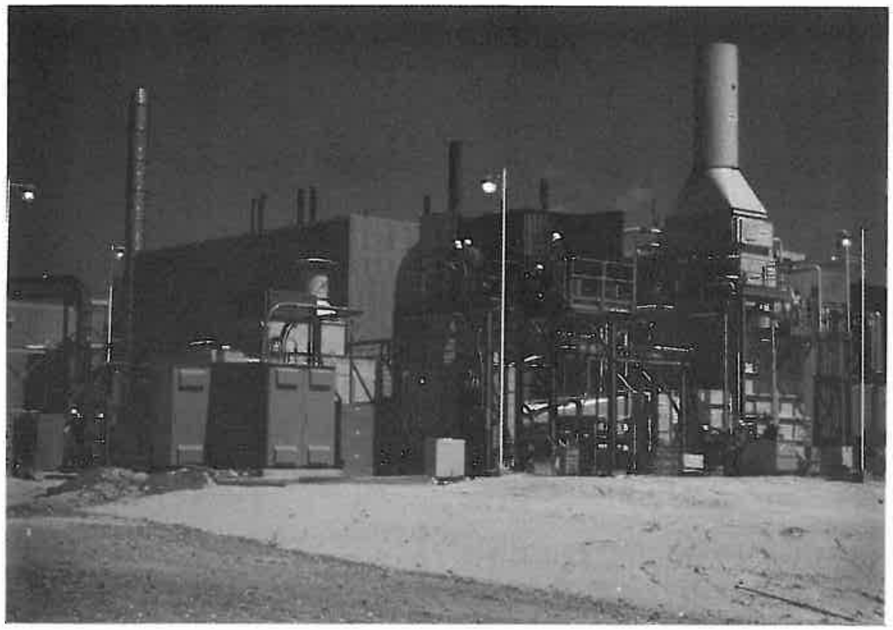
REPRINTED FROM
PREPARED FOODS

Cogeneration enters snack food industry at Frito-Lay

The new Cheng cycle cogeneration system supplies 90% of peak steam requirements and all of the electrical needs for Frito-Lay's newest snack plant near Bakersfield, Calif.

by Dave Keller and Donna Bynum



The cogeneration system at Frito-Lay produces up to 45,000 lbs. of process steam per hour and generates from 3,500 to 6,000 kilowatts of electricity depending on the amount of steam injected into the gas turbine.

Even in this era of diversification, few would expect a successful snack food processor to venture beyond the production and sale of food items and into the markedly different arena of electrical power. Yet, that is exactly what is happening in Kern County, Calif. Frito-Lay, the world's largest snack food manufacturer, generates and sells electricity at its new production plant 150 miles northeast of Los Angeles. The reason is that it is possible to reduce net production costs and actually improve manufacturing methods by generating electricity at the Kern County facility. Thus, Frito-Lay was challenged rather than intimidated by the idea of implementing this innovative technology to improve product quality and price.

The technology installed at the Kern County plant is cogeneration—the simultaneous production of thermal and electrical energy. After carefully considering a number of options, Frito-Lay installed a Cheng Cycle gas turbine cogeneration system. It supplies steam for plant process use, and generates electricity for plant consumption and sale to the local utility. This system is unique in that it injects superheated steam from the waste heat boiler back into the gas turbine combustor. This steam injection process increases the electrical output of the turbine and improves cycle performance as compared with traditional gas turbine systems.

Construction of the snack plant, which produces corn, tortilla, and potato chips, was initiated in October of 1984. Production began in April of 1986. Located outside the city of Bakersfield, the plant encompasses 160,000 sq. ft.

Steam is used in the plant for process applications as well as space heating. Total steam demand is expected to vary between 5,000 and 55,000 lbs. per hour, depending on production and seasonal variations. The electrical usage of the plant is anticipated to fall between 1,000 and 2,500 kilowatts, again depending on plant operations. Current energy costs are on the order of 50 cents per therm of natural gas and 9 cents per kilowatt-hour of electricity.

Reasons to cogenerate

The main factors behind Frito-Lay's decision to cogenerate were efficiency, economics, and electrical independence. Frito-Lay wanted to minimize energy costs while reducing energy consumption. Cogeneration yields overall efficiency around 65% compared to about 50% for separate generation. Economically, energy savings, coupled with revenues from electrical sales to utilities, can result in paybacks of three to four years. Finally, an industrial processor having the ability to generate internal electricity is no longer subject to the electric utility's fluctuations in both cost and service.

Several systems considered

Once the decision was made to install a cogeneration system, Frito-Lay's next step was to determine the optimal system. Based on the plant's relatively high steam-to-electric ratio, a steam turbine (bottoming cycle) system was expected to be more appropriate than a gas turbine (topping cycle). However, after further investigation, the steam turbine was eliminated for several reasons:

- ☐ Steam turbine systems have significantly higher capital costs.
- ☐ Stringent environmental restrictions eliminated the option of using inexpensive fuels such as coal, wood and waste.
- ☐ Tempering the superheated steam prior to process use increases the complexity of cycle flows and controls.

Availability and clean combustion of natural gas, low system capital cost, and cycle simplicity then led to the selection of a gas turbine/waste heat boiler system. Many gas turbine systems were available, but the selection was limited in the appropriate size range. The best system would supply

© Copyright 1986 Gorman Publishing Company

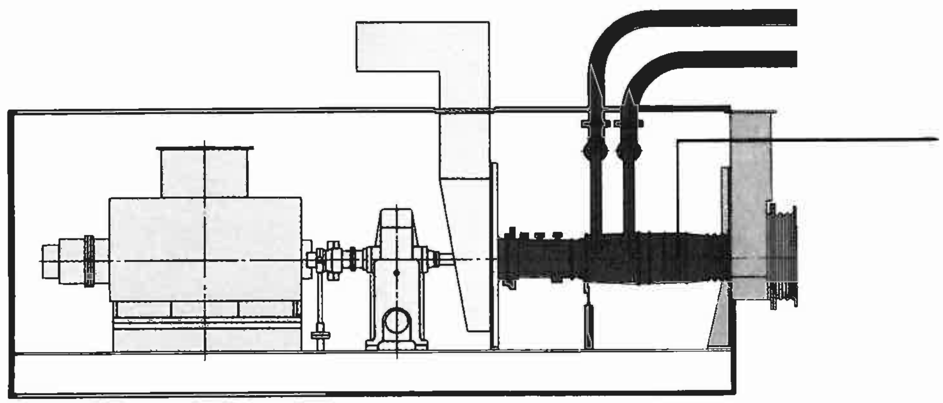
plant steam requirements without generating an excess of electricity.

The major operating concern in applying a traditional gas turbine system was the plant's highly fluctuating steam load. Steam demand for food processing varies drastically as production lines are cycled. Requirements vary from full load down to 10% load almost instantaneously. With a simple-cycle gas turbine system, such a rapid decrease in steam load requires either derating the turbine or venting energy in the form of heat or steam. Either option is highly inefficient and uneconomical.

The next alternative was a combined-cycle gas turbine system. In this design, when process steam demands are low, excess steam is condensed in a second steam turbine to increase electrical output. Although this is more efficient than the simple-cycle system, the capital cost is significantly higher and controls are much more complex because of the need for two turbines and condensing equipment.

Another disadvantage of this system is that the steam turbine cannot absorb instantaneous fluctuations in steam demand. Rather, a lull in the steam load has to be anticipated and has to last long enough to warrant bringing the steam turbine on-line. As with many food processors, Frito-Lay's breaks in production are seldom foreseen and are held to a minimum duration.

The Cheng Cycle system installed at Frito-Lay's Kern county plant provides unequaled load-following flexibility because thermal energy not needed for process is used to boost electrical power output and thermal efficiency. Exhaust heat from the gas turbine is used to produce steam in a matched heat recovery steam generator. The steam produced can be used either for injection into the turbine or for process. Steam is injected when process thermal loads are low or when it is economically desirable to maximize power output.



Generating Set 6000 kW

Cheng Cycle has many advantages

With these concerns in mind, the Cheng Cycle presented a unique solution to the plant's specific needs. The main advantage of this system is its flexibility. If a process line is down for a matter of minutes or even seconds, the Cheng Cycle will absorb the excess steam back into the turbine and generate additional electricity and subsequent revenues. The turbine thus can operate continuously at its most efficient point without wasting steam or heat.

Other attributes of the Cheng Cycle also contributed to its choice for the Kern plant. The system offers all the advantages of a combined cycle system and even better flexibility. Yet the capital cost is comparable to that of a simple cycle system because there is no need for a steam turbine or the associated condensing equipment.

The size of the Cheng Cycle system also is ideal for the Kern County plant. The system is capable of supplying 90% of the peak steam requirements and all of the electrical needs with electricity available for sale to the local utility. Also, the overall heat rate (Btu of fuel per kilowatt-hour of electricity) of the system is significantly lower than that of either simple cycle or combined cycle systems.

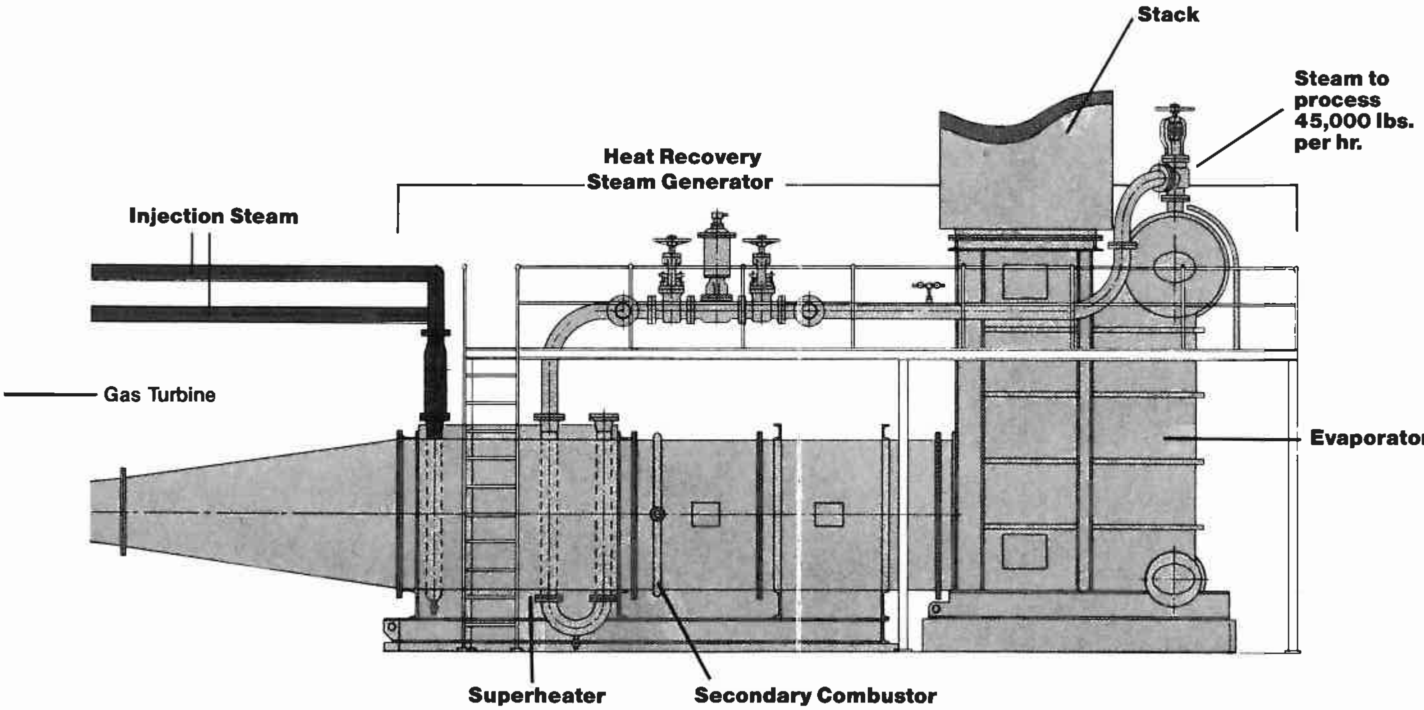
Another advantage of the Cheng Cycle is its projected environmental characteristics. NO_x production is typically the main environmental concern with gas turbines. Emissions are often controlled by injecting water into the combustor of the turbine, thus reducing the combustion temperature and resultant NO_x formation. Although this water injection limits NO_x and boosts electrical output, it reduces system efficiency.

The Cheng Cycle injects superheated steam rather than water into the turbine combustor. This increases electrical output without sacrificing efficiency. The steam reduces the combustion temperature somewhat, and, more importantly, it lowers the partial pressure of oxygen in the combustor, thus inhibiting NO_x formation. Unlike water injection which uses valuable heat energy to evaporate the water, steam injection is highly efficient when properly controlled. It is this controlled optimization of steam injection that makes the Cheng Cycle unique.

The Cheng Cycle system

The Cheng Cycle system burns natural gas or light fuel oil in a gas turbine engine. The engine drives a generator which produces up to six MW of electricity. Although much of the combustion energy is converted into useful electricity, a substantial amount of lower quality energy still is available in the form of 120,000 to 145,000 lbs. per hour of exhaust gas from the turbine at approximately 1,000°F. This exhaust steam is run through a "waste heat" boiler where it produces approximately 22,000 lbs. of steam per hour.

The maximum temperature of the gas passing through the turbine is limited because of the sensitive metallurgy of the turbine blades. Thus, there is a great deal of unburned oxygen remaining in the exhaust stream from the turbine. Additional fuel can be combusted with this oxygen downstream of the turbine in an in-duct (supplemental) burner. Use of the supplemental burner elevates the exhaust temperature and substantially boosts



steam production in the boiler, yielding a maximum process steam flow of about 45,000 lbs. per hour.

Control system optimizes economics

A unique application of the steam from the boiler distinguishes the Cheng Cycle from other gas turbine systems. The Cheng Cycle system superheats a maximum of 22,000 lbs. per hour of steam and injects it back into the combustor of the gas turbine. The remaining steam for process can be either superheated or saturated.

The steam injected into the gas turbine improves electrical output by increasing the mass and the specific heat of the gas flow through the turbine. Electrical generation ranges from 3,500 kilowatts with no steam injection to a peak of 6,000 kilowatts with maximum injection.

The Cheng Cycle equipment is controlled by a sophisticated microprocessor-based system that optimizes cycle performance and economics. Its two-tiered control scheme consists of functional and supervisory control levels. The functional level monitors all flow variables, assures that process needs are met, and optimizes the thermodynamic efficiency of the system. The supervisory level of controls relates all mechanical outputs with pertinent economic data including fuel costs and time-of-day electric rates. Economic performance is optimized by the supervisory controls. Together these control networks yield a sophisticated system that accurately tracks process thermal and electrical loads while maximizing revenues.

Ideally suited for variable loads

The Cheng Cycle is ideally suited for application at the Kern County plant. With its computerized controls, the system is able to precisely follow all process steam and electric loads. In normal operation, the plant steam demand frequently drops abruptly from 50,000 to 15,000 lbs. per hour. The Cheng Cycle is able to track this demand and use the excess steam to generate additional electricity.

The electric generator is tied directly into the utility company's power grid. The utility serves as a back-up to the Cheng Cycle system; neither a utility blackout nor a Cheng Cycle system shutdown affects the plant's continuous electrical supply.

The cogeneration system at Kern County should reduce electrical costs drastically. Frito-Lay will pay only minimal standby charges and purchase electricity from PG&E (the local utility) only during Cheng Cycle shutdowns. And, in addition to offsetting internal electrical bills, the Kern County plant will sell a significant amount of electricity to PG&E.

Under the electrical contract negotiated with PG&E, revenues for energy sold to the utility are directly proportional to current gas and oil rates. Because the Cheng Cycle systems burns natural gas, this virtually guarantees system economics. Increased gas prices elevate both fuel costs and electric revenues proportionally, yielding stable net cash flows. The same economic stability holds true for decreased gas rates, which yield reductions in both fuel costs and electric revenues.

Dave Keller is group manager in the New Products Div. of Process Engineering in Frito-Lay's Dallas R&D Group. Donna Bynum is an engineer in Frito-Lay's Building Mechanical Systems Group at Engineering Headquarters in Dallas.