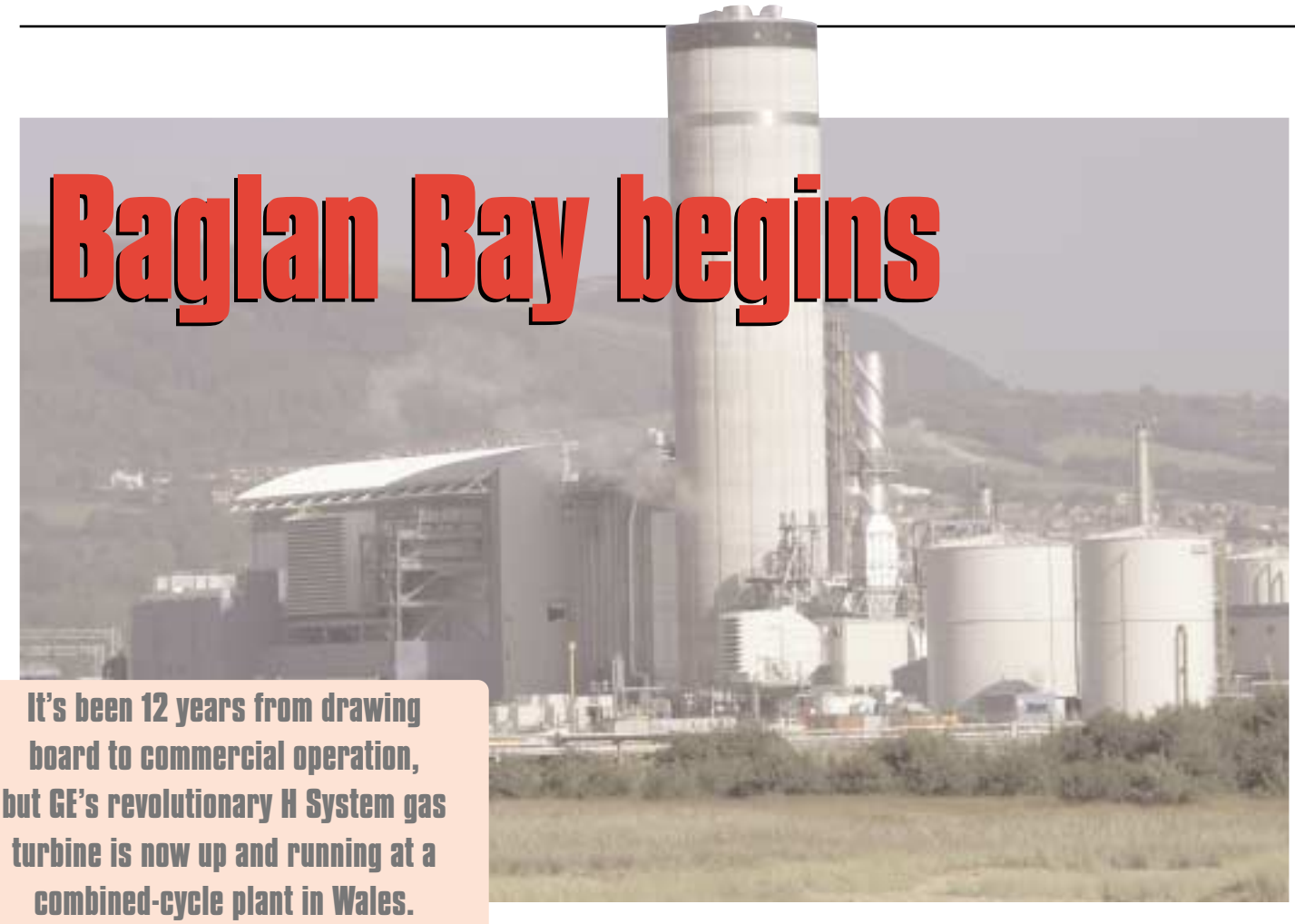
Baglan Bay begins



It's been 12 years from drawing board to commercial operation, but GE's revolutionary H System gas turbine is now up and running at a combined-cycle plant in Wales. James Luckey visits Baglan Bay.

The 510MW Baglan Bay power station in Port Talbot, Wales.

Without doubt, the 9H is the most carefully designed, engineered, tested and validated gas turbine in power generation history.

Its specifications also make it the largest, most powerful and efficient such machine in the world. Using the 50Hz 9H or 60Hz 7H turbine, GE's H System combined-cycle configuration is the first capable of breaking the 60 per cent thermal efficiency barrier. The turbine was more than a decade in the making; it finally saw its commercial launch in September at Baglan Bay power plant in the UK (see sidebar page 12).

The higher thermal efficiency of the H System will translate into lower generating costs and less plant emissions. GE estimates that a natural gas-fired CCGT plant using the technology has the capability of realising fuel cost savings of US$2 million a year, compared to existing combined-cycle plant, which operate in the range of 57-58 per cent at best.

The $500m Baglan Bay power station, is built on land leased from BP Chemicals, and provides electricity and process steam to the adjacent Baglan Energy Park and BP's isopropanol plant. Remaining electricity goes to the UK national grid.

Baglan Energy Park is a joint development between BP, Neath Port Talbot County Borough Council and the Welsh Development Agency. The Energy Park currently comprises approximately 200 acres of development land and will feature business and manufacturing facilities. The Baglan Bay redevelopment is the largest single such site in the UK and is made up of several phases, to be developed over the next 20 years.

The availability of clean, low-cost power is expected to play a significant role in attracting new businesses to the park. With the power plant's proximity and high efficiency, businesses in the Energy Park can potentially benefit from up to a 30 per cent saving in electrical costs.

Development programme

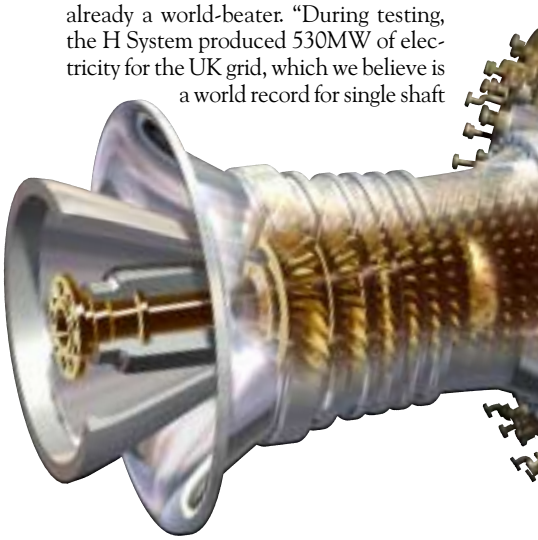
The energy source behind the Park started many years before however. GE engineers produced the H System concept in 1991. It took four years refining the turbine technology before a development programme was announced in 1995.

This was done as part of the US Department of Energy's Advanced Turbine System programme, and included GE Aircraft Engines and the company's Global Research Centre. Two years later the compressor was tested and the first set of single crystal airfoils produced.

Future shipments for the H System will be covered under a previously announced agreement signed by GE and Toshiba of Japan in 1998. Under this agreement, GE has H System integration and performance responsibility, and will design and manufacture the H gas turbines and supply the integrated systems controls for the power train. Toshiba will manufacture the GE-designed compressors, along with Toshiba-designed generators and steam turbines.

A full speed, no-load test was carried out in 1998 at GE's Greenville, South Carolina facility, and the first Frame 9H gas turbine left that factory bound for the Baglan Bay site in December 2000.

Characterisation testing of the 9H began in November last year, and was completed in May. Following a planned outage for instrumented component replacement, the plant was re-started to begin the commissioning process. It is already a world-beater. "During testing, the H System produced 530MW of electricity for the UK grid, which we believe is a world record for single shaft



combined-cycle power generation," says Mark Little, vice-president, Energy Products at GEPS. That recorded output was achieved at site conditions of 7°C, even on a warmer day, the H still produced in excess of 500MW.

The H System integrates gas and steam turbine (single-shaft configuration at Baglan Bay), repressure heat recovery steam generator (HRSG) and 660MVA liquid-cooled generator into one unit, optimising each component's performance. The steam turbine is a D10 three-pressure reheat, single-flow exhaust machine, co-manufactured with Toshiba. Baglan Bay also uses a ten cell cooling tower with low plume, and has its own 2MW diesel generator for black start capability, also used by the CHP plant. The 9H transformer is 22kV, stepped up to 275kV for transmission to the UK national grid.

In addition to the H System, the power station also includes a 33MW combined heat and power plant based on a GE LM2500 gas turbine (see right sidebar).

World's largest turbine

But it is the gas turbine represents the heart and focus of the project. The 50Hz 480MW-rated Frame 9H gas turbine measures 12 metres long, five meters in diameter; and weighing 370 metric tonnes – it is the largest gas turbine in the world. Much of the H design is based on proven turbine technology.

The compressor system is derivative of GE's Aircraft Engine business, the CF6-80C2 engine (and its aero-derivative LM6000 turbine), a core machine with more than 10 million flight hours.

Building on GE's design experience, the H employs a can-annular lean premix DLN-2.5 dry low NOx (DLN) combustor system. Fourteen combustion chambers are used on the 9H, and 12 combustion chambers are used on the 7H. It mixes fuel and air prior to ignition to reduce emissions to 25ppm.

This type of combustion system has been proven in millions of hours of operation on other GE gas turbines around the world. It produces more than a million horsepower alone and is the key energy source for the entire plant, including the power turbine, HRSG and steam turbine.

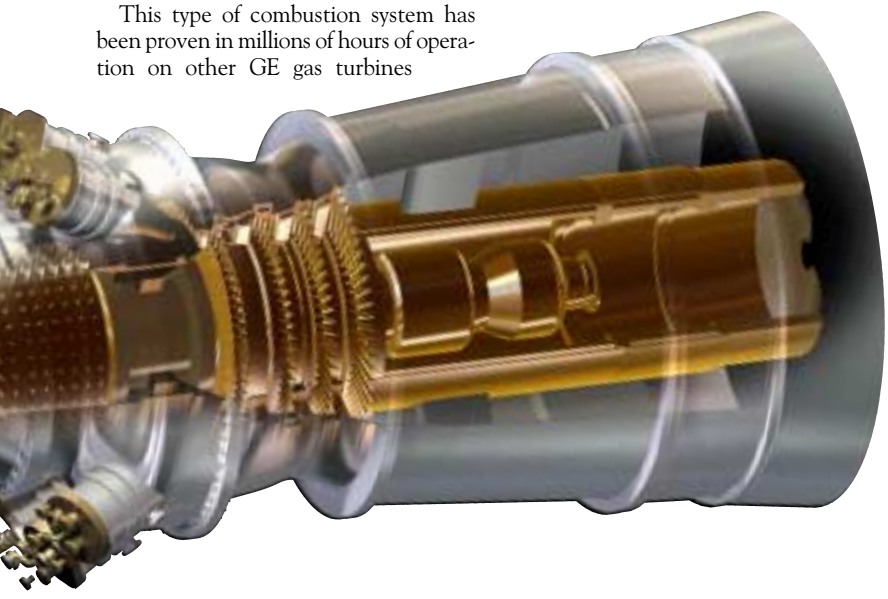
But the revolution so far as gas turbine design is concerned is the firing temperature and cooling system. The 60 per cent plant thermal efficiency is made possible by an increase in gas turbine firing temperature of more than 212°F (100°C) above the most efficient combined-cycle systems currently operating, including GE's own F-technology. Current combined-cycle systems achieve a firing temperature at the gas turbine inlet of around 1,300°C; the new H System increases that to 1,430°C (2,606°F).

This higher firing temperature is made possible by a series of technological advances including the world's largest single crystal airfoils, superior component and coating materials, and an advanced closed-loop steam cooling system.

"It is conditions friendly because the steam cooling in the H System allows the combustion system of the engine to run essentially at the same temperatures as our current F-technology," says Jon Ebacher, vice president of power systems technology at GEPS. "While the turbine inlet is 110°C above that and this is the section that produces power in the gas turbine."

Use of single crystal materials on the first stage nozzles and blades plus the special coatings used ensures that the parts can withstand the high temperatures – temperatures that are significantly higher than the melting point of most metals.

The most critical element of an advanced gas turbine is its hot gas path. The compressor discharge air and fuel are mixed and combusted in a chamber at a specific condition-combustion temperature. The flow stream of high-pressure, high-temperature combustion products is accelerated as it passes through the first stationary airfoil (stage 1 nozzle segment). The firing temperature – the flow stream temperature at the inlet to the first rotational state (stage 1 blade) – establishes the power output. The difference between firing temperature and combustion temperature entering the first stage nozzle is the temperature drop across the stage 1 nozzle.



Cooling process

In current advanced gas turbines, the stage 1 nozzle is cooled with compressor discharge air flowing through the airfoil and discharging out into the combustion gas stream as the airfoil is cooled. The cooling process causes a temperature drop of up to 155°C across the stage 1 nozzle. If the nozzle can be cooled with a closed-loop coolant without film cooling, the temperature drop across the stage 1 nozzle would be less than 44°C, which would permit a 110°C rise in firing temperature with no increase in combustion temperature. That in turn, of course, means no increase in NOx emissions. This is the basis behind GE's steam cooling with the H System.

Steam exiting the HP turbine flows through gas turbine blades, nozzles and other parts, cooling them, and simultaneously re-heating the steam before it enters the IP steam turbine.

The steam cooling concept has a dual effect, allowing higher firing temperatures to be achieved without combustion temperature increases and permitting more compressor discharge air to flow to the head-end of the combustor for fuel premixing.

"The benefit is that for about 8 per cent

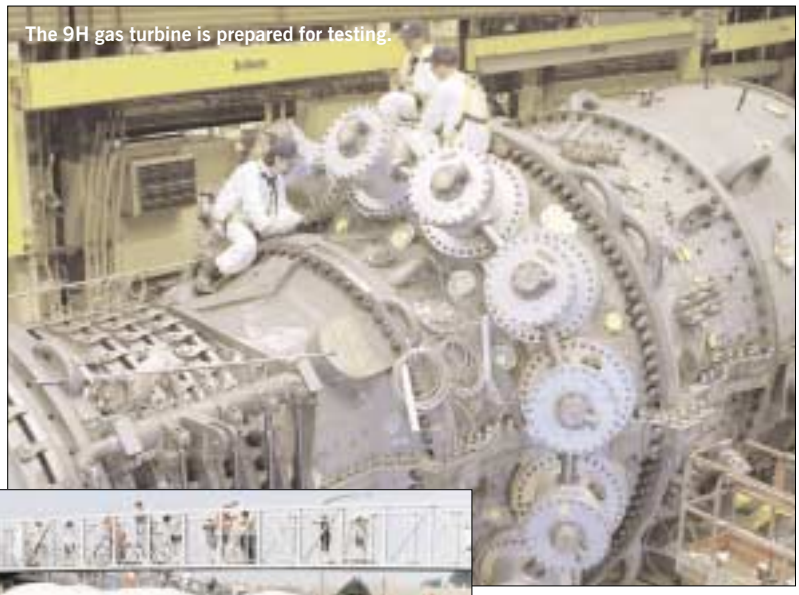
The cogeneration plant

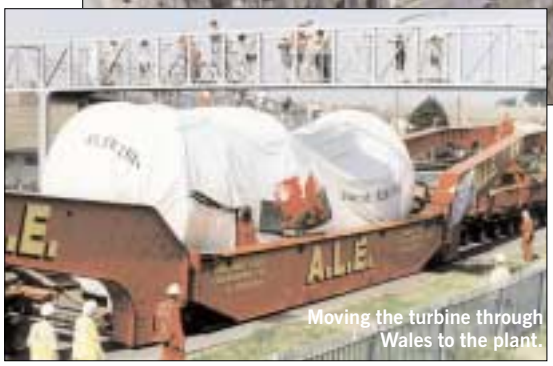
The CHP station at Baglan provides steam and electricity to a BP Chemicals process plant, situated close by.

In terms of configuration, the plant is powered by a GE LM2500 aero-derivative gas turbine, with a bypass stack and a heat recovery steam generator on the back end; this is also connected up to a three flue common chimney (for the LM and 9H). "The third flue is for the auxiliary boiler, which provides redundancy for the process steam that is supplied to BP," says Brian Ray, managing director of Baglan Generating Ltd.

The LM2500 also provides the Baglan Bay Power Station (including the H System) with black start capability, so it has its own diesel generator. "Power from the CHP plant is provided not only to BP Chemicals but also to the surrounding Baglan Energy Park," says Ray. "There is still room for expansion; there are a few tenants already in the Energy Park and some more on the way, but at present it's not fully populated."

The CHP plant also provides process cooling for BP Chemicals, so there is a separate two cell cooling tower for that purpose. In addition, an attemperated feedwater line also gives BP that product along with demineralised water from the site's water treatment plant.


The 9H gas turbine is prepared for testing.


Moving the turbine through Wales to the plant.

more airflow than a 50Hz 9F we get 25 per cent more power with similar conditions," says Ebacher. "As the combustor is running at about the same temperature, there's 200°F less drop across the stage 1 nozzle, so as we go into the first stage blade, that generates the real power, 200°F hotter than we do in the F machine, and that's why we get more power.

"We start the machine on air-cooling, waste heat generates steam and at about 10 per cent power we do a transition to steam cooling. When we first looked at this system we knew that the control system would be challenging to make sure that there was no load transients visible to the grid during the transition to steam cooling."

Most tested turbine

With revolutionary steam cooling capability and the new materials and use of high temperatures, it is little wonder that GE has been extremely cautious with the commercial introduction of the H-technology. The H System represents the most thoroughly tested industrial gas turbine technology in the company's 100-year-plus history. Tests, which involved more than 7,000 sensors placed on the equipment, validated GE's closed-loop steam cooling system.

Following the successful conclusion of the tests, instrumented components used to gather data were replaced with commercial non-instrumented components. The system has been restarted for commercial operation.

The H benefits from four years of extensive testing and design validation," says Mark Little. "From compressor blade tests, combustion tests and launch system integrated control test. Prior to shipping to the Baglan site the 9H gas turbine underwent two full speed no-load tests in the factory, which fully met our design expectations.

"Here at Baglan, GE has undertaken a further five months of full characterisation testing during which time we've validated key technologies at the heart of the H turbine."

This testing phase encompassed materials, component, subsystem, and system testing of the compressor rigs, as well as tests of the combustion, inlet aero, and Mark VI-based integrated control systems.

First firing

First firing of the turbine occurred in November, with validation testing lasting until May. Having met its expectations, GE is naturally proud of the new machine's performance. "As anyone involved in commissioning combined-cycle plant knows it is a difficult process," says Don Hoffmann, H System product line manager.

"Since first firing in November 2002, we've had 29 start attempts and everyone of those has been successful, no failures at all." And after 12 years of design, engineering and testing commercial launch of the Baglan Bay CCGT plant took place in September.

The H System gas turbine plant has been the most eagerly awaited project for many years. On its launch GE executives and UK politicians lauded the technology. Known for its caution and procrastination, the power industry as a whole will watch with close interest the performance of the turbine at Baglan. IPG

The plant launch

Over 200 customers, executives, politicians, invited guests and media were in South Wales in September for the launch of the Baglan Bay project.

The opening conference was addressed by the Secretary of State for Wales, Peter Hain, plus John Rice, GE Power Systems president and CEO, and local Welsh politicians. Hain brought a stark note of reality to the event, "I have noticed that GE's turnover is bigger than the entire Welsh budget!

"Within two years UK gas imports will outstrip its production making it imperative that there is an efficient use of gas. The 9H CCGT plant is capable of 60 per cent efficiency compared to 21-39 per cent for coal-fired power stations, and produces 30 per cent less carbon emissions than a typical coal plant."

These words were eagerly echoed by GE's ensemble of executives. "We have much to celebrate," said Del Williamson, GEPS president of global sales. "This H System is a new technology platform that significantly advances large-scale power generation."

Rice spoke about the teamwork that went into the H System and Baglan Bay, "I can't be prouder of the team that brought the H System to life. In truth, this is a total team effort spanning a multitude of companies, countries and political bodies."

But it didn't entirely go to plan. A couple of days before the launch there was an alarm indicating a localised temperature increase that caused the unit to be taken offline.

As part of the recommissioning process GE found that there were three turbine blades out of 120, in one section, that appear to have restricted steam flow. "That was not present in the earlier testing but it is being addressed and the machine will run again and produce those high powers," said Jon Ebacher, vice president of power systems technology at GEPS.

Subsequent thorough inspection of the stage two blades re-confirmed that the elevated temperature was the result of a localised cooling flow restriction caused by foreign material collecting in the steam cooling path during the supplier's manufacturing process.

The milestone 60 per cent thermal efficiency figure was not realised at Baglan. GE's prime purpose here has been to run and validate the gas turbine technology.

Also announced at the September launch was that GE expects to begin offering the H System as a commercial product beginning in the last quarter of this year. It already has an order from TEPCO to supply three 109H systems for a project in Japan. Meanwhile GE is actively looking for a launch site for its 60Hz 7H gas turbine.