

COGENERATION: DUAL POWER CUTS COSTS

The combined production of electric and thermal energy using a single fuel source is emerging as an energy-conserving technology that not only helps manufacturers reduce costs but promises to provide relief from the electricity shortfalls that are expected during the next decade. Its principal users are processors like steel, aluminum, paper, food, chemical, and petrochemical companies.

The concept, called cogeneration, is not new; it was used by major U.S. industries early this century when utilities could not respond to all their electrical needs. At one point more than 59% of the nation's electric generating capacity came from industry. Cogeneration began its reawakening with the energy crises of the 1970s and the resulting passage of the Public Utilities Regulatory Policy Act (PURPA) of 1978, which requires electric companies to pay competitive market rates for excess power produced by certified cogenerators. Thus in addition to supplying some of a manufacturer's electrical and thermal energy needs, cogeneration can be a modest source of revenue as well.

The growth of cogeneration since PURPA has been dramatic. In 1980, only 16 facilities filed with the Federal Energy Regulatory Commission to be certified as cogenerators. In 1985, there were 676 filings, and nearly 600 in the first three months of 1986.

Steam turbines are traditionally one of the principal cogeneration means because of their high reliability and efficiency. Fuels are burned in boilers, creating high-pressure steam that drives a turbine to generate electricity, and the waste heat can then be used as low-pressure steam for a wide range of industrial processes. Such arrangements are getting a boost from improvements in the economy and efficiency of boilers, particularly fluidized-bed combustion, which can burn such fuels as high-sulfur coal, petroleum coke, or industrial wastes (pulp from paper processing, for example), while keeping sulfur dioxide emissions to relatively low levels. Pressurized air is blown up through the floor of the combustion chamber, "floating" the fuel as the air mixes thor-

oughly with it. This reduces incomplete combustion, which plagues conventional boilers (where solid fuel is simply laid on the bed). To prevent sulfurous emissions, powdered limestone is included in the mixture; it reacts with sulfur dioxide to form calcium sulfate, an ash. Principal suppliers of fluidized-bed combustion boilers include Foster Wheeler Boiler (Livingston, N.J.), Fluidyne Engineering (Minneapolis, Minn.), Thermal-Transfer (Monroeville, Pa.), and York-Shipleigh (York, Pa.).

Pyropower (San Diego) is installing a circulating fluidized-bed combustion unit in Gilberton, Pa., that is fueled by anthracite culm, a low-thermal-value coal-mining

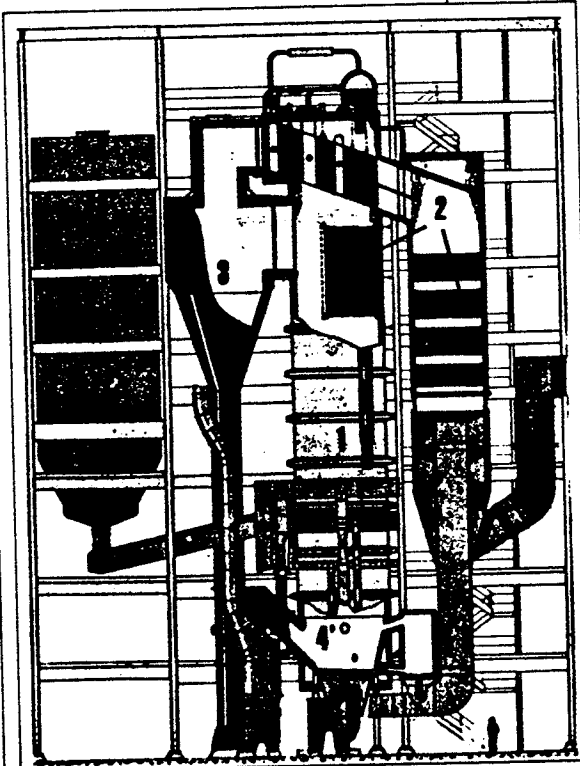
In Pyropower's circulating fluidized-bed combustion boiler at GM's Fiero car plant in Pontiac, Mich., fuel is blown upward into the combustion chamber (1), where steam for cogeneration is made in a series of banks (2). Hot gases exit through the "hot cyclone" (3), shaped to create a swirling action that forces unburned particles downward to the loop seal (4), where they reenter the combustion chamber.

waste that has accumulated in the region for nearly 100 years. This plant takes the combustion efficiency of fluidized-bed boilers a step farther by using a separator that filters unburned fuel and limestone particles from the hot flue gases as they exit the boiler; the particulates are then reinjected into the combustion chamber. Steam from the Gilberton boiler will turn a General Electric turbine, generating about 80 megawatts of electricity to be sold to Pennsylvania Power and Light, and steam will be used by an adjacent coal-drying facility.

Also used in cogeneration, gas-turbine generators operate like jet airplane engines. A rotary compressor feeds pressurized air into a combustion chamber, where injected fuel is ignited. As they exit the engine, the expanding combustion gases force their way through a turbine, causing it to spin. In addition to providing the rotary power for its compressor, the spinning turbine is connected to an electrical generator. In cogeneration applications, exhaust gas is harnessed as process heat as it exits the engine.

Gas turbines can generate more electricity for a given amount of thermal energy (reserving less for processing needs), and are therefore preferred by many companies more concerned with producing electric power than heat. Another advantage is that plants can be operational in only about nine to fourteen months, compared to about one to three years for steam systems, which often require EPA certification and generally must be built on-site due to their larger size. Gas turbines, on the other hand, can often be shipped as "packaged" components that require less on-site construction.

Using turbines as cogenerators becomes tricky, however, if the company's demand for heat fluctuates. In a single-cycle configuration the turbine generates electricity at a constant rate, and when



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process heat demand is low the excess can simply be vented, a costly and inefficient alternative. Or the cogenerator can reduce the speed of the turbine so that only the desired amount of exhaust heat is produced. This approach, however, not only reduces the amount of electricity but also lowers fuel efficiency and usually shortens the life of turbines, which operate best at constant rates.

One alternative is a dual-cycle cogeneration setup, requiring a separate steam turbine (such as that used with a boiler) powered by excess steam. A disadvantage is that the separate steam turbine is used only a portion of the time.

Another alternative is the Cheng cycle, a recent advance in steam turbines that is gaining popularity among cogenerators whose demand for process heat varies. International Power Technology (Palo Alto, Cal.), founded by the concept's developer, Dah Yu Cheng, supplies Cheng-cycle cogenerators that basically recirculate unused steam back into the turbine. The excess steam is superheated by passing it through the engine's exhaust stream and is then injected into the combustion chamber. The steam increases the density of the gases flowing across the turbine blades, basically giving more push to the burning fuel. This improves the efficiency of the turbine by up to 40%, says International Power. To prolong turbine life, Cheng units operate at a constant speed, which requires sophisticated balancing of fuel, air, and recycled steam, accomplished electronically by a Network 90 computerized controller supplied by Bailey Controls (Los Angeles).

Cheng-cycle cogenerators are gaining wide acceptance among food processors, which have seasonal variations in steam requirements. For example, Sunkist Growers uses one at its juice-concentrate facility in Ontario, Cal. Frito Lay and Hershey Chocolate likewise have California facilities that use Cheng-cycle cogenerators.

A promising, though still largely experimental, cogeneration technology is fuel cells—electrochemical devices that convert a fuel's chemical energy directly into electricity and heat with no intermediate combustion cycle. The process starts with a "reformer" that uses steam to convert the fuel (usually natural gas) into hydrogen and carbon dioxide. The hydrogen then goes to the fuel-cell stacks, where the splitting of hydrogen molecules (H₂) at each anode frees electrons, which then flow to the cathodes through an external

circuit. In cogeneration, heat released by the reactions occurring in the cells is collected for use in industrial processes.

Jeffrey Serfass, executive director of the Fuel Cell Users Group of the Electric Utility Industry trade association in Washington, D.C., explains that heat generated by fuel cells meets low- to mid-level heat requirements—from about 150° F to 250° F. So far, however, fuel cells have not been widely considered for cogeneration; instead, emphasis has been on commercializing the technology for mainline power-generating facilities (HIGH TECHNOLOGY, Dec. 1984, p. 52). Nevertheless, a program by the Gas Research Institute (Chicago) successfully demonstrated small, 40-kilowatt fuel-cell cogeneration units. And International Fuel Cells (South Windsor, Conn.) is developing 200-kilowatt units suitable for small industries.

Serfass, however, doesn't expect to see larger-capacity cogeneration until fuel cells are more widely used by the electric

Electric utilities encourage cogeneration in regions where they can't keep up with growth.

utility industry, possibly in the mid-1990s. Until then, he says, their cost and the risks involved will remain too high.

In some regions, industrial cogeneration facilities are being opposed by electric utilities that have sufficient generating capacity and therefore do not want to buy a cogenerator's excess power. "Capacity-rich companies," says Lee Mitterer, a regulatory analyst at the Edison Electric Institute, "are establishing electric rates to prevent the premature development of cogeneration systems." For example, both Arkansas Power & Light and Public Service of New Mexico have created Cogeneration Deferral Programs in which the rate is low enough to compete against cogeneration savings, and is made for a significant term—10 to 15 years—in order to be an attractive way for the customer to defer a capital-intensive investment in cogeneration.

However, in regions where utilities can't meet their current or projected demand for power, cogeneration is viewed as an opportunity to avoid the high costs of new generating facilities. Jersey Central Power & Light, for example, is faced

with a capacity shortage caused by the suspension of the Three Mile Island plant (which supplied JCP&L) and the cancellation of another nuclear facility. Thus, says Glen Steiger, manager of research and development, "we are looking at cogenerated power as an alternative to new power-plant construction." Currently, JCP&L must buy about half of its power from other utilities, but it has signed contracts with Newark Boxboard, which will run a 51-megawatt cogeneration facility, and Marcal Paper in Elmwood Park, which will build a 70-megawatt cogeneration plant. An additional 300 megawatts from two other projects are also anticipated.

The rise in cogeneration is also engendering creative financial arrangements between industries and electric utilities. For example, Celanese Chemical in Pampa, Tex., burns pulverized, low-sulfur coal in two high-pressure boilers, creating steam that turns a 30-megawatt generator and is then reused in chemical processes.

Celanese shares ownership of the cogeneration facility with the utility Southwestern Public Service; Southwestern owns the turbine and sells power to Celanese; the chemical company owns the boilers and sells steam to the utility.

A big advantage of cogeneration is that it can serve as an auxiliary electricity source to supplement potential power shortfalls anticipated in the 1990s. According to the North American Electric Reliability Council, by mid-1990s electric generation capacity in the U.S. will be at a minimum acceptable level, and the electric utility industry will enter 1995 with more than 100,000 megawatts of generating equipment that is 30 years old. Because of environmental considerations, regulatory issues, and costs associated with developing large-scale nuclear and coal-fired plants, U.S. utilities have no new construction scheduled, says executive consultant Robert M. Grant of Stone & Webster Management Consultants (New York), although a number of current projects are near completion. Instead, the trend is to extend the lifetime of existing facilities through maintenance and repair. "But you can only patch for so long," says Grant.

While this trend favors cogeneration, Grant says this is only a partial solution to the expected shortfall: "It would take too much cogeneration capacity." Nevertheless, he says, cogeneration will continue to grow, primarily because cost-conscious manufacturers and processors are pushing it. A recent Department of Energy report, for instance, says current industry has the potential to cogenerate 39,000 megawatts, while projected industrial growth to the year 2000 could add another 47,000 megawatts. □

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