New cogeneration plant provides steam for Oxnard papermaking facility

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The pulp and paper business has become a pioneer of industrial cogeneration.

In January 1990, The Procter & Gamble Co.'s Oxnard, Calif., papermaking facility started up "Cogen Two," the newest of the company's four gas-turbine-based cogeneration plants.

In addition to reviewing Cogen Two project specifics, this article demonstrates the success of state-of-the-art cogeneration systems and the important role these systems play in the pulp and paper industry.

Previous cogeneration experience

Procter & Gamble first used gas turbines for cogeneration power in 1982 and 1983, when both the company's Oxnard paper facility and its Sacramento powdered soap factory built gas-turbine cogeneration plants. Cogeneration is the combined production of electrical and thermal energy from a single fuel source. Large cogeneration plants typically use one or more gas turbines to generate electricity for sale and use the turbine exhaust heat to produce steam for an adjoining facility.

Cogen One, Oxnard's first cogeneration plant, used turbine exhaust heat for hot-air "blow-through" paper drying and to create steam for the papermaking process. At Sacramento, the exhaust heat is used to produce process steam.

Both the Oxnard and Sacramento plants use the GE LM2500 aeroderivative gas turbine to generate electrical power and to provide thermal energy. The LM2500 is derived from the GE CF6-6 aircraft engine developed in the early 1970s. The CF6-6 has accumulated more than 19 million operating hours powering DC-10 jet aircraft.

Both of the LM2500s have set availability standards of more than 96% over the last five years. The Oxnard LM2500 has more than 75,000 operating hours and the Sacramento LM2500 has more than 65,000 operating hours. In 1990, Oxnard's LM2500-based cogenerator logged impressive availability and reliability figures of 98% and 99%, respectively.

We built another cogeneration plant in 1985, powered by a heavy-duty, industrial-type gas turbine. It supplies both electrical power and hot air for papermaking at the company's Mehoopany, Pa., plant.

Background

Cogen Two represents our most recent experience with cogeneration. Through previous projects, management determined that cogeneration was the most cost-effective and energy-efficient way to provide for the Oxnard plant's growing steam demand. For the investment to make strategic sense, Cogen Two was designed to be able to increase thermal energy to the plant as papermaking operations grow and to provide revenue from electricity sales. Thus, the new plant would sell electricity to the utility and offer a reliable source of exhaust-derived steam.

With this in mind, in 1985 the Oxnard plant signed a contract with the local utility, Southern California Edison (SCE). The contract allowed us to develop Cogen Two and to produce and sell 45 MW of power.

We selected the IM5000 STIG® (steam injected gas turbine) system, which is packaged by Ishikawajima-Harima Heavy Industries Co. (IHI). IHI was to provide engineering, all equipment, and construction supervision for the cogeneration plant; it chose Energy Services Inc. (ESI) of Hartford, Conn., the plant design engineering firm, as a subcontractor. Fluor Daniel Inc. was chosen as the general contractor and construction manager for the new cogenerator.

Cogen Two also was to be designed and built as a "qualifying facility" (QF) power producer, under provisions of the federal Public Utilities Regulatory Policy Act. Receiving QF status gives a cogeneration facility a guaranteed customer for its electricity and exempts it from certain state and local regulations.

In 1990—the first year of operation—Cogen Two had an availability of 94% and reliability of 97.5%. During the four-month summer peak period, the plant had an availability and reliability of 98.5% and 99.5%, respectively.

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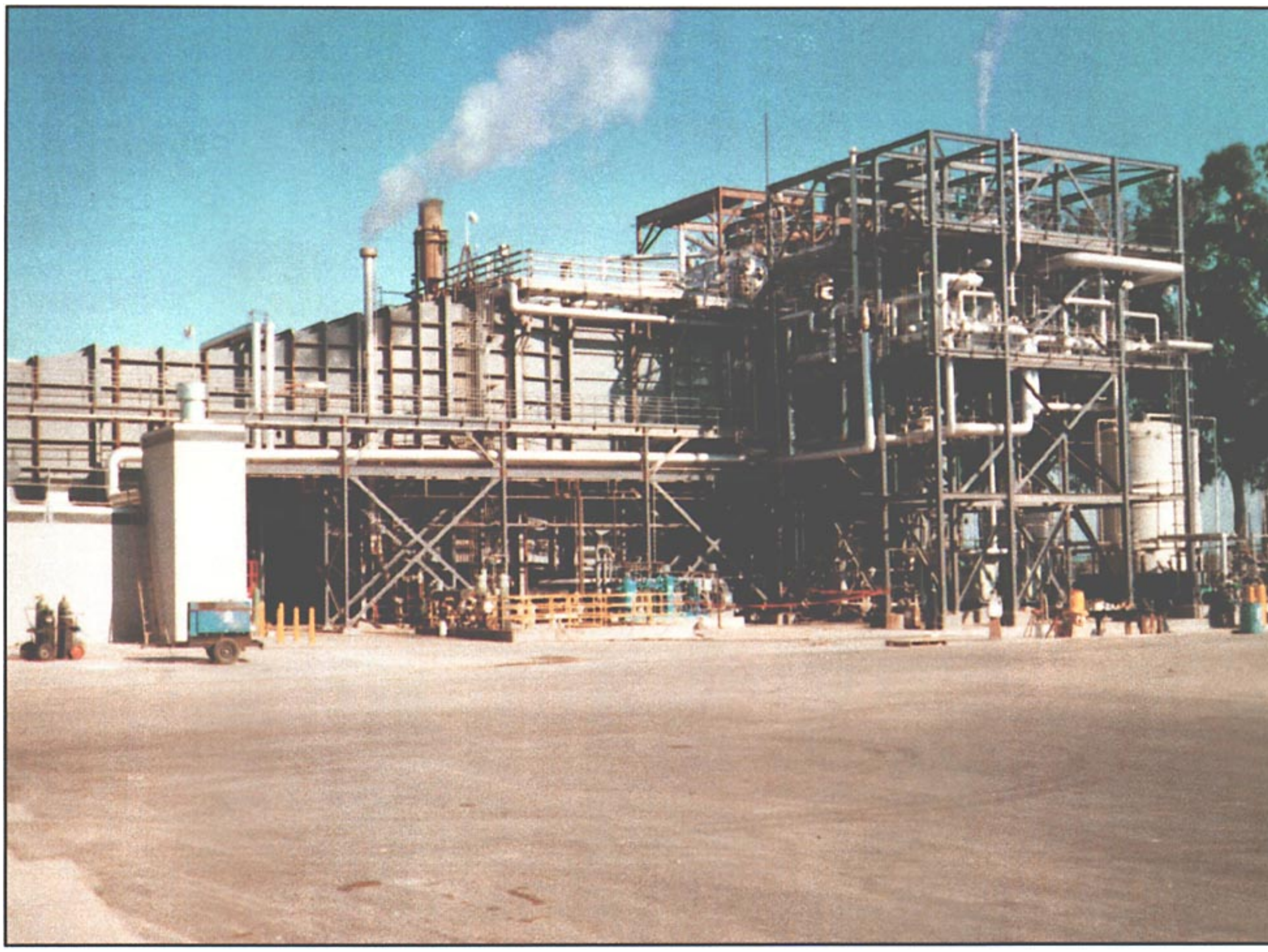
An exterior view of the gas turbine and control room building at the Oxnard cogeneration plant. In the center is the heat recovery boiler where thermal energy from the IHI IM5000 gas-turbine exhaust gases is recovered. The deaerator and boiler feed pump areas are shown to the right of the heat recovery boiler.



System description

Cogen Two's gas turbine is an IM5000 aeroderivative (aircraft engine-derived) which incorporates a GE LM5000 gas generator. The LM5000 generator is manufactured by GE Marine & Industrial Engines and Service, a division of GE Aircraft Engines of Cincinnati, Ohio.

The STIG system injects 700-psi high-pressure steam into the gas turbine at a rate up to 80,000 lb/h and 300-psi intermediate-pressure steam at a rate of up to 50,000 lb/h. This steam raises the gas turbine's output to 49.5 MW from approximately 33 MW in the noninjected mode. In the cogeneration mode, i.e., producing process steam and electricity, efficiency of the plant approaches 50%.

Thermal energy from the turbine exhaust gases is recovered using a Vogt heat recovery boiler. In turn, steam from the boiler is used in the STIG system and in the plant processes.

The heat recovery boiler also houses the selective catalytic reactor, which is required to reduce NO_x emissions to less than 9 parts per million by volume (ppmv). An IHI power turbine drives a generator which produces the power for sale to SCE.

Advantages of the STIG design

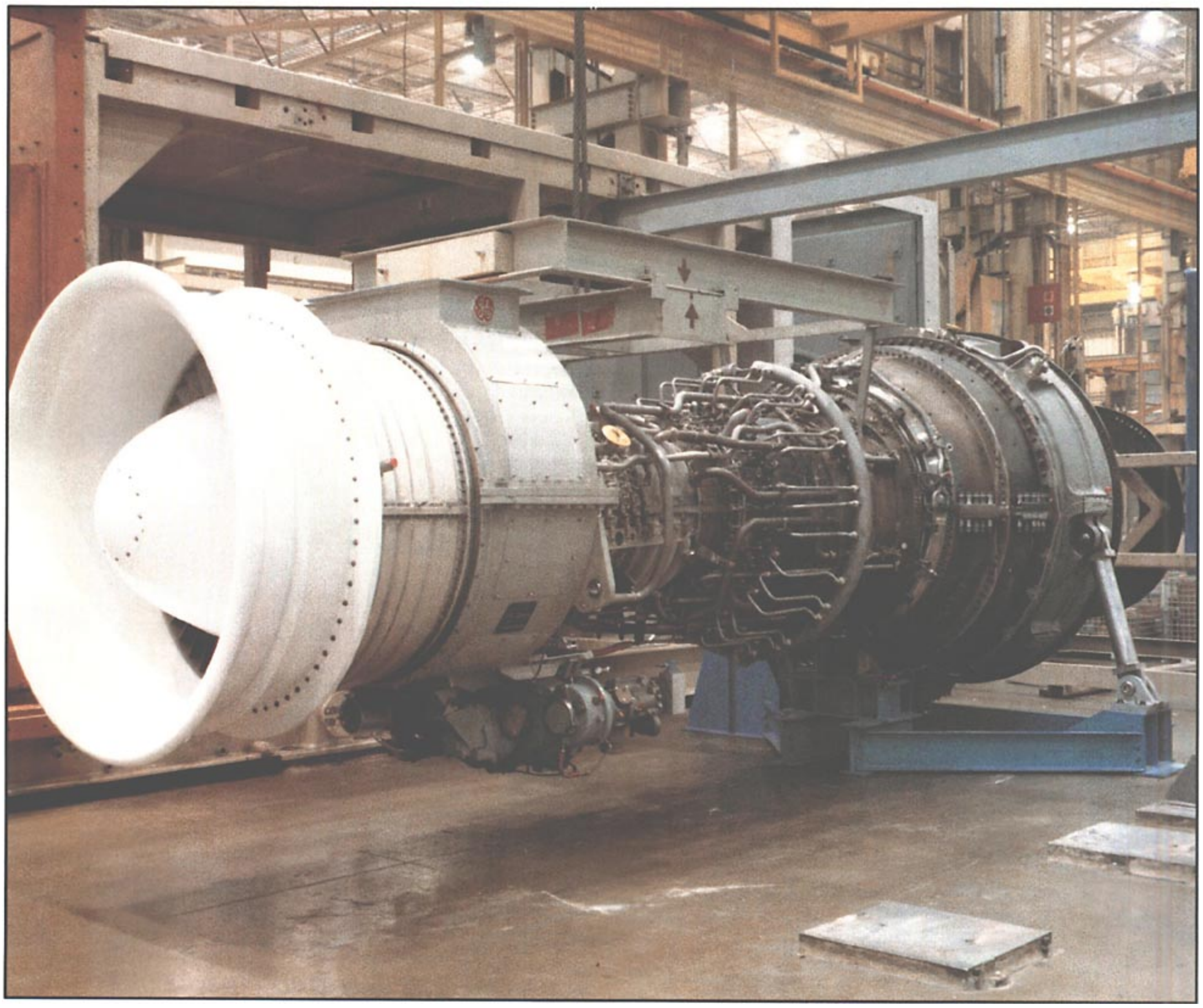
There are several important reasons why we selected IHI for the Cogen Two project. First, the IM5000 aeroderivative gas turbine met the output requirements (power and steam production) of Oxnard's second cogenerator. Secondly, IHI had completed a very similar plant in 1988.

Introduced in the mid-1980s, the STIG system is an advanced cogeneration design that allows for great flexibility and energy savings with lower equipment investment, thus improving overall plant economics.

STIG works like this: Heat from the IM5000 is recovered by directing the turbine exhaust through a heat-recovery steam generator (HRSG), producing steam at three pressure levels. In our case, some of this steam—the low-pressure, low-temperature steam—is used for papermaking and building heating and air conditioning.

Most of the high-temperature, high-pressure steam is used to produce more electricity. In earlier cogeneration plants, this higher-energy steam was sent to a separate steam turbine, in a plant design known as "combined-cycle." This separate steam cycle produces 15–25% extra power and has its own electrical generator, controls, steam turbine housing, condenser, pumps, ducting, piping, and fans.

With IM5000 STIG, this high-energy steam is injected, The LM5000 gas generator is part of the Cogen Two project.



via the fuel nozzles, back into the IM5000 gas turbine compressor discharge ports, and into the low-pressure turbine inlet—thus creating more power with less equipment than the combined-cycle plants. The high-pressure steam injected into the fuel nozzles also reduces NO_x emissions.

While a STIG system has certain added maintenance requirements for the modified aeroderivative turbine, the maintenance is still less time-consuming and less costly than that of combined-cycle power plants.

Greater flexibility for papermaking

Most importantly, the STIG system provides the Oxnard cogenerator with a high degree of flexibility, because steam flow can be diverted either to the papermaking process or the IM5000.

During peak operation, the power plant is contractually required to deliver at least 45 MW of power to the SCE grid. But when steam demand from papermaking drops, the IM5000 STIG can produce up to 49.5 MW.

The plant's HRSG is designed to maximize production of high-temperature, high-pressure steam (750 psig, 610°F). High-energy steam produces the most electricity per pound of steam when injected into the IM5000. However, no more than 80,000 lb/h of high-pressure steam can be injected into the combustor area. The remaining high-pressure steam is combined with the HRSG's intermediate-pressure steam (300 psig) via a pressure-reducing valve. The combined steam supplies up to 50,000 lb/h of intermediate-pressure steam into the IM5000's low-pressure turbine inlet, producing additional power. Intermediate-pressure steam is also throttled down further to create steam for papermaking (250 psig).

There is obviously a limit to how much electrical output can be maintained by this transfer of steam. From a long-term strategic view, however, there is still ample thermal output capacity from the IM5000 STIG cycle to support growth of papermaking and steam demand at the Oxnard plant.

Simplicity of engine removal, modular repair

Another advantage to the system is the ease of removing the gas generator from the IHI turbine enclosure, which simplifies engine exchange. For example, when the Cogen

Two IM5000 required servicing in April 1990, the gas generator was removed. A lease engine from GE was delivered and in place in approximately 72 hours.

The GE lease engine program is especially important to Cogen Two. The largest portions of electricity payments are made by the local utility during the four-month peak summer period, and maintaining operation during this time is crucial.

Lower NO_x levels required

Both Cogen One's and Cogen Two's emissions are regulated by the Ventura County Air Pollution Control District, which recently established an updated NO_x emissions standard of 9 ppmv for new sites. This level of NO_x requires a selective catalytic reactor (SCR). The SCR reduces NO_x using ammonia and a titanium dioxide catalyst and operates via an emissions monitor and computer. Liquid ammonia, vaporized by an electrically heated evaporator, is mixed with air and injected into exhaust gas upstream of the SCR. The gases then pass through the catalyst incorporated into the HRSG, and the titanium dioxide converts NO_x to N_2 and water vapor.

The IHI power module control

Cogen Two's gas turbine module was packed by IHI and is controlled by the company's CSI 7500 triplex digital control. This control package was designed for ease of use by plant operators, who learned the system with help from IHI and ESI engineers familiar with the control.

The CSI 7500 features "triple redundancy," providing more reliable supervision and control of the critical operating parameters by continually selecting the middle value supplied by three sensors. If one sensor fails, the CSI 7500 is programmed to choose one of the remaining two sensors for control. This allows the power module to continue operating, preventing shutdown of the plant.

The CSI 7500 monitors the operating data and can display 80 analog screen comparisons and 30 numerical trend screens. Historical trends created from operating data are held in computer memory for 15 days. That allows options such as one-screen/multitrend analysis of comparative operating data. For example, real-time graphing of the various steam loads versus power output can be plotted in 6-min, 12-min, or 30-min intervals, simultaneously on one screen.

Two of the most useful plant monitoring functions are "event recording" and "trip data storage." Event recording indicates the time-status of all IM5000 turbine contacts through printed time-tagged messages at 20-ms intervals as contacts go on and off. Trip data storage then saves analog data from at least 90 points, as contacts change operating mode. This information is useful for quickly locating sources of a plant trip. The data is stored on a hard drive 96 s before and 48 s after a trip at 20-ms intervals, and is also displayed via monitor and printer. The time resolution of event recording and trip data storage is determined from the time constant of the engine, while the general purpose computer has one-second time resolution.

Balance of plant controls

The balance of Cogen Two plant controls consist of a Westinghouse Distributor Processing Family system. This system controls the heat recovery boiler, ammonia injection system, gas compressors, process cooling water system, air compressors, water treatment system, low-voltage switch gear, and monitors the high-voltage switch gear. Real-time graphing of variables in the system can be plotted versus time. The time interval can be one minute, 10 minutes, one hour, 10 hours, or 24 hours. Data is stored in memory for 10 days before converting to magnetic tape for long-term storage.

Other plant features

Other subsystems include a submicron inlet air filtration system to minimize the need for compressor washing. High-efficiency, deep-pleated filters remove 97.5% of particles larger than a micron, reducing compressor blade fouling that decreases efficiency.

A 98%-efficient evaporative cooler reduces inlet air temperature to essentially wet bulb temperature, improving the turbine's power output.

To meet the purity requirements of steam injection, boiler feedwater treatment begins with a set of activated carbon units to remove organics and chlorine, followed by a set of softeners to remove hardness. Cartridge filters remove particulate matter before the water is pumped to two reverse-osmosis banks. The final stage of treatment is by mixed-bed ion exchange.

Summary

The increased efficiency of a modern cogeneration plant is well documented. According to the Cogeneration Coalition of America in Washington, D.C., a cogeneration plant uses up to 70% of the fuel input, compared to the approximately 35% fuel efficiency of a conventional power plant. A cogeneration plant achieves this increased efficiency by utilizing the exhaust energy that is wasted in a conventional utility power plant.

The pulp and paper business has become a pioneer of industrial cogeneration in part because of its requirements for vast quantities of thermal energy. Cogen Two demonstrates how cogeneration continues to be applied. In addition, it shows how a state-of-the-art gas-turbine cogeneration system can successfully produce much needed electricity for a local utility.□

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