LOW HEAD HYDRO ENERGY CONVERSION

Low head hydro demonstration site on the River Derwent.

HEA-Lanchester

Hydro Energy

HEA-Lanchester Low Head Hydro

A range of devices capable of extracting energy from low head river sites and tidal estuaries has been developed by the Energy Systems Group at Coventry Lanchester Polytechnic working in association with Hydro Energy Associates Ltd (HEA). The low head devices find application where inlet and outlet water levels may differ by as little as 2m and where conventional water turbine installations would not be contemplated. The HEA-Lanchester devices are a latest-technology replacement for the water wheel using simple novel concepts.

Low Head Hydro development.

The Energy Systems Group at Coventry Lanchester Polytechnic has been involved in energy research since 1975. It participated fully in the UK wave energy research programme which began at that time, and has amassed considerable experience in the testing of energy systems at small scale in the laboratory and at engineering scale at a test site at Loch Ness, Scotland.

Of considerable importance in the activities of the group is its work in connection with low head systems. Extracting energy from river sites or tidal inlets using available water flow is a similar problem to extracting energy from waves where there is water particle movement and virtually no flow. In each case, one is dealing with a low head system.

In low head situations it is essential to strike a balance between energy extraction and cost. Efficiency of the system, whilst important, is not the overriding consideration. At the end of the day the installation costs and the price per kWh of generated electricity are the deciding factors.

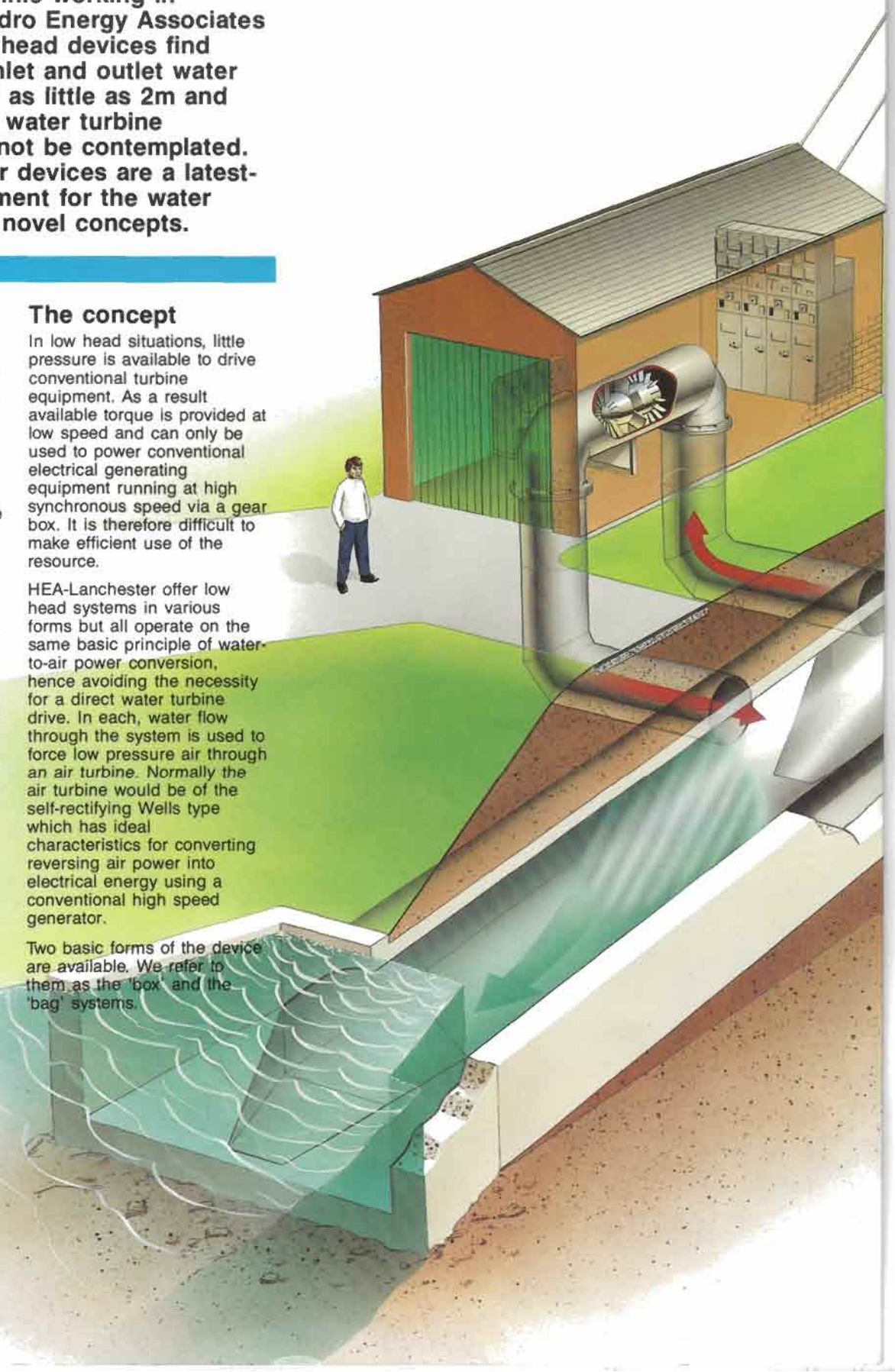
Using modern technology and some new ideas devices have been developed for use at river sites and in tidal estuaries.

The concept

In low head situations, little pressure is available to drive conventional turbine equipment. As a result available torque is provided at low speed and can only be used to power conventional electrical generating equipment running at high synchronous speed via a gear box. It is therefore difficult to make efficient use of the resource.

HEA-Lanchester offer low head systems in various forms but all operate on the same basic principle of water-to-air power conversion, hence avoiding the necessity for a direct water turbine drive. In each, water flow through the system is used to force low pressure air through an air turbine. Normally the air turbine would be of the self-rectifying Wells type which has ideal characteristics for converting reversing air power into electrical energy using a conventional high speed generator.

Two basic forms of the device are available. We refer to them as the 'box' and the 'bag' systems.

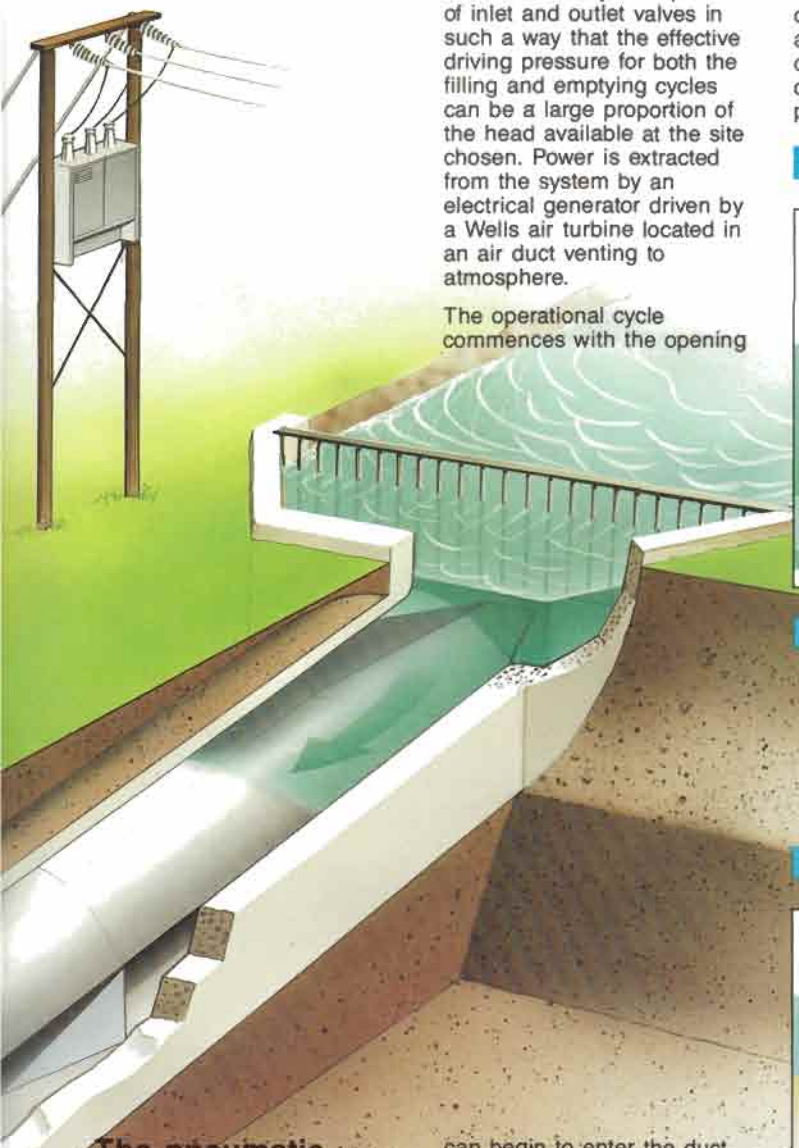


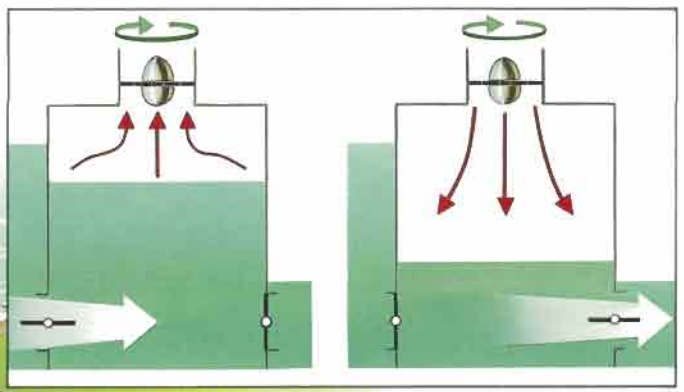
The pneumatic 'box' system

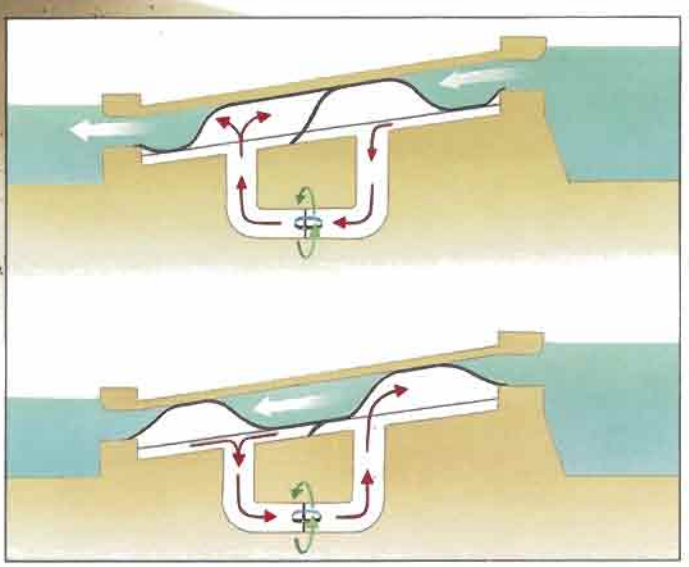
In its simplest form the 'box' system consists of an enclosed chamber into which the available water flow can be controlled by the operation of inlet and outlet valves in such a way that the effective driving pressure for both the filling and emptying cycles can be a large proportion of the head available at the site chosen. Power is extracted from the system by an electrical generator driven by a Wells air turbine located in an air duct venting to atmosphere.

The operational cycle commences with the opening of the upstream water inlet valve, allowing water into the chamber with the outlet valve closed. The chamber fills and expels air under pressure through the rotating Wells turbine. At a suitable point near the end of the filling cycle the inlet valve is closed and the outlet valve is opened, allowing exit of water downstream. The emptying phase causes air to be sucked back into the chamber through the still rotating Wells turbine. At an appropriate point in the emptying cycle valves are again switched and the filling phase recommences.

Where large flows are available multiple units can use individual chambers breathing to atmosphere or twin chambers with closed air systems.







The pneumatic 'bag' system

The basic system uses a flexible membrane separating water above it from air below it in an inclined duct set across the available water head. The membrane is fitted between the upper and lower halves of the duct and is shaped so that it can profile itself to the upper internal duct surface. Further, the membrane has a dividing septum at a point about halfway down the duct, thus providing two separate air bags inside the duct. The bags are externally connected to form a closed air system via a smaller air duct housing a Wells turbine.

If the two bag system is half filled with air, a slug of water can begin to enter the duct and displace air under pressure from the leading bag into the trailing bag via the turbine. Eventually, virtually all air is exhausted from this first bag and the second bag, now fully inflated, becomes pressurised. The membrane then automatically switches to close the duct entrance which allows the second bag to exhaust back through the turbine into the leading bag under the action of the entrained slug of water. When the slug of water begins to leave the duct the process can recommence with the leading bag again starting to deflate as it allows the next water slug to begin entry into the duct. The system is self oscillating; bistable bag operation during each cycle is accompanied by bidirectional air flow through the turbine which can be used to drive a generator at synchronous speed. Output power control is achieved by varying the volume of air in the system.

Parallel ducts can be operated out of phase giving constant water flow into and out of the ducts and, if required, integrated with a syphon intake. Other variations of the basic principle include parallel single bag horizontal ducts for two-way tidal applications and a range of uni-directional air systems.

The Wells Turbine

The self rectifying turbine of the type proposed for use in our low head box and bag systems has been extensively tested at the Polytechnic using a purpose built bag-turbine-alternator rig. The turbine, with its linear damping characteristic ensures good energy capture over the range of heads encountered at low head sites. Its mechanical simplicity and inherent high speed operation makes it inexpensive compared with a hydraulic low head turbine of the same power output capability.

A Wells turbine with a peak capacity of 1MW is already in use at the world's first wave energy site near Bergen, Norway.

State of development

A demonstration pneumatic bag system rated at 150kW is being installed on the river Derwent at Borrowash in Derbyshire and will be commissioned during the summer of 1987. The device will be located at a former water mill site where a head of about 2.8 metres is available throughout the year. Electricity generated via the turbo-generator system will be fed into the electricity grid in the locality.

The demonstration unit is funded partly by a grant from the EEC, with Hydro Energy Associates Ltd providing the rest of the funding. The Department of Energy is funding the comprehensive instrumentation of the Borrowash scheme and is also supporting the generic research into water-air conversion systems.

World Potential

The world potential for low head systems is vast. Our own units can be tailored for use in applications where they may be integrated onto a firm electricity supply system, may supplement other facilities such as diesel generating equipment or may operate on a stand-alone basis. On a small river a simple box design may provide a few tens of kilowatts of power; a larger resource can provide power for an on-site factory or for the local grid, as is evidenced by our river Derwent prototype. Large schemes on major rivers or tidal estuaries would involve multiple units working in pairs which would have the advantages of economy of scale. When used in tidal situations the devices could act as controlled sluice gates, could operate both ways and would not require expensive barrage routes crossing deep water channels as with conventional water turbines.

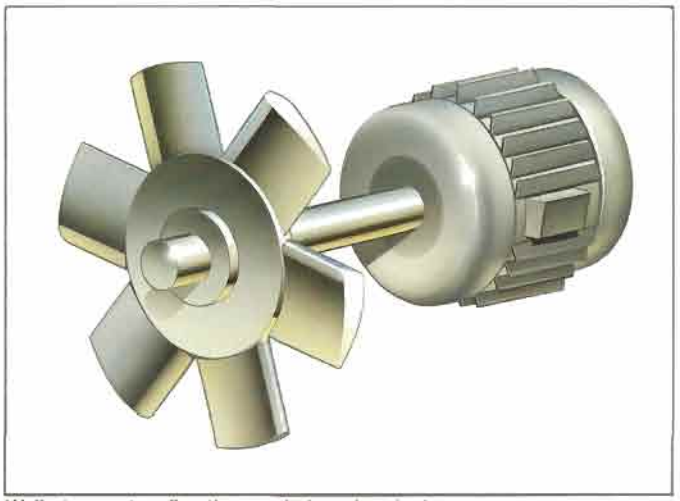
Company involvement

Hydro Energy Associates Ltd is a subsidiary company set up by R.M.C. Group plc in association with the inventors to develop and market low head systems. Patents for the systems have been applied for throughout the world and marketing will be carried out via licensees in countries with a high potential for low head power. Prospective customers with sites of 1 to 5 metres head and with available water powers in excess of 50kW should contact the Energy Systems Group at Coventry Lanchester Polytechnic or HEA Ltd in the first instance.

James Howden and Company Ltd of Glasgow have been appointed as turbogenerator manufacturers for the Borrowash project. The company has a high reputation for its production of large fans for ventilating and power station combustion systems. More recently they have had notable success in the manufacture of wind turbines for installations around the world ranging from a 750kW unit on Shetland to wind farm turbogenerator equipment in California.

Avon Rubber plc have agreed to supply the cross-ply reinforced rubber membrane. The company has been involved with the development of similar flexible membranes for the UK wave energy programme for many years and have developed suitable manufacturing techniques which will give the required operating life time of over 5 years.

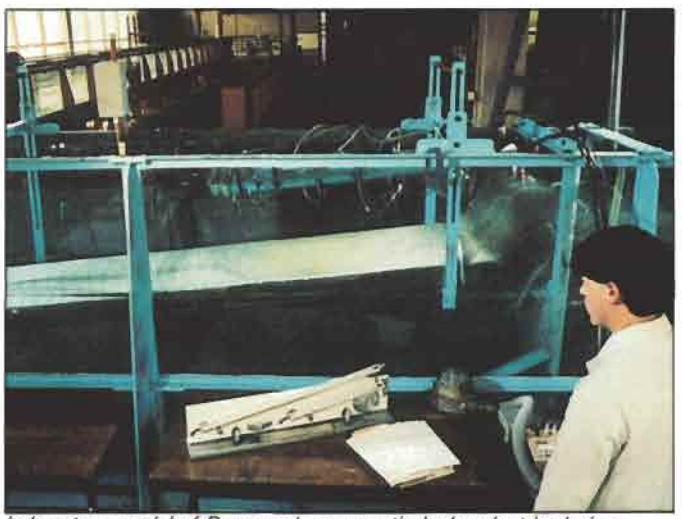
Sir Herbert Humphries & McDonald, consulting civil, structural, mechanical and electrical engineers, have been appointed consultants for this project. They will undertake the development of the detailed structural design and the supervision of construction work on site.



Wells type rotor directly coupled to electrical generator.

Bag-turbine-alternator rig under test at Coventry Lanchester Polytechnic.

Circular SEA Clam wave energy model on test on Loch Ness.



Laboratory model of Borrowash pneumatic hydro electric device.

Hydro Energy Associates Limited,
17 Royal Crescent,
Cheltenham,
Glos. GL50 3DA
Tel: 0242-239565
Fax: 0242-239566

Coventry Lanchester Polytechnic,
Energy Systems Group,
Priory Street,
Coventry CV1 5FB
Tel: 0203-24166
Fax: 0203-20432