Linton Falls and Low Wood Hydropower Schemes

utilising Scheduled Monuments to harbour modern power generation

by Rhianna Rose MEng CEng MICE

In the first half of the 20th Century, the village of Grassington in North Yorkshire, received hydroelectric power generated by the Linton Turbine House on the River Wharfe, in the picturesque surroundings of Linton, located within the Yorkshire Dales National Park, approximately ten miles north of Skipton. In Cumbria, at the Low Wood Gunpowder Works within the scenic Lake District National Park, close to the southern tip of Lake Windermere, water power has historically been provided to the site by the River Leven. This article describes the redeveloped and refurbishment of these two historic sites. Both projects are being delivered by JN Bentley in conjunction with turbine supplier Spaans Babcock. The project at Linton is JN Bentley's own in-house hydroelectricity project, and the sympathetic restoration of Linton's old turbine house, and the installation of new Archimedean Screws Turbines, will see the village generate hydroelectric power for the first time since the 1940s. The project in Cumbria for Low Wood Products Company Ltd, and project managers Inter Hydro Technology Ltd, will see the replacement of the 60 year old turbines to ensure the site can continue generating hydroelectricity into the future.

New generators for Linton Falls, 60 years after the previous units were removed *Courtesy of JN Bentley Ltd*

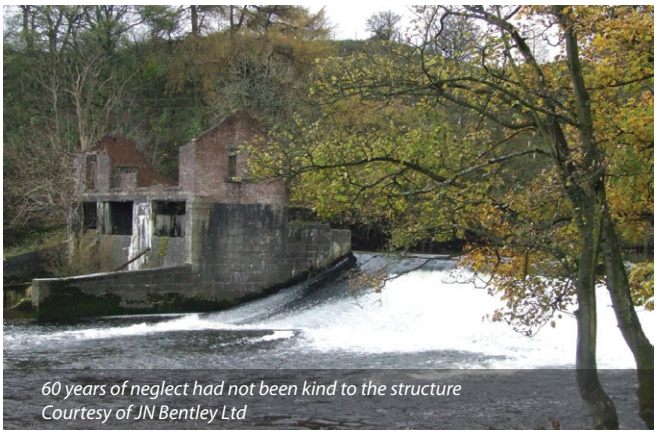
LINTON FALLS - Project need

Following the completion of a nearby residential development project, JN Bentley initiated the idea of restoring the early 20th Century plant back to its former glory. The original hydroelectricity plant at Linton Falls was somewhat pioneering in itself as it was used to generate the first electricity for the village of Grassington.

The plant was built in 1909, taking advantage of an existing 2.7m high weir that had already been constructed at the site to feed a local mill. The plant was extended in 1920 to incorporate two new machines, and ran until 1948 when it fell into disrepair following the arrival of the national grid into the region.

Since this date, the importance of the site as an exceptionally rare example of early industrialisation in the Yorkshire Dales, is such that the plant has been protected as a Scheduled Monument by English Heritage.

The plans for redevelopment devised by JN Bentley received consent from English Heritage and the Yorkshire Dales National Park Authority, together with licensing from the Environment Agency (EA), meaning that work could begin on site in April 2011 to restore the plant, and once again supply the Grassington area with hydroelectricity by feeding locally into the national grid.



60 years of neglect had not been kind to the structure
Courtesy of JN Bentley Ltd

Project scope

The scheme involves the construction of a hydroelectric power installation on the site of the existing derelict hydroelectric powerhouse. Two new Archimedean screw turbines have recently been installed by supplier Spaans Babcock, with whom JN Bentley has an ongoing collaborative working agreement. These turbines will generate 500,000kWh per annum; equivalent to the average energy use per year of approximately 90 family homes. This renewable power source saves over 210 tonnes of CO_2 emissions per year too, when compared with fossil fuel generation.

Valued at over £500,000, the scheme has been developed over a 3 year period, and was procured through NEC 3 Option A (Priced Contract with Activity Schedule).

Design

The plant's sensitive location meant that, together with turbine selection, planning consent was a major consideration for JN Bentley during the design phase. Because of its location – within the confines of a National Park – a sensitive approach was required. Early dialogue was established not only with local residents but regulatory bodies too. An Impounding Licence was sought and successfully issued by the EA, and Scheduled Monument Consent was granted by English Heritage, allowing JN Bentley to start work on the derelict powerhouse.

Restoration of the powerhouse was cause for much consideration during design. The existing structure had lost its roof, windows and large parts of the masonry, and the lintels were cracked. To comply with English Heritage requirements, a design was proposed that involved reusing the existing materials wherever possible. Existing brickwork was dismantled to an agreed level and the existing bricks re-used on the external leaf with the new bricks 'hidden' on the internal leaf where possible. The lintels were repaired using dowels and where lintels were missing completely, new ones were ordered to match as closely as possible. The new windows are single pane and have white frames and openers to match the original. The roof structure and material is true to the original but without containing asbestos. The existing intake screen has remained in position and will be used as the debris screen for the new turbines.

Different turbine options were explored, which led to a choice between a Kaplan turbine and an Archimedean screw generator. Archimedean screws were selected for three primary reasons:

- Ease of installation – a complicated draft tube is not required for screw turbines.
- Lower cost.
- Ecological benefits – the turbines allow fish to pass down them without harm.

Archimedean screw turbines

Spaans Babcock delivered and installed the Archimedean Screw Turbines to site at Linton Falls in July 2011. The screws themselves

One of the screw turbines in the factory *Courtesy of Spaans Babcock Ltd*

have a diameter of 2.4m and a nominal head of 2.7m. They have a combined power output of 100kW when operating at their full capacity, each passing 2,600l/s.

Sizing of the screws was critical to ensure the maximum generation with the available flows. There is a fine balancing act between installing the large generators that make full use of the maximum flow, whilst ensuring that they are not idle at low flows for longer than is necessary to maintain the EA specified minimum weir flow. This is one benefit of installing two screws: at low flows one screw can run whilst the other is shut down, enabling a wider range of flows to be utilised for generation.

The most challenging part of the installation was lifting them into place between the temporary bund and the existing powerhouse. Normally with screw turbine installation, the powerhouse is constructed around the screws once they are in place. On this project this was not possible and great care was taken to ensure that the turbines did not damage the building during installation.

Construction

Construction was split into two phases. Phase 1 comprised the construction of an access track from the nearest highway across farmland to the construction site. Through liaison with local residents and the National Park Ranger it was agreed to close the riverside footpath for the duration of the construction works.

Phase 2 (underway at the time of writing) began with the creation of a temporary dam both up and downstream of the structure to provide a dry working area. This allowed civils works to begin, including the casting of concrete slabs both within the structure and externally to modify existing levels, the casting of a new penstock opening within the building, and modifications to the existing intake screen to allow increased flow into the new screws, and to reduce the risk of debris blinding the screen.

The original 18th Century weir creates the head to create the potential for power - Courtesy of JN Bentley Ltd

Further works include the reconstruction of the derelict turbine house, installation of the Archimedean screw generators, downstream outlet screen, intake penstocks, and the laying of an underground export cable to facilitate connection to the local distribution network.

Ecological challenges

There was evidence of a number of different creatures inhabiting the surrounding area – including fine-lined pea mussels, white clawed crayfish, and bats – all of which require careful management to minimise impact during the construction phase. Fine-lined pea mussels are only located in three places in the north of England. Two of these sites are located at Linton Falls: one on the weir where the hydro is located, and one on the immediate downstream weir. The only known specialist on fine-lined mussels resides in Ireland, and flew over especially to complete the survey and confirm their presence. Each mussel is no bigger than a grain of sand, and they were successfully relocated from the hydro site to the downstream weir to ensure they were not affected by the construction works.

Progress to date

Having commenced construction on site in April 2011, the construction and commissioning of the refurbished hydropower plant are set for completion on time in September. Since coming to fruition the project has enjoyed a large share of regional and national coverage in the media from the likes of the BBC, the Daily Mail and the Guardian.

LOW WOOD HYDROPOWER REFURBISHMENT - Project need

Water power has historically been provided to the Low Wood site by the River Leven. A stone weir is situated upstream of the site and a large mill race runs down its eastern boundary. Off this mill race run a number of small leats that originally powered water-wheels, before evolving to electric turbines as the site modernised.

The existing hydropower installation was installed in the 1950s and utilises two Gilkes Francis turbines, each with a theoretical capacity of 162KW. Now nearly 60 years old, the existing installation is showing its inefficiencies, and so client Low Wood Products Company Ltd and project managers Inter Hydro Technology Ltd (IHT) deemed refurbishment works necessary to ensure that the historic site continues generating hydroelectricity into the future.

Project scope

The current scheme will increase the site's power generation potential by refurbishing the existing hydroelectric power plant site by replacing the two existing turbines with two new Archimedean screws, supplied by Spaans Babcock. Not only will the new turbines increase power generation potential but they will also improve conditions for local fish that use the mill race and leat for spawning. The projected annual power output of the completed site is close to 2,000MWh per annum, the equivalent to the annual average energy usage of 400 family homes. And because the electricity generated is being sourced in a sustainable manner, CO_2 emissions savings equate to more than 1,000 tonnes.

The £490,000 (excluding generator equipment) project has been designed by IHT and is now, at the time of writing (August 2011), being constructed by Principal Contractor JN Bentley, who were appointed to the scheme following a competitive tender process. The scheme is being procured through NEC 3 Option A (Priced Contract with Activity Schedule).

Design

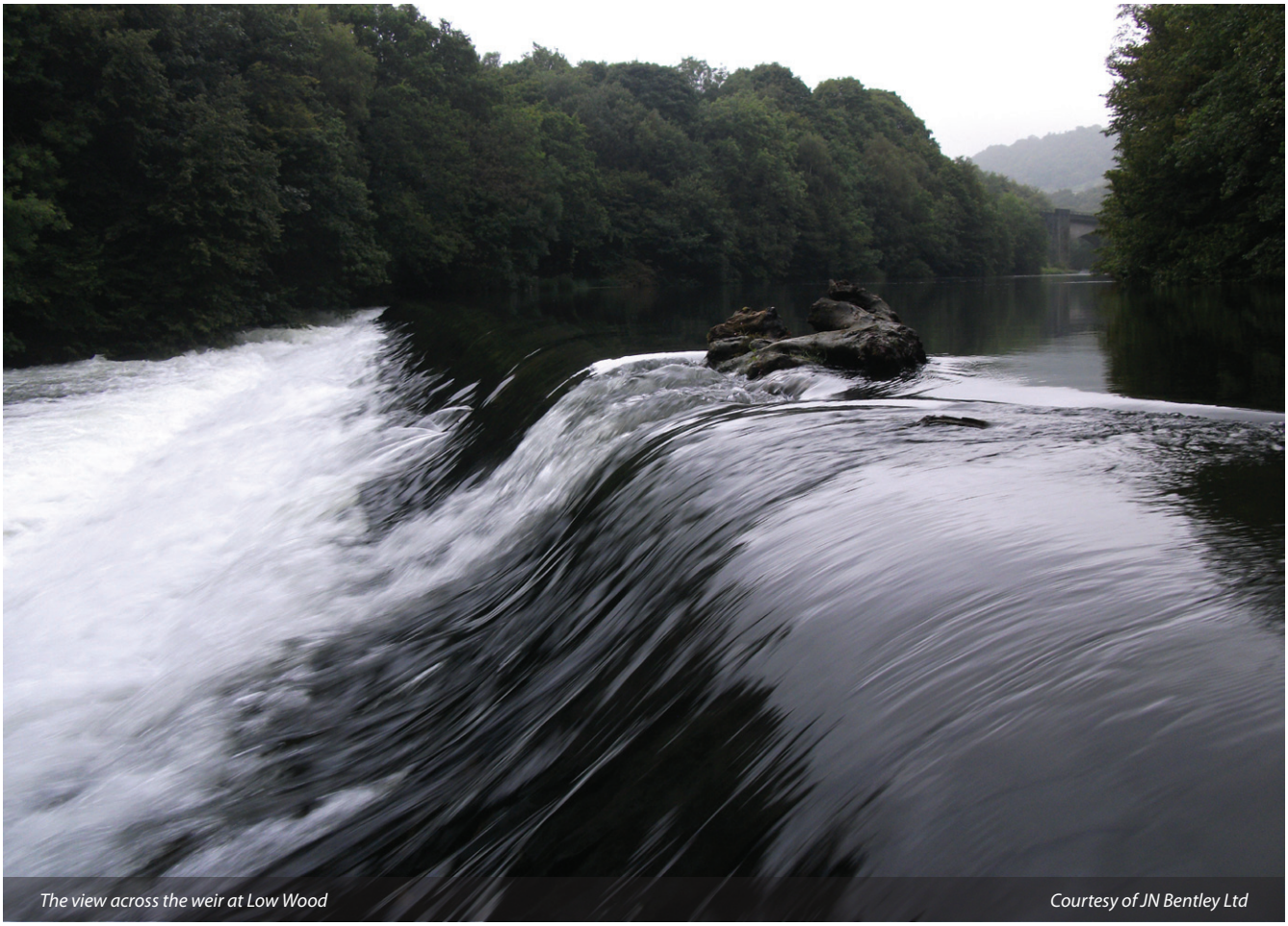
Determining the turbine type and the likely design flow were the two major considerations for IHT in the design phase. A series of cross-sections were surveyed, and a computer-generated ISIS model was built to estimate the theoretical capacity of the channel of the existing mill race. A series of options were then investigated, and it was decided that with some re-grading of the bed slope and widening of the channel the capacity could be increased to 8.0m^3/s.

Turbine options were next to be investigated, with IHT concluding that hydrodynamic Archimedean screw turbines were best suited. A key driver for this decision was the ecological benefits that such turbines offer; the leat is a known breeding ground for salmon and their young hatchlings pass down it. The screw turbines allow safe passage for the fish so they can now safely pass downstream and rejoin the river Leven. Because of this, the option was positively received by the Environment Agency too.

Archimedean screw turbines

Spaans Babcock was nominated as preferred supplier. The two screw generators are 3m dia., 19m in length and weigh 40 tonnes each. Their combined output is 400KW when operating at full capacity passing 4,000l/s each. This capacity and the head of 7.2m makes the project at Low Wood one of the largest Archimedean screw hydroelectric power stations in Europe.

The considerable length of the screws presented an interesting engineering challenge because, in order to function correctly,



The view across the weir at Low Wood *Courtesy of JN Bentley Ltd*

they are required to have just two points of contact: at the top and at the bottom. Considerable time was invested in ensuring that the material used - epoxy coated carbon steel – was of sufficient stiffness to withstand this.

Construction

Prior to commencing construction works on site, JN Bentley worked with IHT and the client to 'value engineer' the design in order to provide optimum value. During this Early Contractor Involvement (ECI) phase, it was decided to simplify the access bridge construction and change the specification of the lifting beam to reduce cost to the client. The stop log size was reviewed and reduced, and the overflow channel completely removed once a proposal to connect into an existing drainage tunnel was agreed.

JN Bentley began delivering the civils works on site in May 2011 by building temporary cofferdams at either end of the leat to enable dry working. The existing powerhouse was then demolished ready for the construction of its replacement. Now all other works under JN Bentley's remit could begin, including the construction of a new reinforced concrete (RC) access bridge, all RC work to the turbine foundations and overflow channel, the installation of a new sluice gate at the entrance to the leat, and the installation of all ancillary metalwork, including coarse screens, stop log and hand railing.

JN Bentley will also act as Principal Contractor when Spaans Babcock are on site installing the Archimedean screws and delivering other elements of the mechanical and electrical package.

Environmental challenges

Environmental management is key on all schemes, but with Low Wood being situated within the Lake District National Park additional challenges were posed. As with the turbine house at Linton Falls, the Gunpowder Works has English Heritage Scheduled Monument status, and is considered the best preserved 19th Century gunpowder works in Northern England. A detailed programme of archaeological excavation and reporting was required prior to consent being granted, and all excavations on site are being overseen by an archaeologist.

A Tree Protection Plan produced by IHT, and approved by the Lake District National Park Authority (LDNPA), is being adhered to as there are several trees with Tree Protection Orders on site. Also, the presence of slow worms (an endangered species) on site is being managed by suitable fencing to the working area, and the choice of an Archimedean screw, with its slow rotation, means that a fish-friendly solution has been found.

Additionally, downstream lies the Morecambe Bay Site of Special Scientific Interest, Special Protection Area and Special Areas of Conservation, so measures have been taken in both the design and construction phases to alleviate any pollution risk from existing contaminants in the ground. Water quality in the River Leven was monitored daily during the excavation phase to prove that the mitigation measures put in place by JN Bentley were effective in preventing a pollution incident.

Progress to date

Having commenced construction on site in May 2011, commissioning of the refurbished hydropower plant are set for completion on time in November.

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JN Bentley would also like to thank local residents and stakeholders for their cooperation as works on the two schemes continue.

A view of the existing sluice gates at Low Wood
Courtesy of JN Bentley Ltd

Linton Falls Hydroelectric plant under construction

Courtesy of JN Bentley Ltd.