

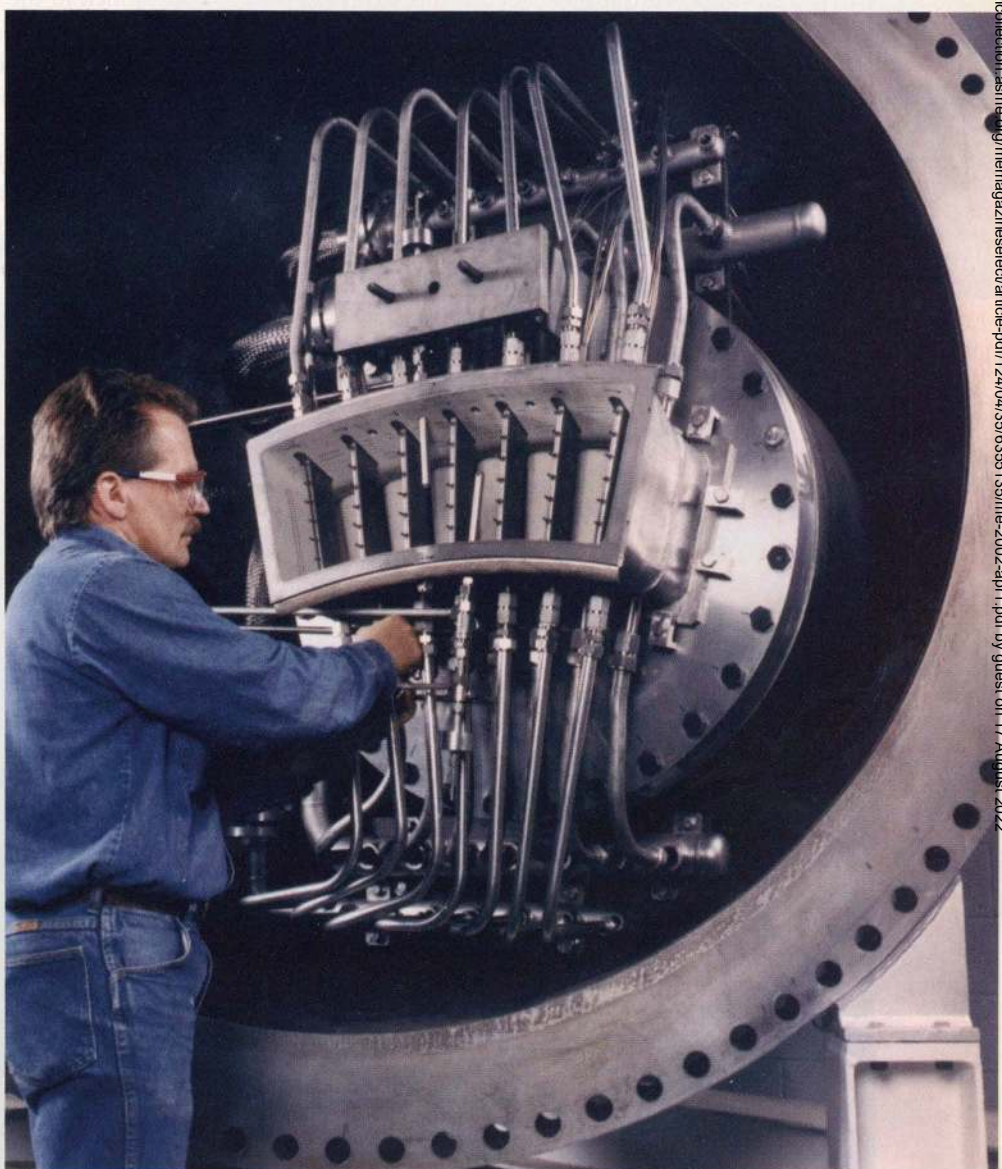
**FEATURE FOCUS: Advanced Energy Systems**

# REACHING FOR 60 PERCENT

The General Electric H turbine system taking shape in Wales is making a bid for a new record in thermal efficiency. **By Michael Valenti, Senior Editor**

**T**HIS SUMMER, ON AN aging industrial site in South Wales, a breakthrough in energy efficiency may take place, when the first General Electric Power Systems H turbine system begins operating. The H turbine is designed to be 60 percent thermally efficient, long considered the four-minute mile of power generation. The Welsh installation will serve as a springboard for two other installations, planned for New York State and Tokyo, so that the technology will span three continents.

The 480-megawatt H system in Wales is designed to be the first gas turbine combined-cycle system in the world to achieve 60 percent thermal efficiency. At the same time, it will produce fewer emissions than conventional combined-cycle plants. The main advantage provided by efficiency is economic, because fuel represents the largest single expense in running a fossil-fueled power plant. A single percentage point of efficiency gained can reduce operating costs by \$15 million to \$20 million over the life of a typical, gas-fired combined-cycle plant rated at 400 to 500 MW, according to an original equipment manufacturer quoted in *Gas Turbine World's* 2000-2001 handbook. GE Power Systems' most advanced



A technician at GE Aircraft Engine's test facility in Cincinnati conducts steam-cooled nozzle cascade testing of GE's H turbine technology to validate the technology's high efficiency and reliability.

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gas turbines to date, the F series, top out at 57 to 58 percent combined-cycle thermal efficiency.

GE is developing the facility in Baglan Bay, Wales, on property leased from British Petroleum. The plant will supply electricity and steam to commercial and industrial facilities being developed in the new Baglan Bay Energy Park. Excess power will be sold to the United Kingdom's electric market.

### RESTORING BAGLAN BAY

The Baglan Bay Energy Park is the first phase of a local redevelopment and, at some 1,500 acres, the site is believed to be one of the largest single areas of industrial development in Britain. The energy park is being jointly developed by a public/private sector partnership, namely, BP plc, the Welsh Development Agency, and the Neath Port Talbot County Borough Council.

BP has processed petrochemicals at part of the site since the early 1960s. A single 98-MW plant, originally oil-fired, but now gas-fueled, provided sufficient electricity and steam for the processing plants that operated at Baglan Bay.

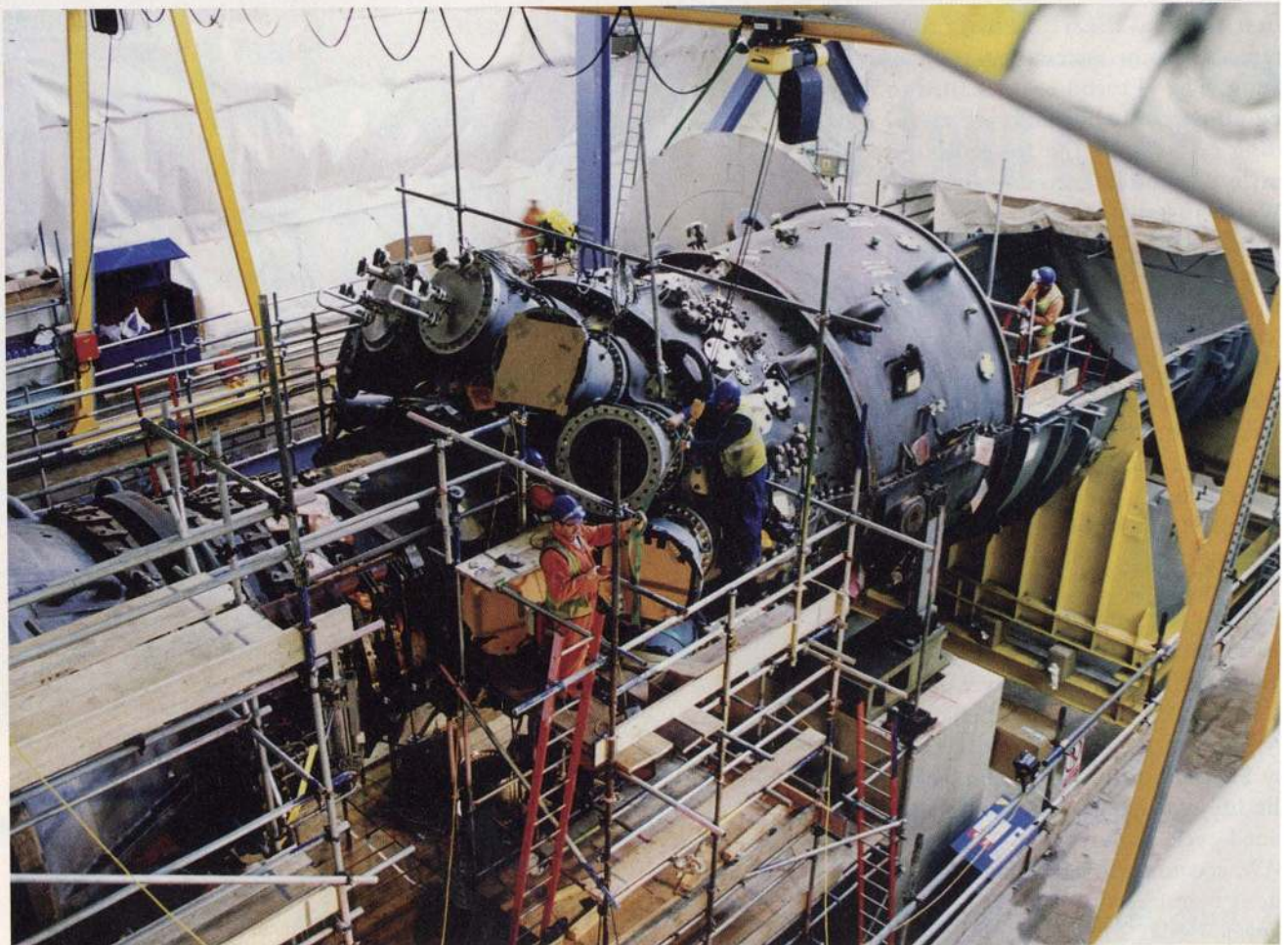
The Baglan Bay chemical complex eventually declined in importance, due mainly to the discovery of gas and oil deposits under the North Sea, which lies off the far side of Britain. By 2000, the site was dedicated to the production of vinyl acetate, ethanol, and isopropanol.

By last February, the vinyl acetate and ethanol plants had closed, as BP shifted production to its facility in Hull, leaving only the isopropanol plant open at Baglan Bay. The chemical is used in formulating deicing compounds, industrial solvents, and some pharmaceuticals. The plant employs about 50 people. The workforce is a shadow of the more than 2,000 who worked for BP at Baglan Bay in the 1970s.

As BP cut back its operations at Baglan Bay, excess electricity generated by its power plant was exported to the local grid. In 1996, BP committed itself to a partnership with local authorities to revitalize the brown-field. The planners reasoned that on-site power generation would eliminate transmission and distribution costs, taking as much as 30 percent off electricity bills, and provide an incentive to attract industrial companies to the site.

South Wales would also benefit from additional electrical capacity. The region has been strapped for power since older coal and oil-fired power plants were decommissioned in the 1990s for environmental reasons.

Closing the old plant and switching to the world's first H turbine system will not only increase available power, but also will reduce the environmental friendliness of the Baglan Bay site. According to BP, emissions of carbon dioxide will fall by 64 percent, emissions of nitrogen oxide by 88 percent, and sulfur oxide emissions by 99.9



Workers install a 9H turbine at Baglan Bay Energy Park in south Wales to provide low cost electricity to attract industrial consumers to the park.



percent. Particulate emissions will be eliminated entirely, BP adds.

The BP site at Baglan Bay offered a number of advantages for the location of a power station. Its size could easily accommodate a large, gas-fueled power plant. It is within 12 kilometers of the national gas transmission system, so a fuel source is near at hand. Cooling water is guaranteed from the Tennant and Neath canals nearby. Proximity to the national energy grid offers a ready market for excess power generated during off-peak periods.

Hi-Lex Cable Systems Co. Ltd., a manufacturer of flexible linear control cables, window regulators, and sunroofs for European carmakers, started operations in the Energy Park's first factory, the Gateway Development, in June 2000. A second factory, called Astral Court, is scheduled to be completed this month.

### USING STEAM TO KEEP COOL

While BP and its development partners were working on their plans, GE developed the H system as part of the U.S. Department of Energy's Advanced Turbine System program.

GE designed and built two models—a 60-Hz version called the 7H, and the 50-Hz 9H, which is the one being installed in Wales. They share similar designs and capabilities. Both derive their performances from their advanced materials and a new steam cooling system that enables the H gas turbines to operate at 2,600°F, or about 1,400°C, firing temperature, more than 200°F, or some 110°C, above previous-generation F technology gas turbines, to increase thermal efficiency to 60 percent.

The combined-cycle system consists of a gas turbine, a heat recovery steam generator, and a steam turbine. The gas turbine is equipped with an 18-stage compressor, a can-annular dry low-NO<sub>x</sub> combustion system and a four-stage turbine.

GE engineers based much of the H design on proven turbine technology, starting with the high-pressure compressors. The H compressors were based on the compressor that GE designed for the CF6-80C2 aircraft engine and its industrial aeroderivative LM6000 gas turbine. The 9H compressor has a 23:1 pressure ratio and a 1,510-pound-per-second (685-kilogram-per-second) airflow. The 7H turbine has a 23:1 pressure ratio with a 1,230 pps (558 kg/s) airflow.

The H system's dry combustion system premixes fuel and air prior to ignition to generate no more than 9 parts per million of NO<sub>x</sub> for the 7H, and 25 ppm for the 9H. This emissions control system has logged millions of hours of service on other GE turbines around the world.

However, in a major departure from most gas turbines, the H system will use steam to cool the first- and second-stage nozzles and buckets. Typically, gas turbines use air for combustion and to cool the turbine nozzles and buckets. Closed loop steam cooling reduces the temper-



GE's thermal barrier coatings will protect the H gas turbine airfoils when the machine operates at 2,600°F, 200° hotter than its predecessor class firing temperature.

ature drop across the cooled part, allowing more energy to be used efficiently to generate electricity.

Also, steam cooling makes more air available to expand and produce work through the turbine stages, reducing what is traditionally labeled as "chargeable air."

The H turbine uses tubular seals called "spoolies" to deliver and return the steam to the rotating buckets of the first and second stages. Spoolies have been used for years on GE aircraft engines. According to GE, engineers have conducted more than 50 component tests on H turbine spoolies to evaluate coating, lateral loads, fits, axial motion, angular motion, temperature, and surface finish.

After passing through the H turbine's nozzles and buckets, the steam, with the thermal energy it picks up from the gas turbine, is recycled back to the heat recovery steam generator. Thus, the H turbine serves as a reheater for the bottoming cycle. In the third stage, the H turbine's nozzles and buckets are air cooled, and the fourth stage is uncooled.

The first single-shaft, 50-Hz MS9001H gas turbine was built by GE in Greenville, S.C., and is 12 meters long, 5 meters in diameter, and weighs 370 U.S. tons. The company said it is unaware of a larger turbine.

In addition to providing steam cooling, GE engineers made the H turbine's first-stage buckets and nozzles out of proprietary, single-crystal materials to withstand the



higher temperatures. "We then applied a dense, vertically cracked thermal barrier coating to increase their heat resistance," said Chris Maslak, a mechanical engineer and H product line leader at GE.

GE shipped the 9H turbine to Wales in December 2000. Its 480-MW generating capacity is sufficient to provide electricity to approximately 600,000 homes in Britain.

The Baglan Bay turbine will run in cooperation with a GE D10 steam turbine. This three-admission reheat turbine with a 33 $\frac{1}{3}$ -inch last-stage bucket is used in many GE combined-cycle systems. The steam and gas cycles cooperate in the same way as other GE advanced single-shaft combined-cycle systems—that is, by solid coupling the gas turbine to the steam turbine and steam turbine to the generator.

"The gas turbine's thrust bearing carries the thrust load, and because the system is optimized for combined-cycle operation, there is no need for additional hardware, such as a clutch, which would increase the plant's footprint," Maslak said.

NEM of Leiden, the Netherlands, built the heat recovery steam generator, or HRSG, for the 9H at Baglan Bay. This three-pressure-level unit can reach 12.4 megapascals, with both main steam and reheat steam at 565°C.

The Baglan Bay steam generator is similar to the NEM units used on GE 9FA and 7FA gas turbines serv-

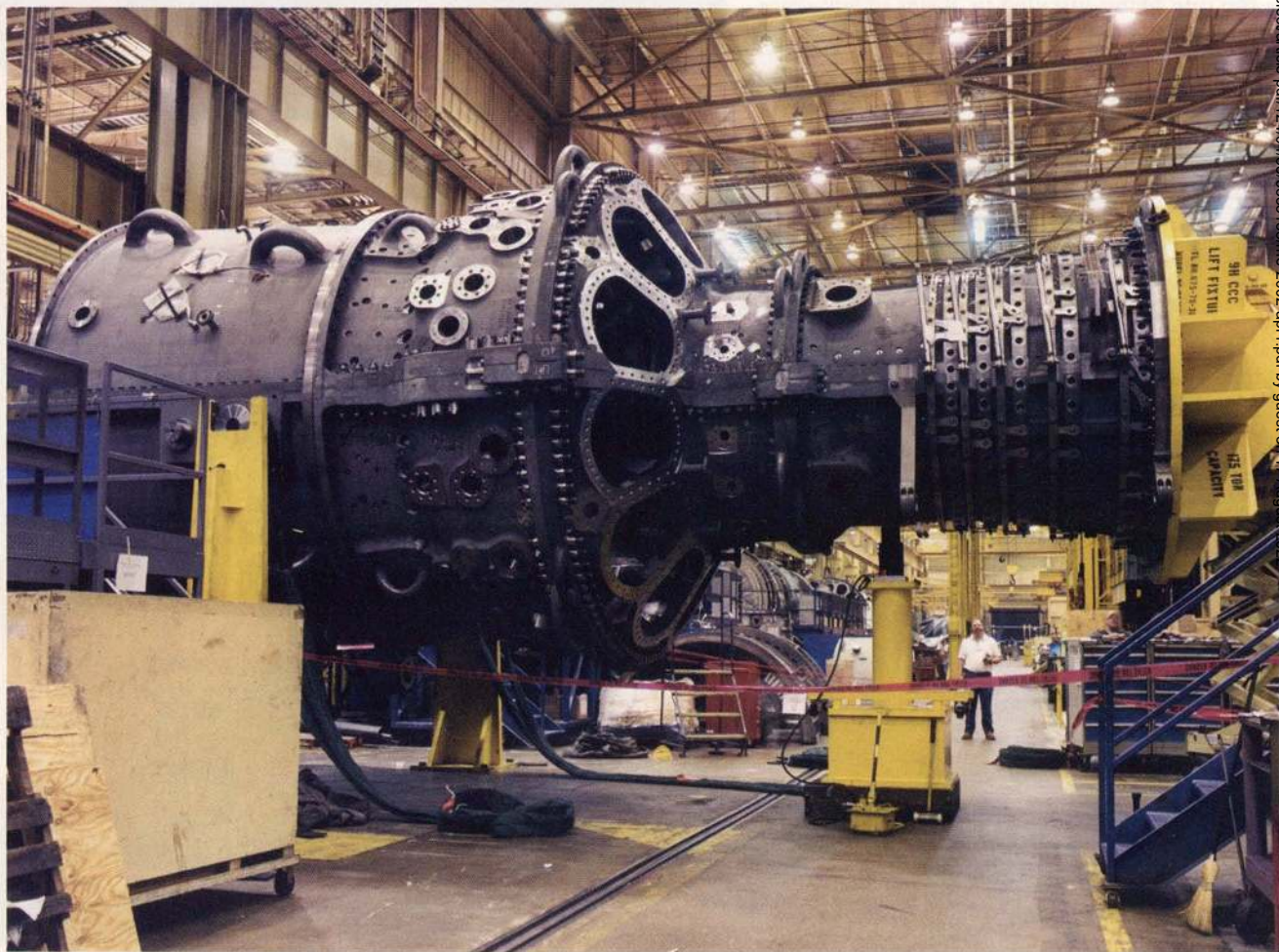
ing in other combined-cycle applications, with a few key differences. "For one, it is larger, to accommodate the greater exhaust flow of the H turbine," Maslak noted. "Conversely, because of the heat it picks up from the gas turbine during cooling, its reheater is relatively smaller."

In addition to the 480-MW H turbine system, GE has another power system at the Baglan Bay power plant. "We have installed a 33-MW, LM2500 gas turbine-based, supplementary fired cogeneration system to send steam to the Baglan Bay Energy Park," Maslak said. "It shares the same chimney as the H system, but uses a separate flue."

GE Distributed Power, a unit of GE Power Systems designed and built a unique 2.3-MW diesel generator set to provide auxiliary power to the 9H turbine system. The auxiliary genset will also assist with starting the 9H without tapping into the electrical grid.

Engineers built the genset package for the Baglan Bay installation on a common base frame. The package includes a GE Transportation Systems 7FDS 16-cylinder diesel engine rated at 3,830 continuous base horsepower and an engine-generator control panel that was designed by GE Industrial Systems. The genset is able to provide stable power within 12 seconds of startup.

During the third quarter of this year, the entire H turbine system will begin characterization testing to validate



The first MS7001H gas turbine is assembled at GE's plant in Greenville, S.C. The 60-Hz turbine is designed for service in the United States.





The turbine building at Baglan Bay will house the 9H gas turbine, its GE D10 steam turbine, and its NEM heat recovery steam generator.

its long-term capabilities, using standard devices, such as thermocouples and speed pickups, and specialized instruments, including strain gauges and light probes. "We have installed approximately 3,000 pieces of special instrumentation on the H turbine itself, and more than 7,400 instruments plantwide that will be used during testing," Maslak said.

### SPANNING THE GLOBE

The first 60-Hz installation of H technology has been planned much closer to the Schenectady, N.Y., headquarters of GE Power Systems, at the 800-MW Heritage Station being built in Scriba, N.Y., in Oswego County on the bank of Lake Ontario. The plant's owner, Sithe Energies Inc., is an independent power producer based in New York City. It operates 40 plants in the Northeast that generate more than 11,000 MW.

Sithe Energies is building the Heritage plant alongside its 46-acre Independence Station in Scriba, which supplies the plant's feed water. The Independence Station produces 1,040 MW. Sithe Energies sells electricity produced at Scriba to the local utility, Niagara Mohawk, and to the downstate utility Consolidated Edison. The additional electricity and steam produced by Independence Station are sold to nearby Alcan Rolled Products, which manufactures aluminum sheets.

The H turbine installation was originally scheduled to begin this spring, but has been delayed because of changes in the "spark spread," or the difference between the cost of natural gas and the price of electricity.

Should the economics for the Heritage Station improve, the installation will consist of two 400-MW 7H systems. They will be connected to steam turbines and electric generators built by Toshiba in Keihin, Japan, under the terms of a previous agreement with GE. NEM will again supply the heat recovery steam generators.

The third announced H turbine installation will represent the largest such installation and the first in Asia. The Tokyo Electric Power Co., more familiarly known as TEPCO, has commissioned GE Power Systems to design and build a 1,520-MW H system combined-cycle plant at TEPCO's Futtsu Thermal Power Station Group No. 4 project, which is scheduled to begin operation by 2008.

TEPCO is one of the largest utilities in the world, producing 60 gigawatts, and is GE's largest customer. Futtsu No. 4 will be the fifth combined-cycle system GE has built for TEPCO. Earlier-generation GE gas turbines are already in service at the Futtsu site. Futtsu No. 1 and 2 are equipped with GE's 9E technology, and Futtsu No. 3 features 9FA technology.

Under terms of the agreement, GE will supply TEPCO with three 9H combined-cycle systems. As the prime contractor for the Futtsu No. 4 project, GE will build the three 9H gas turbines. Toshiba Corp. will build the gas turbine compressors, steam turbines, and generators under the terms of a separate agreement with GE.

The heat recovery steam generators, selective catalytic reduction systems, and accessory equipment for the Futtsu No. 4 project will be built by Toshiba Corp. and Hitachi Ltd. of Tokyo.

GE will begin shipping equipment by April 2006 and expects to have the first unit in operation in mid-2008, joined by the other two H systems by mid-2010.

Another advantage GE intends to stress in marketing its H turbines, along with fuel economy and environmental performance, is their greater power density, according to Maslak. "When the H technology plants are compared to F technology combined-cycle plants, you can install about 45 percent more megawatt capacity per square foot. This provides significant value to customers where space is at a premium." ■