inland Navigation", published in 1805 [1], but there is no mention of the location of the paper mill described. Later in the century, the story was retold in more detail by Smiles, in his "Lives of the Engineers" [2]. He placed the paper mill on the River Dane (not the Clough Brook on which Crag Works stand). In 1912, the Lancashire and Cheshire Antiquarian Society [3] organised a field trip to the area, where they were shown the site of the Brindley paper mill at Gighall on the River Dane, not at Crag. The leader of this field trip, a Rev. W. Beresford, was a distant descendent of James Brindley. It is only in 1915 when the location of the paper mill is given by John Earles in "Old Macclesfield" [4], as "...on the River Dane in Wildboarclough". This is the first time that Wildboarclough is mentioned. Cyril Boucher, in his biography of James Brindley [5], uses the words "...on the River Dane at Wildboarclough". The final act of the story has been carried out by the Ordnance Survey, which now insists in labelling the village of Crag as Wildboarclough, whereas until this century the name Wildboarclough only applied to the parish as a whole. This has been compounded by Helen Harris in "The Industrial Archeology of the Peak District"[6], where she states that it was the Lower Crag Mill that was built by Brindley.

Consequently, I believe we are now faced with a classic case of tradition transfer, from one site (Gighall) to another (Crag).

There is further evidence, albeit of a negative kind, to disprove Brindley's association with a paper mill at Crag. During the period of the eighteenth century and the first half of the nineteenth, paper making was subject to excise tax. The Customs and Excise kept extensive records, which are lodged in the Public Record Office, but there is no entry in these records at all for Crag [7]. Records do exist for two other mills in the area, one near the confluence of Clough Brook and the River Dane, known as Folly Mill, and also for Gighall on the River Dane itself. The date of James Brindley's efforts on the paper mill is given as 1737 by Smiles. The evidence, of the buildings at Crag, which were large; of the machinery, which was very powerful; and of the construction, which utilised a fireproof system of iron beams, support columns and window panels; is not in keeping with a paper mill of this date.

So when were the works built?

Earwaker, writing in 1877 [8], suggests that the works were erected about 1807 by a Mr. Palfreyman, although Ormerod [9] in 1882 suggests 1815. The one **known** fact is that Crag Hall, farm, bleaching and printing works were for sale in 1813, by George Palfreyman, who was bankrupt. At that time the works were described [10] as:-

> "... a well built cotton factory, 65 yds in length & 12 yds in breadth with 2 water wheels, a bleaching house, 3 dye houses, a blacksmith's shop and 12 cottages for the work people, also a very good & convenient house for the overlooker to the works. The works are constantly supplied with a stream of water sufficient for any purpose. These premises are capitally adapted for the bleaching & printing business ..."

It seems likely, then, that the works were built early in the nineteenth century, and possibly Earwaker's date of about 1807 is as close as shall ever be known.

For the next thirty years the works appear to continue to be operated for printing cloth under the auspices of the Palfreyman family. The works appear on the various maps of Cheshire [11] produced during this period, sometimes indicated as "printworks". The printing business does not seem to have been entirely successful, as in 1831 Crag Hall and the estate (but not the works) were put up for sale [12]. In 1834 Charles Palfreyman, a calico printer, dealer and chapman, was declared bankrupt [13]. Finally, in 1839, the whole of Crag Works was once again put up for sale by John and George Palfreyman [14].

In the 1840's Crag Works took on a new lease of life with the arrival of Joseph Burch, who established a carpet printing works there. The Burch family lived and worked at the Froghall colour mill in North Staffordshire, six miles from Leek. Joseph Burch was an inventor, and, like most Victorians, he patented his inventions. In 1839 he took out his first patent, a machine for printing cotton, woollens, and paper [15]. He improved this machine over the years, concentrating on printing heavy materials, such

as terry cloth and pile carpets. To exploit this patent Joseph Burch entered into a business arrangement with J. Bright & Co. of Rochdale, and set up carpet manufacturing at Crag.

The date of Joseph Burch's arrival at Crag is not documented, but his patent in 1845 [16] is the first to give his address as Crag. Other evidence for the beginning of carpet manufacture at Crag can be determined from the 1851 census returns [17]. Here it can be seen that there was a large influx of skilled artisans to Crag in the late 1840's from all over the British Isles. Because of the fact that the census records give an individual's place of birth, coupled with the Victorian habit of producing large families, with only small intervals between the birth of successive children, it is possible to deduce that this influx took place around 1848.

This carpet business was very successful. J. Bright & Co. wove the carpets at Rochdale, and then shipped them to Joseph Burch at Crag for printing. The machinery at Crag was capable of printing up to six colours in one operation. (A one eighth scale model of this machinery is part of the Bennet Woodcroft bequest in the Science Museum, London [18].) The carpets produced were imitation Brussels carpets, but they cost 20% less than the real item. During the carpet boom years of the 1840's and 1850's, the carpets made at Crag were in considerable demand, both at home and overseas [19].

The height of Crag's fame and prestige came in 1851 with the Great Exhibition. Local tradition would have us believe that the red carpet used for Queen Victoria to walk on when opening the exhibition was made at Crag. There is no evidence to support this story. However, carpets from Crag were present as exhibits, and were awarded a prize medal [20]. During the decade of the 1850's, Joseph Burch continued to patent various improvements to his machinery, indicating that carpet manufacture continued during this period. However, when the 1861 census was taken, it is apparent that there were no longer any skilled workers residing in the neighbourhood, and that the locals, who provided the labourers for the works, had reverted to agricultural activities [21].

So, what had happened to close such a successful enterprise? One theory was that political enmity between the Prime Minister, the Earl of Derby (landowner of Crag), and John Bright, parliamentarian, whose family firm was in partnership with Joseph Burch [22], spilled over into their commercial activities. Alternatively, John Bright's support of the 1860 Free Trade Act, which had disasterous consequences for the silk trade, could have caused a rift with Joseph Burch, who had relatives in the silk business. The first clue to the demise of carpet manufacture at Crag turns up at the 1862 International Exhibition. Although there was **no** exhibit from Crag, the Juries Report [23] stated:-

> "The terry fabrics made some years ago in Rochdale (woven plain by powered loom and the printed) ... and exhibited in 1851, have disappeared, **their manifest inferiority** leaving no cause for regret at their absence."

This is an obvious reference to the Bright/Burch carpets, and is a particularly strong statement for the Chairman of the Jury, J. Crossley, to make about something which was **not** exhibited.

At this time the firm of J. Crossley was pre-eminent in the carpet world, a position attained by marketing a good product, and by using patent legislation against possible rivals. In 1858 the Crossley firm had bought a patent from Moxon, Clayton & Fearnley, concerning a "wire motion" loom for carpet manufacture, and in 1859 they started a patent action against J. Bright & Co., due to their (Bright's) use of a similar "wire motion" machine. This case lasted until 1864, and it is probable that the production of carpets at Rochdale (and hence at Crag) ceased until the case was settled. It would seem that J. Crossley was not above using his position at the 1862 exhibition to denigrate his commercial rivals whilst the patent case was still in progress! In 1864, after many tribulations, the court found in favour of J. Bright & Co. The main reason for this conclusion was that Crossleys were only holding the "wire motion" patent to oppose their rivals, and were not themselves commercially exploiting the patent. This became obvious during the trial when the loom, supplied to the court by Crossleys as an example, broke down, and Crossleys were unable to repair or replace it. It turned out that this was their only example of this type of loom, and it was only used for fighting patent cases [24]! Justice had prevailed in the end.

After the case, J. Bright & Co. decided to consolidate their manufacture at Rochdale, by concentrating on woven carpets only [25]. Consequently, Joseph Burch, with his carpet printing business, was left out in the cold, and Crag works never reopened for carpet manufacture.

During the late 1860's, Joseph Burch's patents show that he was taking an interest in a variety of areas besides printing machinery, notably in steam engines, and ship hull design [26]. The local tradition is that Isambard Kingdom Brunel used to visit Crag Hall, and used Crag Pool as a "test tank" for models of the Great Eastern. Whatever the truth of this legend, Brunel was certainly aware of Burch's work, as the lifeboats of the Great Eastern were reputed to be based on one of Burch's patents [27].

After the finish of carpet manufacturing, the works were never to be operated as a complete unit again. They were still unoccupied in 1874 [28]. Various uses were made of some of the buildings from time to time; the Lower works became the office and workshop of the Crag estates of Lord Derby; part of the Upper works became the telegraph office, and then the post office. One of the floors was used as a Tenants' Hall for local activities, and other areas as storage. In the second world war, munitions were stored at Crag, and a detachment of Dutch soldiers from the Princess Irene Brigade based at Congleton was billeted there as a guard [29].

In the end, the vandals won, the local council considered that the buildings were unsafe, and they were demolished in 1958, ninety-nine years after they ceased production.

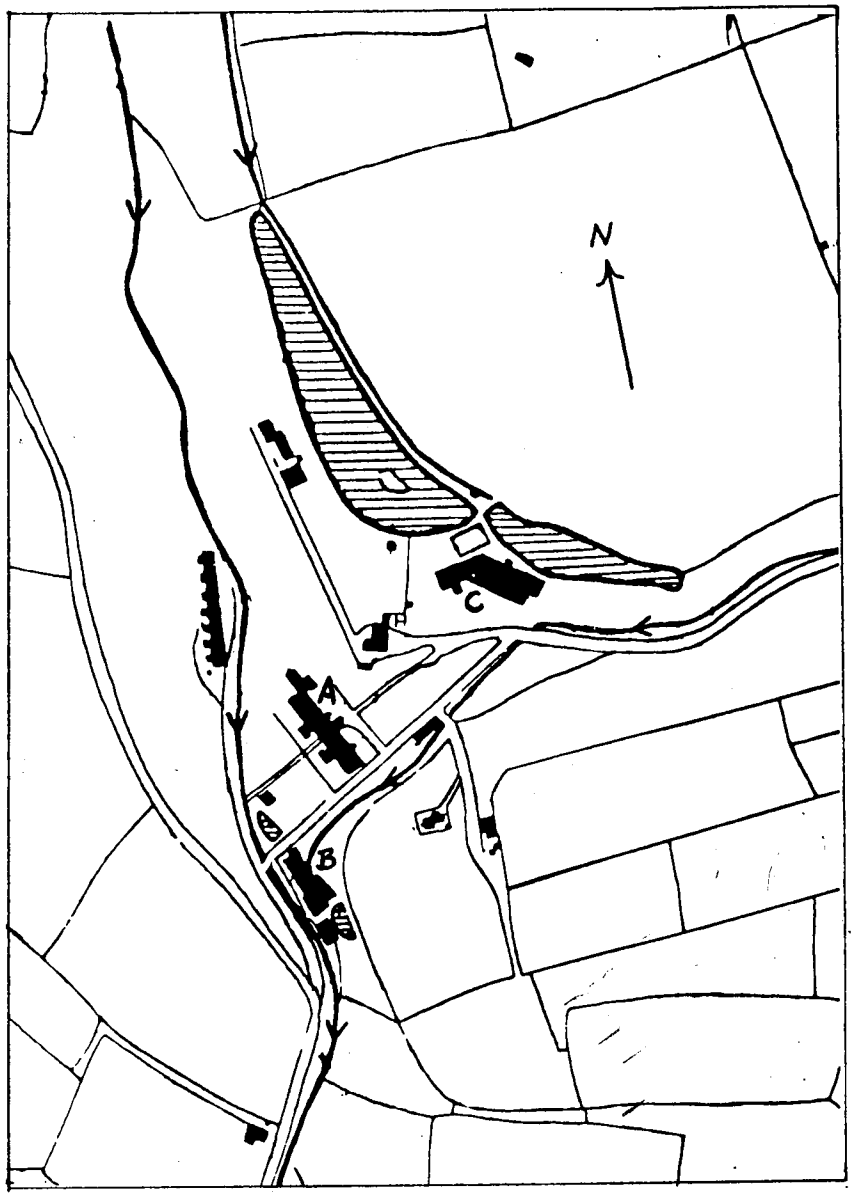


Figure 1 Crag Works. Wildboarclough Tithe Map 1849.

The general arrangement of the buildings at Crag is shown on the 1849 Tithe map, see Figure 1. Buildings "A" and "B" were the Upper and Lower works respectively, whereas building "C "was the dye house. The water supply originated from a weir on the Clough Brook about half a mile north of Crag. The water flowed from this weir via a covered leat to Crag Pool. At Crag, the water in the pool is some 55ft above the brook. The pool was used to supply the Upper works and the dye house. Any overflow from the pool went into the small side stream running down into Clough Brook. The waters of this side stream were stored in a small pool alongside the Lower works, and used to power the water wheel within that building.

The main building of the Upper works was four storeys high, built of squared masonry with prominent quoin work, raised gable ends, and roof of local stone. Internally iron columns were used to support 38ft cast iron beams that supported the floors. The window frames were also made of cast iron, they all had 30 lights, each one being 9in. by 6in. The Lower works also used cast iron extensively. On the ground floor there was a row of pillars running centrally along the building supporting the first floor. These pillars stood on slightly raised padstones, and their heads contained sleeved bearings through which a 5 $^{1}/_{2}$ inch diameter line shaft passed. The roof of the Lower works was supported by queen posts rising from eight tie beams. All the iron work was reputedly cast on the site during construction [30].

Although powered by water, by 1839 there were also two steam boilers installed, of 18 and 30 HP respectively, to provide heating for the works [31]. Also, coal gas was manufactured and stored in a small gas holder, and was used for lighting the works [32]. The Upper works had two waterwheels that worked side by side in a large wheelhouse which had tall arched windows, the whole wheelhouse being similar in style to the steam engine houses built in the 19th century for large cotton mills. These two wheels were present in 1813 [33] and in 1839 were described as giving about 60 HP, and having a pentway, governor, and gearing [34]. The wheel that powered the Lower works was situated at the southern end of the building. It was a breast shot wheel of over 18ft in diameter, and about 4 ft wide, built on the suspension principle, with one inch diameter cross bracing iron spokes. Although the wheel rotated in the longitudinal axis of the building, the penstock was at right-angles to the wheel, a rather curious arrangement [35]. Even more curious was the type of governor used to control the speed of the wheel, see Figure 2. As the wheel turned, it operated a belt drive to a force pump "A" As the speed of the wheel increased, the extra pressure of the water produced by the force pump raised a weighted ram "C" with teeth. These teeth engaged a geared crank, which in turn closed the sluice on the penstock "E", causing the speed of the wheel to decrease. If the speed decreased too much the weight of the ram would overcome the pressure of the water from the force pump, and as it fell, it would operate the crank on the sluice, so as to allow more water to the wheel, hence increasing the speed again [36]. The speed of the wheel was controlled by the outlet valve "B". The greater the opening then the greater the amount of work required to achieve the water pressure in cylinder "D"necessary to shut the sluice. Hence the wheel would be governed at a higher speed.

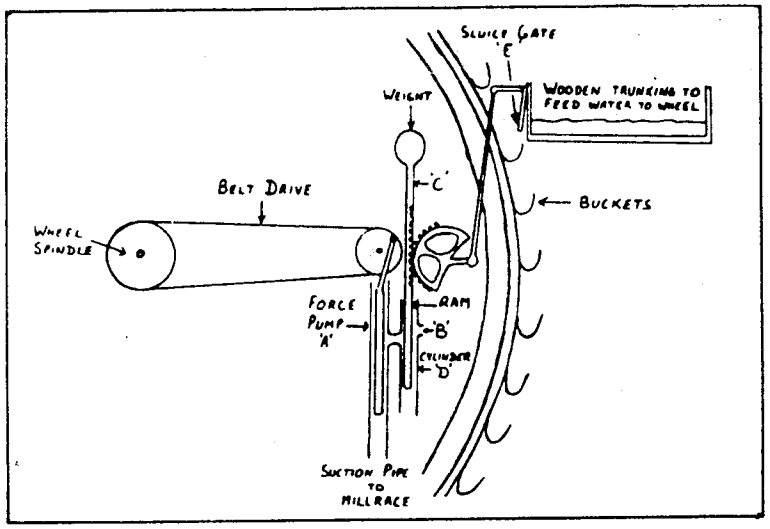


Figure 2. Waterwheel govenor. Lower Crag Works.

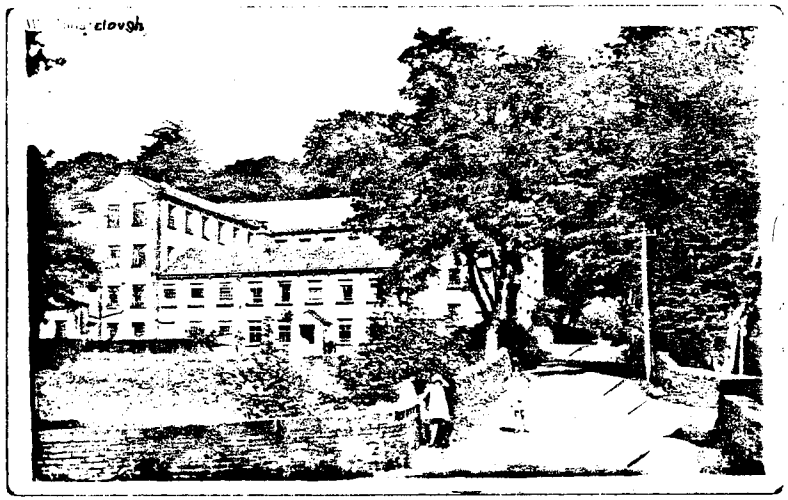


Figure 3. Postcard showing Upper Crag Works. 1908.

Today, most of the buildings have been demolished, however, the water supply remains virtually intact. The low weir on Clough Brook is still in position, directing a supply of water half a mile through the covered leat to Crag pool. This is a delightful spot in the summer months, a shimmering sheet of water, favoured by fishermen, perched on the side of an escarpment, surrounded by trees, and overlooked by the moorland hills of the Peak District. The two sluices can still be seen, one for the Upper Works, and one for the dye house, as can the overflow. The dyehouse itself disappeared many years ago, being replaced by the little church of St. Saviour. Although the main buildings of the Upper works have gone, the works offices remain, an imposing three storey building that really emphasises the magnitude of the undertaking at Crag, and the wealth it generated. These offices were built in the carpet heydays, some time after the tithe map survey. They stand between the sites of the Upper works and the dye house. One small two storey block of the Upper works remains, today converted into a residence known as "The Millhouse". Crag Hall still stands in isolated splendour overlooking the pool. Lower down the hill many of the workers cottages and the children's schoolroom can be seen. The stone foundations of the Lower works, with the tailrace outlet, are still to be seen. The position of the waterwheel is easy to determine due to the presence of the lower half of the mainshaft bearing. This is the last lingering evidence of the highly unusual waterwheel installation that was in use untill 1859, and then remained in situ unused for almost another hundred years. Two other survivors from the heydays at Crag are the firms of J. Crossley & Sons, still one of the leading carpet manufacturers, and also that of John Bright Brothers, still in business today in Rochdale.

References.

1. Philips, "Inland Navigation", 1805, reprint. pub. David & Charles

2. Smiles, S., "Lives of the Engineers", Vol I 1862.

3. *The Lancashire and Cheshire Antiquarian Society* **Vol XXX**, 1912.

4. Earles, J., "Old Macclesfield", 1915.

5. Boucher, C.T.G., "James Brindley - Engineer", pub. Goose.

6. Harris, H., "The Industrial Archeology of the Peak District", pub. David & Charles.

7. Shorter, A. H., "Paper Mills & Paper Makers in England 1495-1800", pub. Paper Publishing Society, Holland, 1957.

8. Earwaker, J. P., "East Cheshire", 1877.

9. Ormerod, G., "History of Cheshire", 1882.

10. **Macclesfield Courier**. 27th March, 1813.

11. Greenwood 1818, Swires & Hutchinson 1828, Bryant 1831.

12. **Macclesfield Courier.** 16th June, 1831.

13. **Macclesfield Courier**. 15th February, 1834.

14. **Macclesfield Courier**. 25th May, 1839.

15. Patent AD1839 No. 7,937.

16. Patent AD1845 No. 10,657.

17. 1851 Census, Wildboarclough.

18. Beeken, B., "Wildboarclough".

19. Neville Bartlett, J., "Carpeting the Millions", pub. John MacDonald.

20. *Report of the Juries*, 1851, **Vol 2.**

21. 1861 Census. Wildboarclough.

22. Trevelyan, G.M., "Life of John Bright", pub. Constable, 1913.

23. *Juries Report International Exhibition,* 1862 **Class XXII.**

24. Neville Bartlett, J., "Carpeting the Millions", pub. John MacDonald.

25. Neville Bartlett, J., "Carpeting the Millions", pub. John MacDonald.

26. Patent AD1852 No. 1473, Patent AD1852 No. 1160.

27. Patent AD1852 No. 393.

28. Morris's Directory 1874.

29. Beeken, B., "Wildboarclough".

30. Beeken, B., "Wildboarclough" (based on thesis in Macclesfield library, now missing).

31. **Macclesfield Courier**. 25th May, 1839.

32. Beeken, B., "Wildboarclough".

33. **Macclesfield Courier**. 27th March, 1813.

34. **Macclesfield Courier.** 25th May, 1839.

35. Beeken, B., "Wildboarclough".

36. Stoke on Trent Reference Library, S192. (H. Bode).

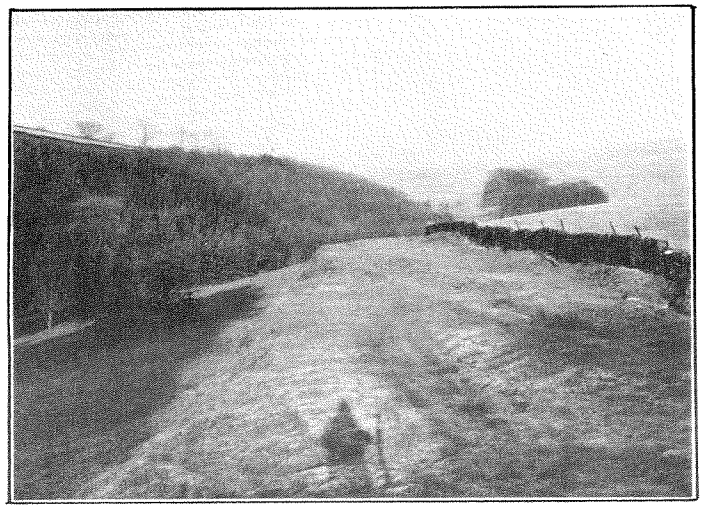


Plate 1. The covered leat leading to Crag Pool.

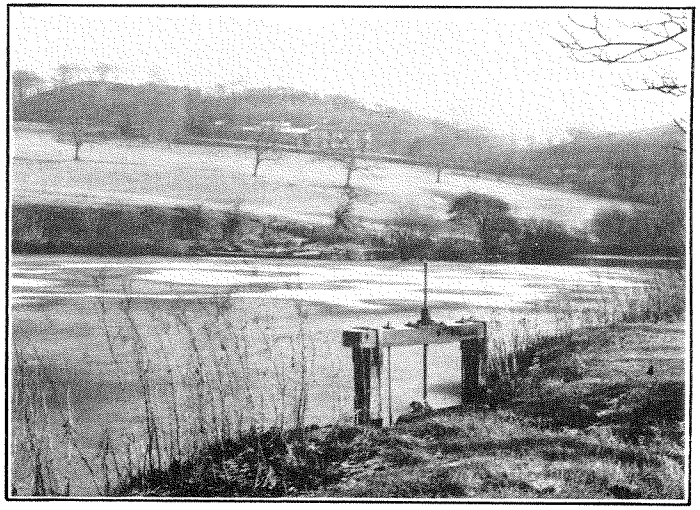


Plate 2. Crag Pool and sluice, with Crag Hall in the background.

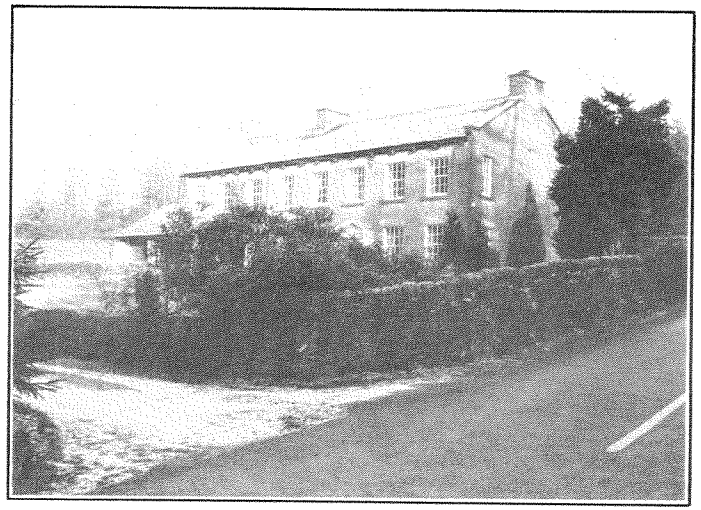


Plate 3. "The Millhouse", part of the original mill, now a private residence.

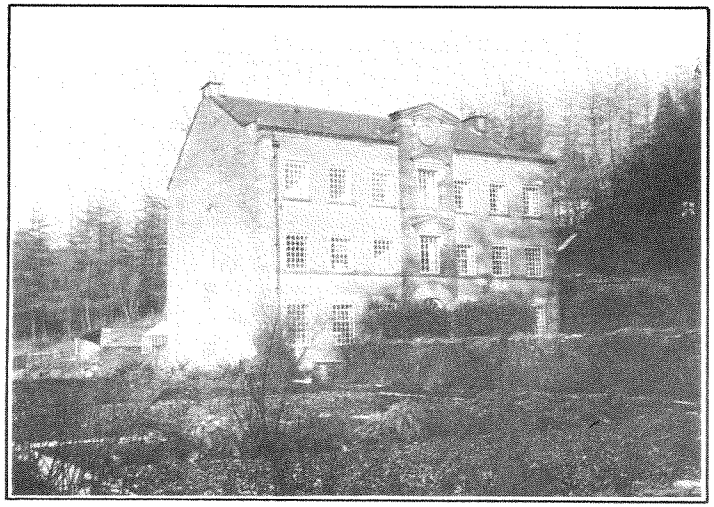


Plate 4. Crag Works offices, later the Post Office, now a private residence

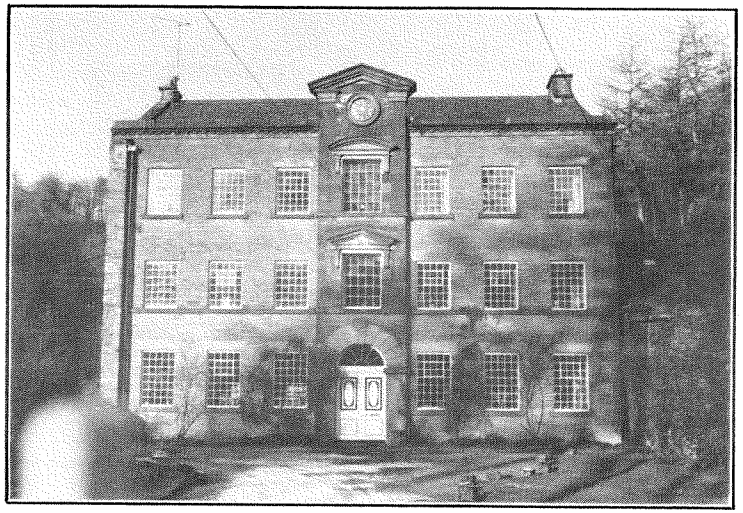


Plate 5. Crag Works offices.

Plate 6. Workers cottages, Crag.

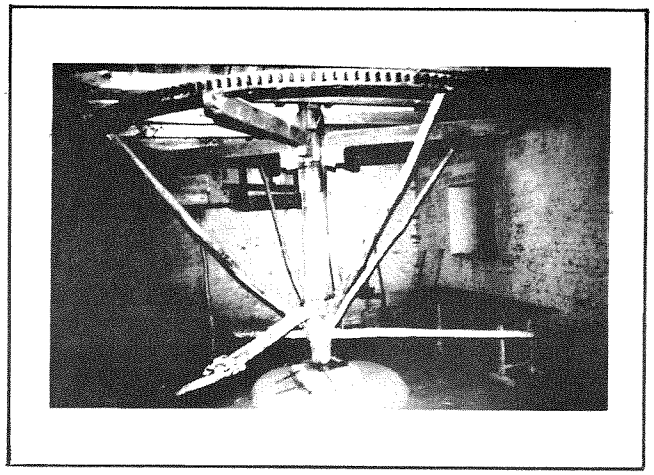


Plate 7. Donkey wheel at Worcester, South Africa.

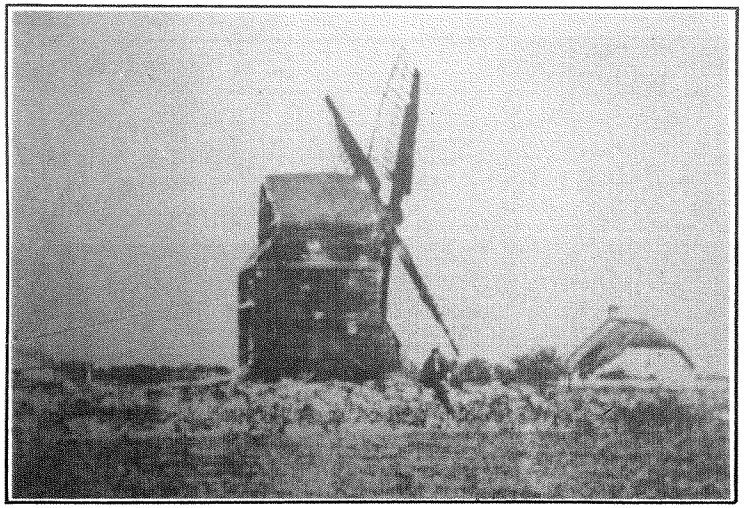


Plate 8. Birkdale mill, about 1850. (see pages 22-25.)

SOME SOUTH AFRICAN WATERMILLS

by Niall Roberts

In the autumn of 1985, my wife and I spent seven weeks in East and Southern Africa (visiting two sons then working in, respectively, Tanzania and Lesotho). Whilst in South Africa itself, we visited five watermills (and two windmills) in Cape Province. Only two were on their original sites. The others had been moved and re-erected at open-air museums or in the grounds of a historic residence. These three mills were small, with nearly all wooden machinery and each one had only a single pair of stones. The two larger mills, on their original sites, had all (or mainly) iron machinery. Each drove at least two pairs of stones. One accomplished this by means of a lay-shaft (and an oil engine), and the other partly through a belt drive to two pairs of stones. All the small "wooden" mills had lantern pinion wallowers (though with metal staves).We also saw at least one horse mill and one (working) donkey pump.

Worcester Watermill

This is located in the Boland Open Air Farm Museum just outside Worcester, itself situated on the N1 Highway about 90km North-East of Cape Town. The museum is rather like the countryside museums in this country (e.g. Weald & Downland Museum at Singleton, Museum of East Anglian Life at Stowmarket, Avoncroft Museum at Bromsgrove, Welsh Folk Museum at Cardiff, Ulster Folk Museum, Belfast....) but in South Africa this kind of museum relies more on full-size replicas - at least of buildings - because of the problems of dismantlement, transport, and reconstruction of rural buildings in so vast a country. The mill building is a replica but the machinery is said to be at least partly original. A clasp-arm over-shot wheel on a wooden shaft drives a single pair of fairly small diameter stones through a wooden compass-arm pit wheel and iron-staved lantern wallower on a rather modern-looking steel upright shaft. The very large hopper sits on an outsize "horse" whose legs wholly encompass the tun. There is no bell alarm. Tentering is by an L-crank handle and screwed suspension rod to one end of the bridge-tree.

Montagu Watermill

Montagu is an attractive little town with astonishingly hot springs arranged to flow through a series of three or more bathing pools each a little cooler (or hotter - depending on one's direction of progress) than the last. This town lies about 70 km East-South-East of Worcester. The small mill has been removed from its original site and has been re-rected in a restored building in the grounds of a large, former residence of famous local composer of the last century. Again, as in Worcester, there is a clasp-arm overshot wheel on a wooden shaft driving a single pair of stones through a wooden pitwheel (clasp-arm in this case) on a wooden shaft and an iron-staved lantern wallower. At this mill, the relative sizes of hopper, horse and tun are more orthodox. All the stone furniture is very new and restoration is not yet complete: there is at present

no shoe, and the tentering screw control for the end of the bridge tree has not yet been fitted .

Swellendam Watermill

Swellendam lies about 180 Km due East of Cape Town on Highway N2. Here there is another museum of life a century and more ago (the Drostdy Museum). Among the exhibits is a small watermill removed from its original site, re-erected and restored in a reconstruction of the mill building. A rather small undershot wheel on a wooden shaft drives its single pair of stones through a wooden clasp-arm pit-wheel and iron staved wallower. In his book, Walton points out (p.47) that two early illustrations of Swellendam show a mill with an undershot wheel. However, when we met Mr.Walton in Cape Town last autumn, he drew attention to the fact that, as sited, the slender leat runs down the hill to the mill from a height level with, or maybe even higher than, the mill roof. The mill, as now sited, could have been powered by an overshot wheel - but the mill as constructed can and does grind.

In this mill, as in that at Worcester, the hopper and horse are - by European standards - unusually large and straddle the relatively small tun. The upper end of the shoe is suspended from two cords attached to the hursting (and the hopper.) The stone drive is through a wooden clasp arm pitwheel and iron-staved lantern wallower.

Genadenal Watermill

This mill is situated in the Moravian Mission village of the same name, about 25Km North of the N2 highway at about 100 Km East of Cape Town. Our guide book said the mill was still working, but when we found the mill it had clearly been out of use for some years. The building is on two storeys with a thatched roof and orange-brown rendered walls. There are white mouldings around the windows and doorways, and lines of white quoins down two ends of the front facade . The water wheel, of about 3 metres diameter, is wholly in iron and is overshot from a shallow leat presently supported rather precariously on steel poles . The pitwheel drives a layshaft which itself drives two pairs of stones through bevel gearing . A belt pulley on the end of the layshaft is available to drive other machinery. The tuns are in metal, and only one pair of stones has furniture in place. Beneath the metal chutes is an Archimedes conveyer leading to a bucket elevator. The tuns are painted orange-brown as is the conveyor housing. The stone furniture and the finely shaped wooden hursting are painted blue.

Other rooms contain the remains of other machinery, and one room still houses a more or less complete Crossley engine

Company's Drift Watermill (Bot Rivier)

The small town of Bot Rivier (on the river of the same name) is about 75 Km South-East of Cape Town on the N2 highway. We arrived at this mill just as Mr. Beaumont, the owner, was leaving to supervise work on his farm. He very kindly returned in order to show us over the watermill (and later to offer us refreshments in

his house and nectarines from his farm). This mill has a large over-shot wheel. At least one rough whitewashed stone pier and an iron support for the leat are still in place, but the leat itself is missing . The iron watershaft carries both a large clasp-arm wooden pitwheel and an almost equally large iron belt pulley to power two other pairs of stones. Unlike other mills described above, in this mill the wallower is an all-iron spur pinion, tentering is by means of a hand-wheel and screw acting directly through the footstep bearing of the stone spindle. The bridge tree consists of two lengths of angle iron fixed rigidly to the upright timbers of the hursting. An even more curious feature of this particular mill is that the last dressing the main pair of stones received, was never completed. The bedstone was fully dressed though with an unusual pattern. This is repeated on the runner but work on the latter was abandoned well before the task was finished. The two other pairs of stones are mounted in belt-driven "portable mills". One is a neat wooden unit from Germany standing on an iron hurst frame and with the label "A.Gutman - Maschinenfabrik & Kesselschmiede (machine and boiler maker) Franfurt a O" (an der Oder) . The other is a wholly iron structure enclosing a pair of vertically mounted French burrstones and with the words "Stamford Stone Mill - Blackstone & Co. Ltd., Stamford, England" incorporated in the casting of the underframe.

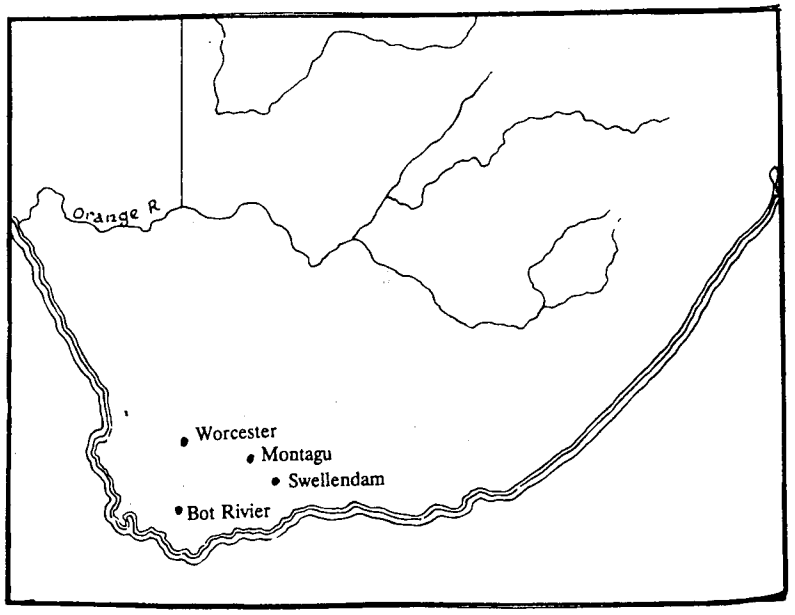


Figure 1. Map of South Africa showing the mills visited.

Other Mills

We also saw another belt-driven "portable mill" at Boland Museum in Worcester. I could not find a maker's plate on this neatly made, all-metal, machine. It had with a modern "silent feed" to the horizontally mounted stones inside. This particular mill is located near a slot in the wall of the relatively large building housing it, and is aligned with a horse engine outside. The other end of the same building houses a horse mill, which can take two animals. Our charming and most informative lady guide (dressed in costume of the early settlers) told us that the mill is sometimes set in motion using a horse and a donkey. In this mill the upright shaft carries a large great spur wheel, with its rim partly supported by diagonal struts from near the base of the upright shaft. This wheel drives a lantern pinion on the stone spindle beneath the stones, which are themselves on the upper floor of the building. Also at Worcester was an animal powered machine, a small donkey bucket pump.

We did see another horse mill at Swellendam. It was rope-driven from the rim of the great wheel on the upright shaft. (In his book, Walton records that usually rope-driven horse mills are over-drift, though at least one is underdrift. pp.172-3).The stone furniture for this horse mill is "robust", with a square topless tun and a very large hopper. Tentering is by "bedspanner". Last but, historically speaking, not the least was a hand quern set with what looked like the bottom section of an iron bound wooden cask.

Selected Bibliography

1. Walton J. "South African Mills" *Transactions of the Third Symposium of The International Molinological Society,* 1973.

2. Walton J. "Watermills, Windmills and Horse Mills of South Africa" C.Struik, Cape Town 1974.

3. Major J.K. "'Animal Powered Engines." Batsford, London 1978.

A FOURTEENTH CENTURY MILLSTONE TRANSACTION

An awful warning about quoting secondary sources.

by Gordon Tucker

I recently published a major paper on millstone making in England [1], and although it was concerned almost entirely with the 18th and 19th centuries, I did include a little data on millstone costs in earlier centuries. One item was a 14th century transaction, which I quoted from Leslie Syson's well regarded book "British Water-Mills" published in 1965 [2]. The transaction was the purchase of five foreign millstones in London and their transport to Henley, boring holes in them, and then the transport of two stones to Cuxham in Oxfordshire and another two to Oxford. Syson gives the cost of the stones themselves as £3.3s.4d., and all the other costs he lists add up to £1.14s.10$^{1}/_{4}$d. He comments that "the transport adds almost 50 per cent to the original cost". The cost of the stones was so low that I commented in my paper that "these must have been very small stones". [3]

Just as my paper was about to be published - long after the proofs had been returned - Mr.W.A.Seaby discovered in a drawer at the Warwick Museum a sheet of paper containing a typed translation of the original Latin manuscript account of this transaction, and knowing my concern with millstones, sent a copy to me. This sheet showed the cost of the five millstones as £15.16s.8d., with 63s.4d. as the cost of **each one.** The other costs agreed with those quoted by Syson, so that, in fact the transport from London added almost 10 per cent - not 50 per cent - to the original cost. The discrepancy was so serious that I decided to investigate the matter, starting with the original manuscript, which is in the remarkable collection of the Cuxham manorial archives at Merton College, Oxford. A book containing a general discussion of these documents and their background, and transcriptions (not translations) of a large proportion of the collection, has been published by Professor P.D.A.Harvey of Durham [4], but this particular roll, which is identified by Merton College as MCR 3853, is not included. A slightly touched-up copy of the relevant section of this roll is reproduced here by courtesy of the Warden and Scholars of Merton College Oxford. No exact dates are given, but the year was 1330-31. Although the script is difficult to read, and the Latin words are much abbreviated, it is not too difficult to discern, in the first line, very near the beginning, "*v molis*" (5 millstones) [5], and about the middle of the line "*xv.L xvj.s viij.d*" (15L.16s.8d.), followed after two abbreviated words by "*Lxiij.s iiij.d*" (63s.4d.) as the price of each. So the translation found at Warwick was correct and Syson was wrong. The translation turned out to be a very old one by Professor Harvey, who has been kind enough to polish it up to his satisfaction; and with his permission it is set out below:-

> "The same [i.e. Robert Oldman, reeve of Cuxham] accounts for five mill-stones from abroad (*de partibus transmarinis*) bought in London, £15.16s.8d., the price of each being 63s.4d. In God's

Copy of a portion of Cuxham Manorial Roll (Merton College reference MCR 3853) dealing with the purchase and handling of five foreign millstones in 1330-31. The copy has been slightly touched-up by D.G.Tucker. Reproduced here by courtesy of the Warden and Scholars of Merton College Oxford.

money (*in argento dei*) for the said stones 1d. In 5 gallons of wine bought for drink-money (*beveria*) for the same 2s.1d. In loading the said mill-stones on to the boat at London 5s. In wharf-dues (*warvagium*) there $7^1/_2$d. In murage (*muragium* toll for the upkeep of town walls) there 10d. In carrying the said mill-stones from London to Henley-on-Thames (*Henle*) 11s. 2d. In murage at Maidenhead (*Meydenehuth*) 10d. In the expenses of the reeve, his boy and his horse for three days going and returning to buy the said mill-stones at London 3s.$0^1/_4$d. In the expenses of the same going there another time for four days to have the said mill-stones transported 4s. In the expenses of three men for three days at Henley boring (*penetrand*) the said mill-stones together with the expenses of two carters taking two of the stones to Cuxham (*Couxham*) 3s.9d. In iron bought for the mill-stones 2 1/2d. In steel bought for the implements (*biles*) for boring (*penetrand*) the said mill-stones 9d. In the smith's wages for making the said implements and sharpening them many times 2s. In four hoops (*in iiij hopis*) bought for two mill-stones taken to Oxford 6d."

The most probable explanation of the four hoops for two millstones is that they were iron hoops or bands shrunk on the stones to prevent shattering under stress - a practice very common in more recent times.

The last full line of the reproduced piece of document refers to an unrelated transaction (a big rope bought for the Great Hall) costing xiij.s iiij.d (13s.4d.), which when added to the total of £17.11s.$6^1/_4$d. of the millstone transaction, correctly comes to xviij.L iiij.s x.dq (£18.4s.$10^1/_4$d.), as given at the bottom of the extract.

A much earlier translation was published by Rogers [6] in 1866 and in effect formed the basis of all subsequent published mention of the transaction. Roger's translation differs little from Harvey's in the reading of the script and the meaning of the words, and agrees exactly in all the figures of costs. So it may be taken as essentially correct. Yet when reproduced in summarised form in Bennett and Elton's highly respected treatise "History of Corn Milling" in 1900, [7] the cost of the five stones in London appears as £3.3s.5d. (although two pages earlier they correctly state £3.3s.4d. as the cost of **each** !). This mistake is inexplicable.

Harvey's book of 1965 on Cuxham [8] mentions the transaction but refers to Rogers for details. Syson, who so badly misled me, quotes as his own source a book by Hassall [9], but the latter author, who also refers to Rogers as his source, correctly gives the cost of the millstones as £3.3s.4d. each. Syson's error seems inexplicable too.

The details of the millstone transaction are in themselves very interesting, and they were discussed fascinatingly and at length by Rogers in his book [10], so will not be further discussed here

It is hoped this note will have proved interesting anyway, but the lesson to be learnt is: quote from other authors at your peril: get back to the original source if you possibly can.

I am very grateful to Professor Harvey for his co-operation and permission to use his translation, to Mr.J.B.Burglass of Merton College Library for supplying a copy of the original document, Mr.R.A.Holt and Dr.B.S.Benedikz of the University of Birmingham for advice, and most of all to Mr.W.A.Seaby for finding, and thinking to send to me, the sheet containing Professor Harvey's early translation which started off this small investigation.

References and Notes.

1. D.G.Tucker, "Millstone making in England", *Indust. Archaeol. Rev.*,**9**, Spring 1987, pp.167-188.

2. L.Syson, "British Water-Mills", London, 1965, pp.113-4

3. Mr.R.A.Holt, who has studied medieval mills in depth, tells me that he does not consider this figure of cost exceptionally low, although in this particular case it does turn out to be wrong.

4. P.D.A.Harvey, "Manorial Records of Cuxham, Oxfordshire, circa 1200-1359", H.M.S.O., London, 1976.

5. Strictly "*mola*" (of which "*molis*" is presumably the the dative plural) means mill, and the word for millstone is "*molaris*", but it seems this usage is not unusual.

6. J.E.Thorold Rogers, "A History of Agriculture and Prices in England, 1259-1793", Vol.1, Oxford, 1866, p.505.

7. R.Bennett and J.Elton, "History of Corn Milling", Vol.3, "Feudal Laws and Customs"', London, 1900, p.104.

8. P.D.A.Harvey, "A Medieval Oxfordshire Village: Cuxham 1240 to 1400", Oxford, 1965, p.103.

9. W.O.Hassall, "How They Lived", Oxford, 1962, pp.43-4.

10. Rogers, *op.cit.*, pp.505-8.

BIRKDALE OLD MILL

by Jo Roberts

Once there were many old wooden sunken peg mills on the Fylde and in the north west of England. Now only a lone wooden peg (post) remains at Warton on the Fylde (NGR SD416286) to remind us of this now extinct species of windmill. These old mills were of the sunk post type and many had "panniers" or protuberances added on to the back, sides and even the front of the buck. One such mill stood at Birkdale (better known for its golf rather than mills). It started off as a Fylde windmill being built at Kirkham (which still boasts a windmill tower, now a house). In 1780 [1] the mill was dismantled and shipped across the Ribble to be rebuilt at Birkdale.

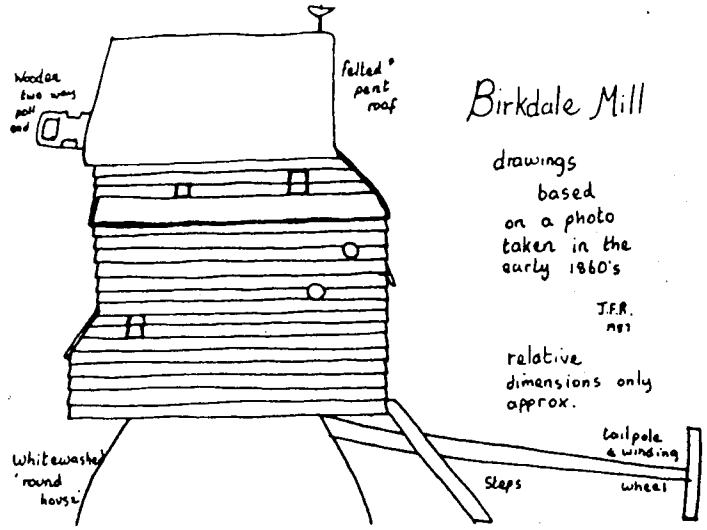
Sylvia Harrop [2] sets the scene:-

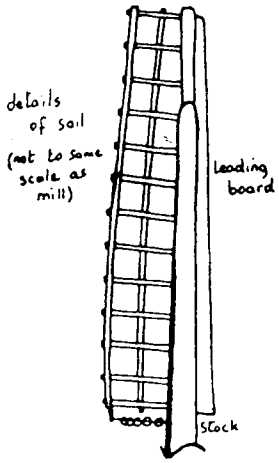
> "Crossing the boundary between North Meols and Birkdale one almost immediately came upon Birkdale Mill, standing on a high point with views all round. This mill had come to Birkdale second-hand. It originally stood on the Fylde, at Kirkham; but then around 1750 was dismantled, packed up, ferried across the Ribble and reassembled in Birkdale. It was a post or peg-mill with the main body of the mill and its sails constructed of wood, standing on a brick base, and with a wooden post or peg which turned the mill into the wind. It became a favourite subject for artists in the mid 19th century. The miller's cottage was across the road from the mill. Built in the early 1790s, it was of the usual local type with whitewashed walls of mud and timber, small windows and a thatched roof. The out-buildings were also thatched."

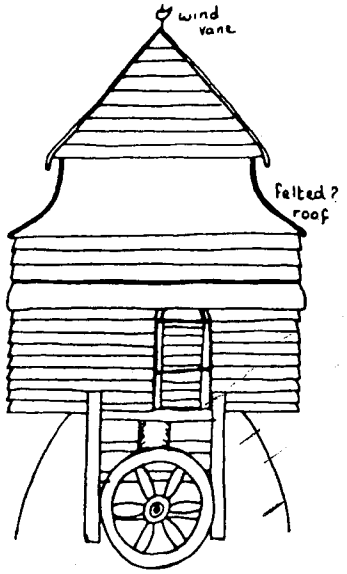
Unfortunately the mill was burnt down in 1868 [1]. It stood at what is now the corner of Mosley Street and Grove Street. There is now no remnant of the mill left, the area being totally built up. Today a school stands very close to where the mill would have been. Mill Lane is now part of Mosley Street. Birkdale Mill is shown on the Birkdale Manorial Map of 1809 with a little drawing of a postmill.

The mill was not overlooked by the relatives of the famous either, for Miss Hannah Jones[3] wrote in 1824:-

> "In the course of our ramble we came to an old corn mill, built on a very different principle from those of modern architecture. The whole structure was movable, for the purpose of catching the wind from whatever point it might blow. The gentlemen of the party would explore the interior and they came out powdered in fine style the effect of the flour on their black coats being very imposing.".







The mill was a sunken post mill where the bottom of the post and crosstrees were buried in the ground, making the actual mill body very near the ground [4]. The mill had a horizontally boarded body with additions at both sides and the back. There was even a low one at the front, behind the sails. There were small flaps and circular openings instead of windows. The buck was entered by a door in the right of the rather porch-like addition at the back of the mill. It was reached by a short set of steps. Through these ran the tailpole, (shown at the FRONT of the mill in a watercolour painted about 1850!). The tailpole was almost horizontal due to the post being sunk in the ground [4]. From various paintings and the photograph some approximate drawings of the mill have been produced. The various panniers, porches and protuberances seem to have fallen off the mill from time to time. Some may well have been rebuilt at some time. There were four common sails spread with canvas, in the normal way with the usual settings. They (at least the one studied) had 12 bays, 13 sail bars and a curtain rail at the heel for the cloth. There was only one uplong. The sail frames were on stocks morticed in the usual way through the wooden poll end. (They are often on an iron cross in this area but the cross fixing is only used in the form of an an iron casting.) The sails appear to taper a little towards the tip as was often the custom in the north west [5]. The sails have a good twist with a reverse twist near the heel to enable them to avoid hitting the mill body.

This mill has been much painted and drawn [6]. Many of the paintings do not tally in detail with each other on the mill's looks and construction, and sometimes considerable inaccuracies have been made. Fortunately an early photograph of the mill exists which clears up some of the discrepancies (see plate 8).

Two other mills of this type, of which there are many pictures and photographs, show the nature of the exterior of these mills very well. The first one was at Hambleton [7] (NGR SD380418) in the north of the Fylde and the second was at Warton, Fylde [8] (NGR SD416286). This is a little consolation, there being now no mills of this type to examine.

References

1. Southport Visitor "Now and Then" Special Christmas edition 1986. p.5.

2. "Old Birkdale and Ainsdale" by Sylvia Harrop pub. The Birkdale and Ainsdale Historical Society. Some details given, together with a photograph of nearby Ainsdale Tower Mill (now also sadly no more).

3. Miss Hannah Jones was the grandmother of Rudyard Kipling and wrote these words on a visit to Southport in 1824.

4. "History of Cornmilling" vol.2 p.278 - sketch by W.G.Herdman (sketch then in the possession of R.Bennett himself.) R.Bennett and J.Elton 1899.

5. "Review 1984" of the North-west Mills Group p.3. "Comparitive notes on tower mills in Anglesey and North West England." by J.F.Roberts.

6. List of Illustrations consulted for this paper -

a) Birkdale Old Mill - Painting by W.G.Herdman undated. Housed in the Botanic Gardens Museum, Churchtown.

b) also see ref.4 another Herdman picture.

c) Slides shown by D.Peterson at S.P.A.B. Windmill meeting 1981.

d) Everyday scene beside Birkdale Mill by E.Vernon

e) Photograph of Birkdale Mill taken about 1860.

f) Birkdale Mill - watercolour painted about 1850 (shows tailpole at front of mill!)

7. "Windmill Land" by A.Clarke pub. J.M.Dent and Sons Ltd. 1916. Photographs of Hamble Mill facing pp. 262 and 263 show it to be very similar to Birkdale Mill.

8. "Victorian and Edwardian Windmills and Watermills from old photographs" J.K.Major and M.Watts pub. Batsford Ltd. 1977. Photograph 4 shows Warton (misnamed Freckleton) Mill and photograph 136 the mill at Warton in decay, showing the lantern wallower.

FROM MILL TO MEGAWATT

The first half-century of hydroelectricity

By Gordon Tucker

1. Introduction

Electricity began to come into general use around 1880 with the availability of the recently-invented incandescent filament lamps of Swan and Edison in addition to the existing range of arc-lamps and other electrical equipment. The filament lamps could be worked in parallel across an electrical supply main, and made central generating stations possible. Public supply started towards the end of 1881, and legislation controlled it from 1882. Although the steam engine had been the most important source of power for almost a century, and internal combustion engines had started to come into use, yet there was still a deep-seated preference to use water power and its presumed economies wherever it was available. It was therefore natural that water power should be used for electricity generation as much as possible, and many mills were adapted to drive dynamos for both private and public supply of electricity. It was nearly a decade before purpose-built hydroelectric generating stations were built, except in one or two special cases.

At this introductory stage it will be useful to consider the potential of water power in different parts of the world. Table 1 sets out a summary. From this it will be seen that water can produce a very great deal of the world's demand for electricity - but not very much of Britain's. The total British water-power potential only equals the output of a really large modern thermal power station. So it will be misleading to discuss hydroelectric developments in Britain without putting them in context with the rest of the world. This paper will attempt to do this.

TABLE 1

Estimated World Hydroelectric Potential

Total between 0.5 and 1 m MW distributed roughly thus:-

Africa	41%
Asia	23%
N.America	13%
S.America	10%
Europe	10%
Oceania	3%
(Britain	0.2%)

Actual development was about 10% of total in 1960 but most of this was in N.America and Europe.

We look first, rather briefly, at the hydroelectric developments in Britain during the first decade or two after 1880, and then in more detail at the public supply schemes in the Midlands, both those actually built and those proposed but not built. The Midlands included the largest water-powered public-supply scheme in Britain during this early period, but we go on to describe two industrial systems of greater interest - one of them of much greater size, and both in the North. We then consider the early development of hydroelectricity in the world outside Britain, particularly on the continent of Europe, and at Niagara Falls and at Shawinigan Falls in North America. Finally we consider British developments in the first third of the 20th century, culminating in the highly successful Galloway scheme which produced a power of 102 megawatts.

2. Early hydroelectricity in Britain: the first decade or two.

The early use of water power for public electricity supply has received a good deal of attention in recent years, [1-6] and it is not necessary to go into much detail here. Table 2 lists all those sytems known to the author which came into operation up to 1900. The first two were experimental and short-lived. Wickwar, Blockley and Okehampton were based on existing industrial premises (loosely describable as "mills"), and only the last-mentioned used a turbine rather than a water-wheel; even that produced only about 8 kW of electrical power. Keswick and Lynmouth had specially-built premises, and produced 30 kW and 75 kW respectively; the former had supplementary steam drive, and the latter was notable in developing a system of pumped storage (probably the first in the world) by which surplus water power during the day could be used to pump river water to a great elevation in order to recover extra power at night when the demand for electricity was greatest. The Worcester station was by far the largest, with about 400 kW water-generated output, and is descibed in more detail in the next section. The water-generated supply survived half-a-century or more at Keswick, Lynmouth, Chagford, Worcester and Monmouth (at least), although not always with the original equipment.

Many hydroelectric schemes were proposed but, in the event, not built, and those known to the author are listed in Table 3 for the years 1881-94. Information about these schemes has been gleaned by assiduous searching of weekly reports in the electrical press of the time, mainly "The Electrician" and "Electrical Engineer". Anything approaching complete data regarding hydroelectric installations in private premises is very difficult to come by, but Tables 4 and 5 give some data on this matter.

TABLE 2

Hydroelectric Stations for Public Supply in Britain 1881-1900 - actually built

1881 Goldalming, Surrey.
1885 Greenock, Renfrewshire.
1888 Wickwar, Gloucestershire.
1888 Blockley, Gloucestershire.
1889 Okehampton, Devon.

1890 Keswick, Cumbria.
1890 Lynmouth, Devon.
1891 Chagford, Devon.
1894 Worcester.
1894 Milngavie, Dunbarton.
1896 Fort William.
1898 Salisbury, Wiltshire.
1899 Monmouth.
1900 Fladbury, Worcester.
1900 Ingleton, Yorkshire.

TABLE 3

Hydroelectric Stations for Public Supply in Britain 1881-1894 - Proposed but not built.

1881 Aberystwyth, Durham.
1882 Exeter.
1886 Lanark
1887 Cockermouth.
1888 Otley, St.Albans.
1889 Ayr, Burton-on-Trent, Penrhyn, Windsor.
1890 Llangollen.
1891 Egremont, Elgin, Helston, Hexham, Inverness, Matlock Bath, Plymouth, Richmond (Surrey), Shipley.
1892 Barnard Castle, Bridgend, Chester, Guildford, Moffat, Queensferry, Reading, Rochdale, Tutbury, Willesden.
1893 Bewdley, Cardiff, Crieff, Glynceiriog, Hawick, Llandrindod Wells, Montrose, Tiverton, Workington.
1894 Baslow, Bromsgrove, Conway, Newby Bridge, Ulverston.

TABLE 4

Some Hydroelectric Installations for Industry in Britain, 1882-1894

1882-3 Cone Paper Mill, Woolaston, Gloucestershire.
1886 Flour Mill, Boroughbridge, Yorkshire.
1886 Industrial premises in Okehampton, Devon.
1887 Flour Mill, Knottingley, Yorkshire.
1887 Paper Mill, Hope, Cefn-y-Bedd, N.Wales.
1888 Flour Mills, Buckingham.
1890 Greenside Lead Mines, Westmorland.
1893 Yeo Mill, Chagford, Devon.
1894 Paper Mills, Watchet, Somerset.
1894 Parndon Mills, Hertfordshire.

TABLE 5

Some Hydroelectric Installations in Private Houses and Estates in Britain, 1880-1889

1880 Cragside, Northumberland.
1881 Alnwick Castle, Northumberland.
1882 Carsaig, Mull.
1883 Dunphail House, Morayshire.
1884 Linden Park, Roxburghshire.
1885 Arborfield Hall, Berkshire.
1885 Bremore House, Scotland.
1885 Rothiemurcus House, Scotland.
1886 Hatfield House, Hertfordshire.
1886 Impney House, Worcester.
1887 Dovedale House, Blockley.
1887 Staghills, Bury, Lancashire.
1889 Scatwell, Inverness.
1889 Ancrum House, Roxburghshire.
1889 Ardwell House, Wigtownshire.
1889 Clapham, Yorkshire.

3. Hydroelectricity for public supply in the Midlands.

The Midlands had their fair share of hydroelectric development [7] in the early decades, with three small systems at Wickwar, Blockley and Fladbury, and what was for its time a large one at Worcester.

3.1 Wickwar, Blockley and Fladbury.

The public lighting of the little town of Wickwar in Gloucestershire was only an offshoot of a private installation started during the winter of 1887-88 by Arnold, Perret & Co.Ltd. at their brewery. It was a large brewery and had about 100 incandescent lamps. The overshot water wheel of 36 ft. diameter gave surplus power, and the town gladly accepted the offer of a public-lighting system eventually extending to 20 lamps over a mile of road, for which the town paid £15 p.a.

On the same sort of basis, some public supply was given from a mill at Blockley, also in Gloucestershire but once in Worcestershire, in 1888. The hydroelectric system at Fladbury, Worcestershire, was also based on a mill, but was a definite commercial operation with a limited company, and offered a D.C. supply to private consumers. It used two Armfield turbines. It was taken over by the Shropshire, Worcestershire and Staffordshire Electric Power Co. in 1927. A full description has been published by Mr. J.A.Crabtree in No. 5 of this journal.

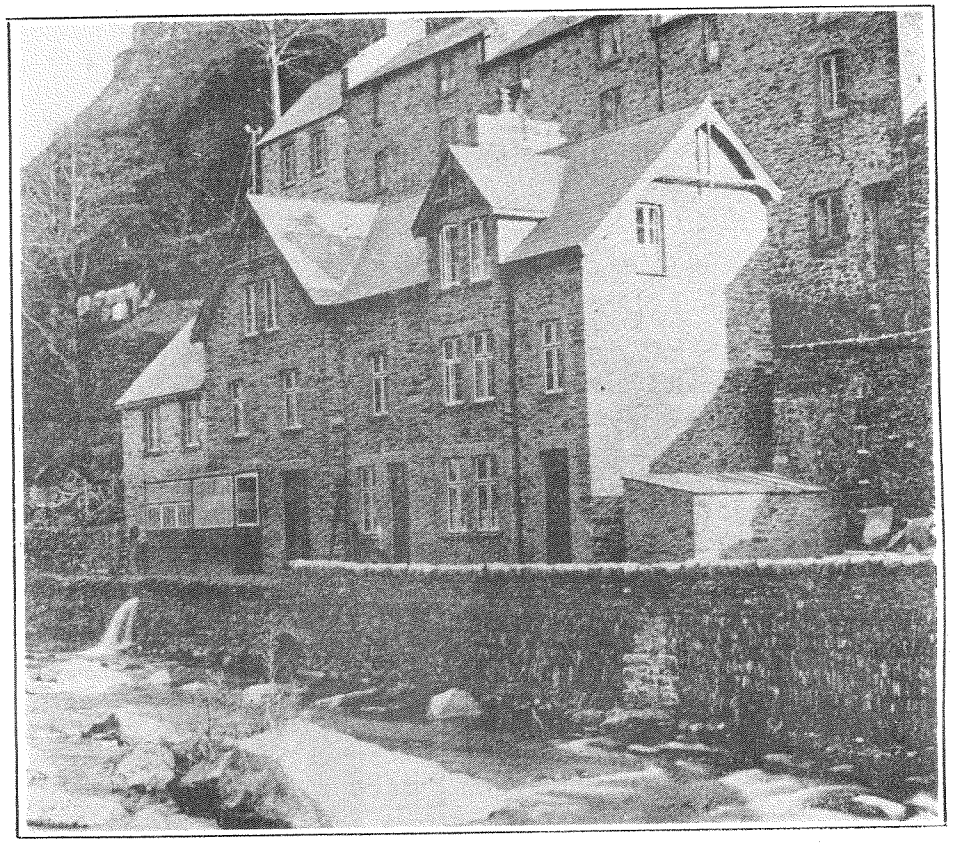


Plate 9. The hydroelectric generating station at Lynmouth, Devon. (From "Electrical Engineer", 1899.) This was opened in March 1890, and within a few years was using a pumped-storage system with a head of 760ft. and a reservoir capacity of nearly 200,000 gallons to help with peak loads. The power came from the East Lyn river, and about 75KW could be generated directly, with another 75KW when required from the water pumped to the high reservoir at times of low load. The station remained in use until destroyed by the great floods of 1952. By this time it had internal combustion engines to supplement the water power. (See Section 2 of article)

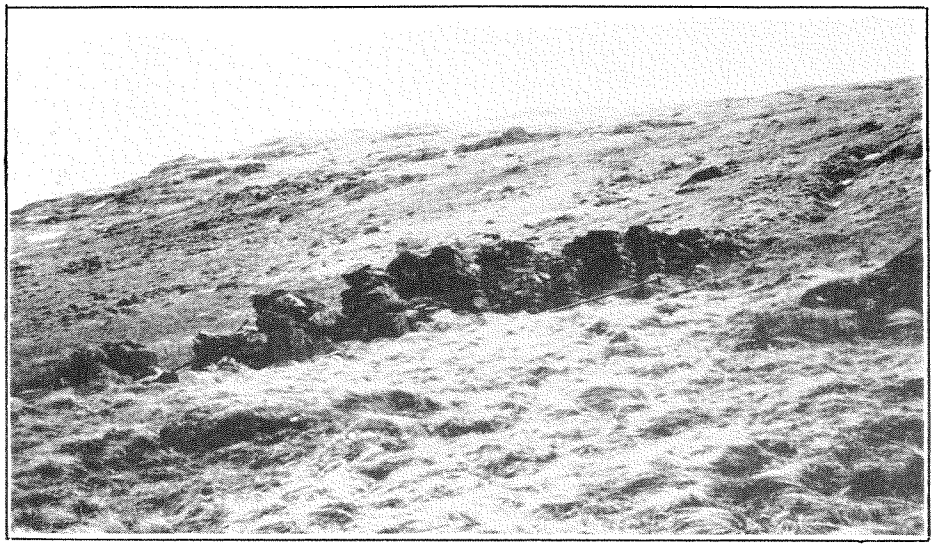


Plate 10. The remains of stone piers which supported the 15 inch iron headrace pipe which fed water at a head of about 400ft. to the hydroelectric generating station of the Greenside Lead Mines from 1890. (See Section 5.1 of article.)

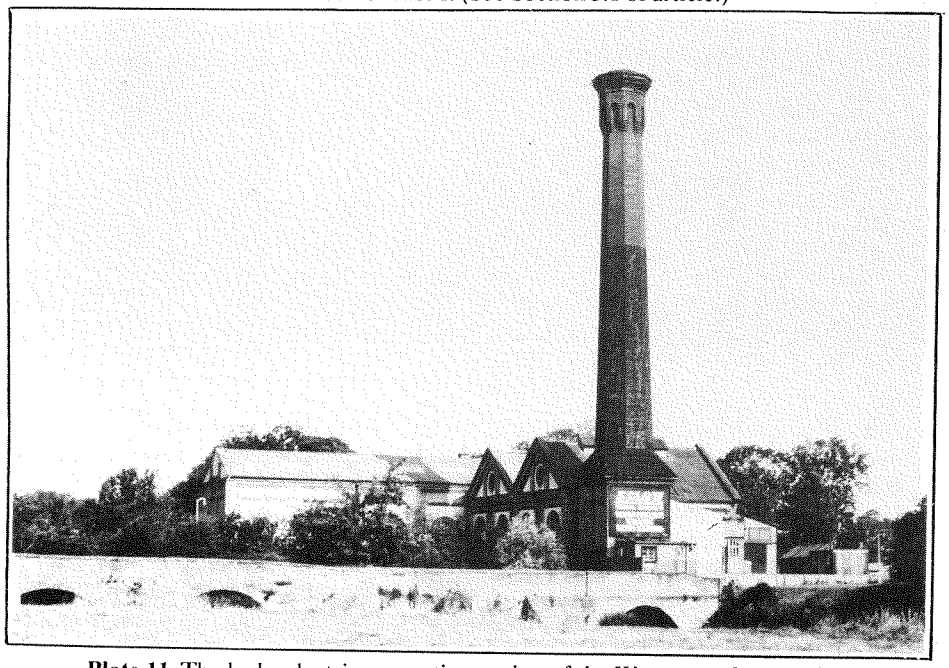


Plate 11. The hydroelectric generating station of the Worcester Corporation had steam auxiliary plant from its opening in 1894 until 1902. The boiler room, shown at the front in this photograph, was then let for commercial use. (See Section 3.2 of article)

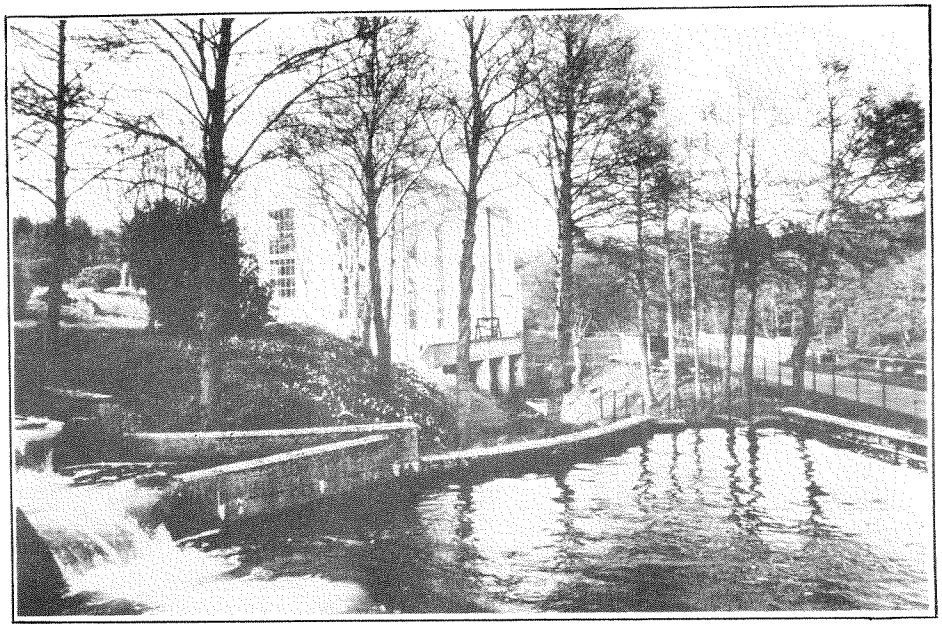
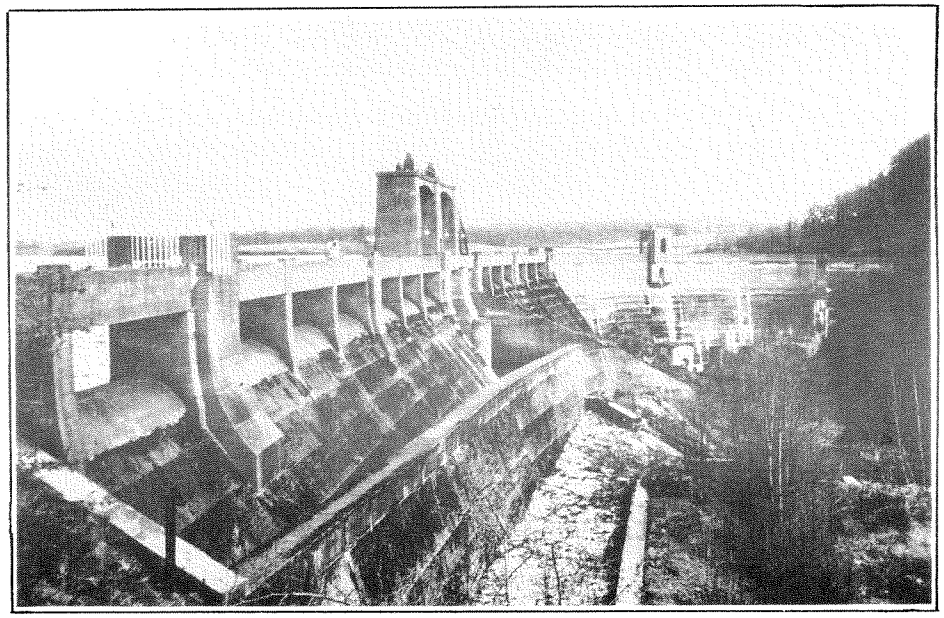


Plate 12.(above) The Earlstoun generating station of the Galloway hydroelectric power scheme of the 1930s. (See Section 7.1 of article.)

Plate 13.(below) The dam of the Galloway scheme.



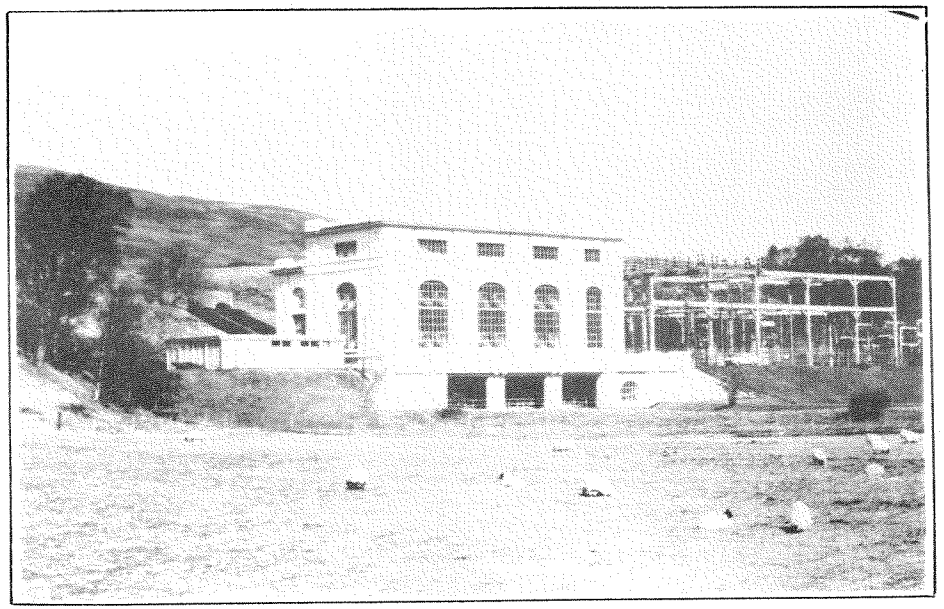


Plate 14. The hydroelectric generating station at Rannoch in the Highlands of Scotland, built in 1930 as part of the 42MW scheme of the Grampian Electricity Supply Company. It was planned by George Balfour, of the firm of Balfour Beatty, who had already developed the 20MW scheme at Kinlochleven for the British Aluminium Company. (See Table 6 of the article.) In the Grampian case the electricity had no local market and was dependent on long transmission lines to enable it to supply the industrialised Forth-Clyde belt of Scotland. Another hydroelectric station in the same scheme was opened at Tummel in 1933.

3.2 Worcester.

The Midlands had the honour for many years of having the largest hydroelectric generating station in Britain used for public supply. The City of Worcester was the first municipality in Britain to build and operate on a long-term basis its own hydroelectric station. It was opened in 1894, and had a water-generated power of up to about 400 kW. It operated from the River Teme at Powick, two miles to the south-west of the city centre, on a site where several old mills had stood. (Map ref. SO835525). It continued to generate electricity for well over half a century, and the main part of the buildings still stand on the site, used for another purpose.

As a result of several companies notifying their intention to apply for a Provisional (Parliamentary) Order to enable them to supply electricity in Worcester, the City Council decided in 1889 to apply for an Order to generate and supply electricity themselves. They duly obtained the Order and, after some delay, made plans in consultation with the Brush Co. and W.H.Preece, F.R.S. The use of water power was proposed, using the Diglis weir on the River Severn. Preece thought that the saving due to the use of water power justified quite a large cost for works at the weir. There was argument as to whether AC or DC should be used. Then in October 1892 it became evident that the Severn Conservators would not allow the use of the Diglis weir for electricity generation. However, negotiations for the use of the Powick site on the smaller River Teme were successful, and as this was some two miles from the city, the choice of AC for supply was sensible. It was estimated that up to 1500 hp of water power was available, and turbines of 600 hp were to be installed. Work started in late Autumn 1893 and the station opened on 11 October 1894. The electricity supply was taken to the city by oil-filled cables at 2200 V, and then transformed down to a suitable voltage for the consumers. The load at the opening was supplied entirely by water power.

The only water storage available was that in the headrace itself, there was sometimes a shortage of water in the river, and sometimes the Severn flooded up from its confluence a mile or two below so reducing the head; thus it was essential to have steam engines in reserve. The arrangement installed provided a great deal of flexibility; there were four 125 kW alternators in a row. The two middle ones could be driven by 160 hp water turbines or by 286 hp Brush compound vertical steam engines or by both. One of the other alternators was coupled only to a steam engine, and the remaining one only to turbines; a 60 hp turbine or a 100 hp one or both. The turbines were of mixed-flow type with a cylinder gate.

The electricity undertaking was in profit for the first time by 1899, when over half a million units were sold. The use of water power does seem to have resulted in a cheaper electricity supply, for the Worcester charge was only 2.0d per unit by 1899, whereas at Bristol, where all electricity was generated from coal, albeit cheaper coal than was obtainable at Worcester, the charge was 2.5d.

The electrification of the tramways at Worcester led to a demand for more electricity, and moreover for DC. It was decided to build a new central coal-fired steam station at Hylton Road in the city, which was opened in December 1902. From that date the steam plant was removed from the Powick station, and it functioned as a purely hydroelectric station thereafter. The no-longer needed boiler room was let for other uses. In recent years the whole station was let as an industrial building.

4. Abortive hydroelectric schemes in the Midlands.

The list of early abortive schemes in Britain, given in Table 3, includes five which can be regarded as in the Midlands. These are Burton-on-Trent, Matlock Bath, Tutbury, Bewdley, and Bromsgrove. The first four had some possibility of being viable schemes, but Bromsgrove, with only the little Spadesbourne Brook available for power, was really a non-starter. In most of these cases there is little information available.

4.1. Burton-on Trent.

In 1889 the Town Council was discussing the matter of electric lighting. According to the "Electrical Engineer" of 23 August 1889, p.141, "the proprietor of a cotton-mill has offered to let the water power on lease for the purpose of generating eletricity for the electric lighting of Burton. The gas manager has been asked to report on the matter". His report was received a few weeks later, but its contents were not reported. When, in the middle of the next year, a Provisional Order had been obtained, and demand was being assessed, there was no mention of water power.

The site offered was probably Winshill Mill, for this was, according to Owen, [8] the only mill in Burton still producing a cotton product at that time; all the earlier cotton mills had closed by 1860. The proprietor would have been glad to lease his mill, for the business was failing. The location is SK263240. Burton used a lot of water power in earlier times, and many of the leats and weirs still exist.

4.2. Matlock Bath.

The "Electrical Engineer" of 13 Feb. 1891 stated the proposal to use water power for the electricity system here, but it does not seem to have been followed up.

4.3. Tutbury

The proposal to provide this little Staffordshire town with electric light using water power appeared in the "Electrical Engineer" for 29 Jan. 1892. The source was Staton's Mill. This was an alabaster mill at SK213293, supplied with water power by a long leat from the River Dove. It seemed a reasonable proposal, but came to nothing.

4.4. Bewdley

As this small town is on the River Severn, there was undoubtedly sufficient water power available, although it might have proved expensive to harness it. The Town Council discussed a scheme early in January 1893, and appointed a committee to look

further into the matter. According to the "Electrical Engineer" of 5 May 1893, the scheme was considered too risky, and was dropped.

4.5 Bromsgrove.

This sizeable Worcestershire town lies on the diminutive Spadesbourne Brook, which later, with other streams, becomes the River Salwarpe. Admittedly there were many mills on this brook [9] but at no site was more than a few horse-power available. Yet when an electricity scheme was proposed for Bromsgrove ("Electrician", 31 August 1894, p.529), it was stated that "It was proposed to use both steam and water power, the latter being utilised as much as possible". This proposal shows very clearly how often the promoters of electricity schemes failed to appreciate the enormous rate of growth of demand there would be for electricity. Fortunately this proposal fell through.

5. Major industrial hydroelectric schemes in Britain in the 1890s

Although the Worcester hydroelectric scheme was by far the largest in Britain for public supply before 1900, yet there were at least two industrial schemes of comparable size and much greater interest in this period; namely the electrification of the Greenside lead mines in Westmorland and the development of aluminium smelting at the Falls of Foyers in the north of Scotland.

5.1 The Greenside lead mines

The Greenside Silver-Lead Mining and Smelting Co. had been operating on the slopes of the mountain Helvellyn in the English Lake District for over 50 years and had made extensive use of water power when it was decided in 1890 to install a hydroelectric system as a more convenient means of transmitting and utilising water power in the mines [10]. The consequent economies are thought to have accounted for the survival of the company as a going concern until 1962. The electricity provided lighting, pumping, winding, and locomotive haulage underground. The initial installation comprised one 100 hp Vortex reaction turbine, but later a 100 hp Pelton wheel was added, and by 1911 the total turbine power was at least 300 hp and may have been 400 hp. Electrical distribution was by bare overhead wire, outside the mine, and insulated cable inside.

The mines were to the west of Glenridding at around NY365174. The generating station was on the wild mountainside at NY358168. Watercourses were built (and still remain) to bring the water of Keppelcove Tarn, Red Tarn, Brown Cove, and the Red Tarn and Glenridding Becks to a suitable point on the 1750 ft. contour, giving a head of about 400 ft. at the generating station. A 15-inch pipe, partly supported on stone piers, some of which remain, carried the water down to the station. The site is still detectable by some of the foundations. It was a wild spot, and one feels for the lone station attendant on a winter's night.

The underground electric railway was one of the more interesting features of the system. It was about 1.5 miles long, in the Lucy level of the mine, and of about 2ft.

gauge. It had one locomotive of 14 hp, weighing 2.5 tons, collecting its electric supply by two pairs of contact pulleys running on two bare phosphor-bronze conductors attached to the roof of the tunnel. The voltage was 250 and the situation was damp, but no accidents appear to have been reported. The locomotive was still in existence, and probably running, in 1921. It is supposed to have hauled a train of 12 wagons (about 18 tons) over the route in about 20 minutes.

5.2 Aluminium Smelting at Foyers

In the Herault process, aluminium ore (bauxite), which is aluminium oxide, is reduced to metallic aluminium by melting in an electric furnace in which electricity is passed through the molten ore from carbon electrodes [11]. The carbon combines with the oxygen in the oxide, leaving aluminium. The economics of the process depend on a very cheap supply of electricity. Hence the development of smelters near the sources of hydroelectricity.

The British Aluminium Co. was formed in 1894 to exploit the Falls of Foyers in Inverness-shire, where the River Foyers runs out of Stratherrick, giving a fall of over 350 ft. into Loch Ness [12]. The bauxite was mined in Ireland, concentrated at Larne, and then shipped to Foyers. The smelter went into operation in 1896. There were a tunnel and pipes to bring the water to the generating station, and initially there were five large Escher-Wyss turbines each directly coupled to a dynamo giving 7.5 kA at 64V; so the total power generated was about 2,500 kW. The installation was roughly doubled in capacity by 1905, and remained in use until 1967.

There were smelters in other countries too, and in Britain the industry expanded so that by 1909 the B.A.Co. had another big hydroelectric smelter at Kinlochleven, with an electrical capacity of about 12,000 kW, and another company, the Aluminium Corporation, had one in North Wales, at Dolgarrog, using a head of over 1000 ft. and with an electrical capacity of about 4,000 kW. It was at Dolgarrog that the dam burst in 1925, killing 16 people.

The B.A.Co. expanded still further in the 1920s, with the big Lochaber scheme at Ben Nevis, the smelter being at Fort William, and the electrical capacity being around 60,000 kW.

Before the reader is unduly impressed by the magnitude of these figures, it should be pointed out that the total aluminium production in Britain in 1921 was only 5.35% of the world's production, that it fell to 2.95% by 1945, and to only 0.75% in 1960. The largest producer of aluminium has long been the U.S.A. However, when the Foyers scheme was opened in 1896, it was one of the very few in the world, and rated as a large one.

6. The early years of hydroelectricity in Europe, North America, & elsewhere

As would be expected, the much greater availability of water power in convenient places in most of the other countries of Europe, in much of North America

and in other countries such as Australia, New Zealand, India etc., led to much more widespread development of hydroelectricity in most such places. One or two examples will give the idea. In France, for instance, a very useful list of electricity generating stations, mostly for public supply, was given, complete with capacity and date and source of power, in the French journal "L'industrie electrique" for 10 June 1892. A total of 104 hydroelectric stations was listed, roughly half the total number of generating stations. Capacity was given in horse-power of the turbines; 10 hp would have corresponded roughly to about 6 kW electrical output. The largest station was of 1280 hp; there were another 16 between 100 and 1000 hp; the remaining 87 were under 100 hp. This is a very different picture from that for Britain.

Over the years 1880-1894, even the British electrical journals reported, according to my recording, about 160 hydroelectric stations on the Continent and over 50 in the rest of the world. The largest noted in Europe had an electrical capacity of the order of 5,000 kW.

As to North America, "The Electrician" for 10 September 1886 reported that up to mid 1886, it had been estimated that not less than 14,000 hp. (say 10,000 kW electrical power) was derived from water power in the U.S.A. and Canada in the form of electricity, mostly for arc lighting. By the 1890s, the giant Niagara hydroelectric scheme was under way; we shall discuss this later.

One of the most important influences in all this was the development of long-distance electrical power transmission. So much of the water power available was in the wrong places, remote from the centres of population and industry. Occasionally it was possible to set up a new industry where the power was, as at Foyers for aluminium smelting; but the real need was to get the power from the source to the place where it was needed. There were, in the 19th century, many examples of very long leats, or power canals, to carry water power over many miles, in the Welsh lead mines, for example. In Switzerland [13] there were interesting examples of wire-rope and high-pressure hydraulic power transmission; the former at Schaffhausen on the River Rhine, where from about 1874 some 1500 hp from the great waterfalls was transmitted to the factories by wire ropes; and the latter at Geneva where the lake flows out into the River Rhone and from 1886 afforded about 6000 hp, converted by turbines and pumps into the supply for a hydraulic piped power distribution system. But the development of electrical power distribution revolutionised all this.

The most important experimental electrical long-distance system was that between Lauffen and Frankfurt in Germany in 1892. It was 105 miles long, three-phase AC, operating at 40,000 V, transmitting about 150 kW. It was real pioneering, and it was successful. It was seen at once as the answer to the water-power problem, and was applied in numerous cases, although rarely involving such great distances. By 1895, "Cassier's Magazine" was able to tabulate some 25 examples, totalling over 44,000 hp, or say, well over 30,000 kW electrical power. Clearly, hydroelectricity could now develop rapidly, and outside Britain it did.

6.1 Some major European schemes of the 1890s

Even before the influence of long-distance electrical transmission was felt, there were some notable installations in Europe, much larger than the 400 kW scheme at Worcester. At Neuhausen [14], on the Rhine in Switzerland, an aluminium smelter using the same process as later used at Foyers in Scotland was established as early as 1888, generating about 2000 kW of electrical power. A few miles above it, the old wire-rope system at Schaffhausen was supplemented in 1890-91 by a 400 kW electrical system. In 1892, an earlier small system at Tivoli [15], about 20 miles from Rome, was replaced by a large system generating about 2,700 kW which was fed by single-phase line to Rome. Then, around 1896, the great hydraulic-power system at Geneva, previously described, was supplemented by a much greater electrical system of about 13,000 kW, using two-phase transmission over the four miles from the station to the town.

6.2 The Niagara Falls scheme [16]

The Niagara River is only about 30 miles long, flowing between Lakes Erie and Ontario, and separating Canada and the U.S.A. The main falls have a head of 165 ft. and above them is a half-mile stretch of rapids with a fall of 55 ft. The ordinary flow is about 275,000 cu.ft. per second, giving a maximum generating capacity of about 5 million kW or, 5,000 MW. The water power was used for minor industrial purposes from 1725, but in 1861 a major development was opened, with a mile-long power canal, 35 ft. wide by 8 ft. deep, bringing water from above the rapids to a basin 214 ft. above the lower river. Many mills were built to use this power, and although the head was not fully utilised, the flow in the canal was; about 10,000 hp was obtained; not much more than one-thousandth of the power of the falls.

In 1886, Thomas Evershed put forward a plan with a view to attracting industry to Niagara. To preserve the environment of the falls, he proposed the industrial area should be a mile above the falls, turbine-powered, with the tail water taken through a long tunnel to an inconspicuous point well below the falls. This scheme would provide 100,000 hp on the American side. If required, a further 250,000 hp could later be provided on the Canadian side. Financial support was forthcoming, and the Niagara Company was formed in 1889. They went ahead with the provision of huge turbines (5,000 hp each), ultimately to number 20, made by Faesch and Piccard of Geneva, placed 140 ft. below the surface, transmitting power to the surface by shaft.

An international panel of consultants, under Lord Kelvin, considered further developments, and decided on electrical generation and transmission. They thought industry would develop at Buffalo, only 20 miles away, and planned a two-phase system. But industry developed mainly on the spot at Niagara.

The power was first used in 1895 by an aluminium smelter at Niagara. The transmission line to Buffalo was opened as a three-phase system in 1896. Already the scheme had the world's largest generators and transformers. Electric lighting and an electric tramway were provided at Niagara, and many other industries moved there to

use the cheap power. So Niagara was a great success. By the 1960s, over 4,000 MW were generated there.

6.3 Early hydroelectric development in Quebec

The area of Quebec in Canada, to the east and north-east of Montreal, was, in the 1890s, a practically empty land with enormous water power potential. The development of the Shawinigan Water and Power Co., which began seriously in 1898, is an example of how the availability of what is seen to be cheap power can produce a new pattern of industry [17].

The territory of the company was the land around the St.Maurice River, a northern tributary of the St.Lawrence about halfway between Montreal and Quebec City. The main power location was Shawinigan Falls, and the nearest established city was Three Rivers. The electricity generated was transmitted eventually over 100 miles, even to Montreal, and also to the south and south-east. But as elsewhere, the first big load was an aluminium smelter which came to Shawinigan and purchased about 3,500 kW; then a pulp mill, then a carbide-manufacturing plant. Urban development went along with the industrial development, and lighting companies were being supplied.

This kind of story can no doubt be repeated for many other places.

7. British hydroelectric schemes in the first third of the 20th century.

We have already mentioned the expansion of aluminium smelting by hydroelectricity in Britain after 1900; this did indeed represent the greater part of hydroelectric development between 1900 and 1930, as the data in Table 6 shows [18]. During this period there were numerous small installations of purely local significance, but in the light of the very large schemes in other countries, it is only our larger ones that we should now consider. It will be seen from Table 6 that there was no large system built between 1908 and 1926. The reasons for this were many; environmental objections had been significant even in regard to Foyers; the coal industry saw hydroelectricty as a threat to its business; Wales saw developments in Scotland as a threat to the exploitation of its own potential. These matters are discussed by Hennessey [19]. After the First World War a Water Power Resources Committee was set up by Parliament, and reported in 1919 and 1921. It set out many possible schemes, and clearly one of its most important considerations was the creation of employment and the prevention of depopulation in the Highlands. Cost and the need for long transmission lines were not obstacles; the proposals seemed economically viable. It can be seen from Table 6 that a few schemes did develop. But the factor which led to the largest and most interesting scheme - the Galloway scheme [20] - was the development of the Electricity Grid in Britain. The Grid was authorised by an Act of Parliament in 1926, and opened for service in 1933. The Galloway scheme was originally conceived by the Galloway Water Power Co. as having a capacity of only 20 MW, but the availability of the grid to carry away its electricity to the industrial parts of South Scotland and North-west England (and elsewhere) caused the planned

capacity to be raised to 102 MW. The scheme will now be considered in a little more detail.

TABLE 6

Principal British hydroelectric stations in 1930

Station	Date opened	Output (MW)	Purpose
Foyers, Inverness	1895	4.5	Aluminium Smelting
Cym Dyli, N.Wales	1906	4.5	Public Supply
Dolgarrog, N.Wales	1907	10	Aluminium & public supply
Kinlochleven, Argyll	1908	20	Aluminium
Falls of Clyde	1926	15.5	Public Supply (2 stations)
Maentwrog, N.Wales	1928	18	Public Supply
Lochaber	1929	75*	Aluminium
Grampian scheme	still under construction	42*	Public supply(4 stations)

(* when complete)

TABLE 7

The Galloway Hydroelectric Scheme (early 1930s)

Generating Station	Catchment Area(sq.mi.)	Ave.Net Head(ft.)	Total Gen. Cap.(MW)
Tongland	393	102	33
Glenlee	46	365	24
Kendoon	152	150	21
Earlstoun	193	65	12
Carsfad	171	64	12
			Total 102

7.1 The Galloway hydroelectric scheme

The Act of Parliament for this scheme was passed in 1929, and electricity was supplied from 1935. It had been largely the brainchild of William McLellan (of the famous firm of Merz & McLellan of Newcastle upon Tyne), but he died in 1934 and so did not see the completion of the scheme. The main particulars are shown in Table 7. The water of a very large area of Galloway, in South-west Scotland, was used, one or two existing lochs were enlarged and some new ones created, care was taken in the planning and it is probably now generally agreed that the already high landscape value was enhanced. Three principal lengths of tunnel were built, of 3.6, 1.4 and 1.0 miles respectively. In spite of the high head at Glenlee generating station, which operated entirely on the water tunnelled down from the man-made Clatteringshaws Loch, all turbines used in the scheme were of reaction type with vertical shafts. Those at the relatively small and low-head stations at Earlstoun and Carsfad had skirtless runners. The angling interest in the rivers had to be taken into account, and fish-ladders were provided at Tongland, Earlstoun, and Carsfad.

The capital cost of the whole scheme was about £3 million. Over 50 years later, it is still working; evidently capital charges on the original investment have long since become negligible. Not only is it still working, but it has even been recently expanded by the addition of a small new generating station up in the mountains at Drumjohn.

8. Conclusions.

It will have been seen that long-distance electrical power transmission is the key to the long-term development of hydroelectricity, for the possibilities of full use at the generating site are limited. In Britain, the electricity grid has permitted a good use of the very limited supplies of water power available. The Galloway scheme, with which this paper finished, was effectively the beginning of the modern era of hydroelectricity in Britain.

Hydroelectricity uses an everlasting source of energy and gives no pollution. It is highly desirable on these counts, but does not necessarily give an economic advantage over rival systems. Its capital costs are very high. However, the life of an installation is also high compared with that of a thermal or nuclear plant, for it is not so liable to technical obsolescence.

The early hydroelectric stations were indeed conceived as a sort of mill development; by the time the output had risen to megawatts their technology had become all their own.

References.

1. D.G.Tucker, "Hydro-electricity for public supply in Britain, 1881-1894", *Industrial Archaeology Review*, **1**, 1977, pp.126-163.

2. D.G.Tucker, "Hydroelectricity for public supply in Britain, 1881-1894", *Proc. Inst. of Elect. Engrs.*, **123**, 1976 pp.1026-34.

3. P.Strange, "Early electricity supply in Britain: Chesterfield and Godalming.", *ibid*, **126**, 1979, pp.863-8.

4. D.G.Tucker, "Early years of hydroelectricity for public supply in Devon.", *Devon Historian*, **15**, 1977, pp. 21-32.

5. D.G.Tucker, "Half a century of hydro-electricity at Monmouth", Presenting Monmouthshire (*J.of Mon.Local Hist.*), **37**, 1974, pp.27-38.

6. J.A.Crabtree, Fladbury Mill, Worcs., and the Fladbury Electric Light and Power Company", *Wind & Water Mills*, **5**, 1984, pp.2-4.

7. As references 1,2 and 6.

8. C.C.Owen, "Burton Upon Trent: the development of industry", Phillimore, 1978, pp.139-151.

9. J.D.Briggs and G.Tucker, "Watermills of the River Salwarpe and its tributaries", *Wind and Water Mills*, **2**, 1981, pp.6-15 and 3, 1982, pp.2-19.

10. D.G.Tucker, "The hydroelectric power station for the Greenside lead mines, Westmorland, C 1890". Papers presented at the Weekend Meeting on the History of Electrical Engineering, July 1973, *Inst. of Elect. Engrs.*, pp.7/1-7/8.

11. L.Ferrand, "Histoire de la Science et des Techniques de l'Aluminium et ses Developpements Industriels", Humbert et Fils, France 1960, Vol 1, Le Passe, Vol 2, Le Present.

12. Numerous articles in technical press of the time. See particularly "The British Aluminium Works at Foyers", *Electrical Engineer*, **17**, 1896, pp.456-9, 510-513.

13. T.Turrettini, "Notable European Water Power Installations", *Cassier's Magasine.*, **8**, 1895, pp.322-330.

14. H.H. Suplee, "Hydraulic power in Switzerland", *Cassier's Magasine.*,**11**, 1896, pp.3-9.

15. A.O.Dubsky, "The Rome-Tivoli installation", Ibid, 15, 1899, pp.331-358.

16. See special Niagara Number of *Cassier's Magasine.*, **8**, 1895, pp.173-362; also British technical press of the time.

17. J.H.Dales, "Hydroelectricity and Industrial Development: Quebec 1898-1940", Harvard, 1957.

18. E.W.Connon, "Hydroelectric developments in Great Britain", *J.Inst.Elect.Engrs.*, **69**, 1931, pp.203-5.

19. R.A.S.Hennessey, "The Electric Revolution", Oriel Press, Newcastle upon Tyne, 1972.

20. G.Hill, "Tunnel and Dam: the story of the Galloway hydros", South of Scotland Electricity Board, 1984.

Publications: (continued)

Wind and Water Mills No.5.

Published July 1984. 48 pages, 17 drawings and maps.
Contents: Fladbury Mill, Worcestershire.
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