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A NOTE ON SOME EARLY WATER TURBINES AND HYDROELECTRIC GENERATING SCHEMES

(With reference to the Chatsworth House HEP scheme)

Stephen Mills

As with many aspects of technology, the water turbine gradually developed over several centuries, one of the first known examples being of all wooded construction, working in a French mill early in the 18th century. Important advances were subsequently made by Dr Robert Barker in 1742, his new design now supplying water to the centre of the hub, this being forced out through jets at the end of two side arms. This was further improved in 1833 by Glasgow engineer, James Whitlaw, the water now being admitted from below, and forced out through tapering, S-shaped arms. Patented in 1839, many of this type were sold, few, however, were destined to survive. A local example, reputedly one of only three survivors of this type, still exists in its pit below the floor of the great Frocester tithe barn. This takes the form of a Whitelaw and Stirrat turbine, fed from its pond via an iron pipe, and used to power a variety of farm machinery up to the Second World War. A second, smaller unit also powered equipment in the dairy/cheese room of the nearby court. Speed control was greatly improved over earlier units, by means of spring-loaded sector gates which partly closed the jets, courtesy of attached weight acting as governors.

The first all-metal turbines appeared around the 1830s, and through their greater efficiency, proved equally useful in such diverse situations as little village corn mills and large textile factories. In Gloucestershire, a number of mills switched from water wheels to turbines. Stanley Mill, for instance, replaced its wheels with five turbines.

Numerous improvements came in the ensuing years, an important one coming when James Thomson, Professor of Engineering at Queen's College, Belfast, began testing a new development. A patent (of 1850) resulted, the Thomson turbine being produced under licence by Williamson of Kendall, and following the acquisition of the company in 1881, by Gilbert Gilkes and Gordon, for over 80 years. The first units were produced in 1856 and during this lengthy period, many vortex turbines were sold, but despite numerous refinements, the basic design was to remain largely unaltered.

The Advent of Electricity

Electricity came into general use during the early 1880s, with the first public supply starting late in 1881. Not surprisingly, many existing mill sites were at least partially converted for the production of electricity, their water wheels being harnessed to drive dynamos. The advent of the incandescent lamp was largely responsible for boosting interest in this form of energy, a reliable power source for driving dynamos clearly being necessary. As mentioned, this often took the form of an adapted water-powered site or in some cases, the use of a steam engine. In some cases, the existing water wheel was used to provide the power, although in others, water turbines were installed. Precisely who the first major producer of turbines was remains unclear, however, the Finnish manufacturer, Tampella, certainly had one of their turbines powering a mill by 1856 and the Williamson Brothers of Kendall, were also in production.

1867 had seen a water-powered generating set installed and working in Bavaria, followed by a similar setup in Northumberland, in 1880. The latter utilized a 7kW Thomson turbine driving a 90 volt dynamo, the output being used to power lamps in the home of Sir William Armstrong. Many such schemes followed during the 1880s, some continuing to make use of old water wheels and others, newly installed, more efficient turbines.

Throughout the 1880s and into the 1890s and beyond, numerous small-scale hydroelectric schemes were installed around the country. Many of these enjoyed only limited success, partially because the exact requirements had not been fully appreciated and partly because the technology was still in its infancy. In and around the county of Gloucestershire, a number of such schemes came into existence, more often than not, taking advantage of an existing water-powered mill site. Such a setup was operated in 1888, albeit with limited success, using a site in Blockley, which at the time, formed a detached part of Worcestershire. The undertaking was for a public supply but was apparently short-lived.

Other local electricity generation schemes for private use were to be found in a number of local mills at different times. For instance, Abbey Mills in Tewkesbury was, for one period in its working life, driving 8 pairs of stones via an 80 HP turbine and two water wheels, powered by the Avon. An installation of unknown make also produced all of the mill's electricity although this appears to have been limited to lighting. Abbey Mill's grandiose neighbour, Healings Mill, was also generating electricty for lighting by 1891, although in this case, like the remainder of the mill, this was derived through the use of steam power.

In the Stroud area, Oil Mill (Ebley Corn Mill) featured in an attempt to use the waters of the lower Frome for hydroelectric generation. The grandfather of the present owner installed a generator around 1908-1909, although technical problems apparently robbed it of any great success. A concrete arch, forming part of the installation, and turbine, of which the main shaft and part of the gearing is still visible, survive at the site. The manufacture is not known, although it appears that turbines manufactured locally were few in number. A handful were produced, however, from the mid 1880s by the Newmarket-based engineering company of H.J.H. King.

Further south, during the late 1880s, Wickwar was partially lit by electricity supplied from the local brewery of Arnold, Perret and Co. Ltd. A large diameter water wheel was used to power a generator which supplied electricity to the brewery, the surplus being sold to the town. Recent local enquiries and a site visit, not surprisingly, revealed no remains.

Another mill to have produced its own electricity in a similar fashion was Cone Mill, in the Forest of Dean, although details of the installation are unknown. Kilcott Mill also produced its own electricity for a time.

It was not only public bodies or commercial concerns that recognized the potential of the "new" source of energy, some members of the landed gentry were not slow to investigate its use. One notable example was the system installed by the Duke of Devonshire in 1893, at the family seat of Chatsworth House. In this particular case, it proved possible to utilize the water catchment system and pipework already in place for supplying the Emperor Fountain (supplied by the Emperor Lake, plus two others) the highest in Europe to be driven by gravity alone (reputedly 280 ft). The hydro-electric scheme involved extending the pipeline to a lower level, the result being a static head of water of over 120 m.

For many years, the system provided a useful supply of electricity to Chatsworth, however, like many such small-scale schemes, it eventually fell into a protracted period of disuse,being taken out of use in 1936, when the Grid system was adopted. It was, however, left virtually intact, consisting of no less than three water turbines, installed by the Kendal-based manufacturer, Gilkes. Two were rated at 50 HP and the smaller one at 25 HP. the electrical output was produced by a generator which developed around 83kW (at 110 volts DC).

By the close of the 19th century, Gilbert Gilkes had supplied a large number of turbines from their Canal Iron Works, one having been supplied to Queen Victoria, for electricity generation at Balmoral. The Dukes of Devonshire, Marlborough, Buccleuch, Argyl, Montrose, Northumberland, and Cleveland, were all using Gilkes turbines on their respective estates, for various purposes including pumping, blast fans, saw mills, and flour milling, as well as assorted agricultural uses. In addition, innumerable Marquesses, Earls and Lords also applied Gilkes turbines to similar tasks, as well as for bobbin manufacture, dairy work, and for driving coffee grinding machinery. Some units were even shipped as far as Greece, where one was in use for corn milling, and Russia, where another was being used for pumping petroleum. Others were put to use by H M Government for India, driving a disintegrator, and for irrigation purposes, and by the Crown Agents for the Colonies, for pumping.

The three Chatsworth turbines were of the vortex variety, based on James Thompson's original design. Apart from these and the recently installed unit, over nearly a century's working relationship, Gilkes installed a further six turbines at Chatsworth [Table 1, the first order for two turbines being received by the company, via Drake & Gorham, in July 1893. A further order was subsequently placed in February 1894 for a third. These units used cast iron turbine cases, brass runner wheels, and four guide vanes (used to direct the water onto the runner) made of gunmetal. Also included in the contract were such items as girdles, bedplates, valves, pipework and strainers, a Gilkes engineer overseeing the actual installation.

The passing years were to see the potential of small-scale power re-emerge, largely as a result of the tremendous advances made in hydro-electric technology coupled with the increasing costs of alternative fuels, and the mid 1980s saw the Chatsworth scheme examined with a view to re-commissioning, obviously with new equipment.

On-site investigations revealed a major problem in that the original cast iron pipe, 800m long and of 15 inch diameter, supplying water from the lake to the turbine, was heavily clogged with scale and other corrosion products. The possibility of replacing this with polythene pipework was examined, however the decision was taken to attempt to clear out the original 145 year old pipe instead. Not surprisingly, this was a job for the experts, and Clearline Services of London were called in.

Their process involved the use of "pigs"; compressible, bullet-shaped structures of polyurethane foam, coated with different abrasive materials. These were inserted into the pipe at the lake end, and forced through using water pressure, dislodging and scouring out much of the corrosion en route. The effect of their efforts were dramatic to say the least, the improved water supply meaning that the fountain was able to reach its full height for the first time in many decades. Measurement confirmed that although the flow had been greatly improved, it was still marginal when it came to operating the proposed hydro-electric generator at its potential full power. Further investigation revealed that although the iron pipe had not been completely restored to its original diameter, there was a serious risk of structural damage if any further efforts were made in this direction, so a halt was called.

The proposed hydro-electric generating system was to be capable of producing 250kW, however, due to the constriction in the pipe, this would only be operated at around half of its potential output.

The replacement turbine installed is a Gilkes Turgo unit, normally driven by two jets of water, but currently only being operated with one, due to the pipeline problems. The new system was installed during 1988 and produces around 220 BHP (compared with the 125 BHP of all three turbines) and revolves at 1500 rpm. Water consumption is no less than 3000 gallons per minute.

The system makes use of some of the latest high-tech equipment now available, equipment that was never even dreamt of a century or more ago, when the first HEP schemes were being installed. For instance, apart from the turbine's obvious sophistication, the Reliance alternator installed is controlled by a specially designed solid state electronic setup that monitors the speed and the electrical load placed upon the unit, and automatically adjusts the flow of water to suit.

It is gratifying that the viability of such small-scale hydro schemes has once again been recognised, changes in regulations governing water abstraction in recent years having made this much easier. Perhaps it is time for owners of the many old mill sites that the country possesses (especially around the Stroud valleys) to give serious consideration to this valuable asset that moore often than not, runs to waste 24 hours a day. Their potential and cost-effectiveness has already been established at Coaley Mill, where a sophisticated setup has been in operation for some years, supplying electricity for both domestic and industrial purposes.

The Chatsworth House hydro-electric scheme was inaugurated by the Duke of Devonshire in January 1989 and to date,has operated with few problems. It now supplies all of the electrical needs of the house, except at very occasional times, when exceptional loads require additional input from the Grid. Future plans include extensions to the area of water catchment and public display of the surviving equipment from the original system, displayed alongside the new installation.

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TABLE 1

Details of the three original Chatsworth vortex turbines

Turbine No	874	875	908
Date of order	July 1893	July 1893	Feb 1894
Rated output [bhp]	50	20	50
Head of Water [ft]	360	360	360
Wheel diam [ins]	20.5	16	20.5
Rated speed [rpm]	1000	1250	1000

Details of the six other turbines supplied

Turbine No	876	903	1306
Date of order	July 1893	Dec 1893	May 1899
Type of Turbine	Vortex	Pelton	Pelton
Rated output [bhp]	20	10	1.5
Head of Water [ins]	310	300	120
Wheel Diam [ins]	16	24	12
Rated Speed [rpm]	1160	600	700

Turbine No	1307	3133	3134
Date of Order	May 1899	June 1924	June 1924
Type of Turbine	Pelton	Pelton	Pelton
Rated output [bhp]	4	30	4
Head of Water [ft]	120	300	300
Wheel diam [ins]	18	24	9.5
Rated Speed	550	760	1510

[No 903 was the first turbine manufactured to the Pelton design] captions.