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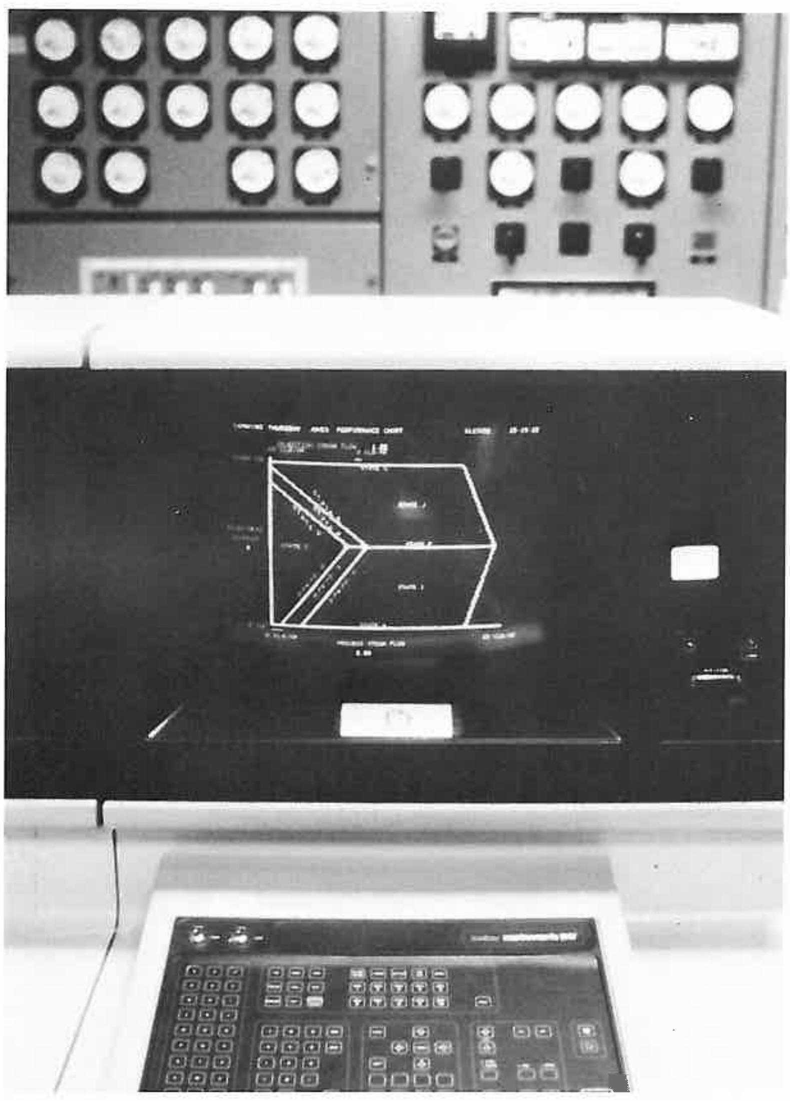
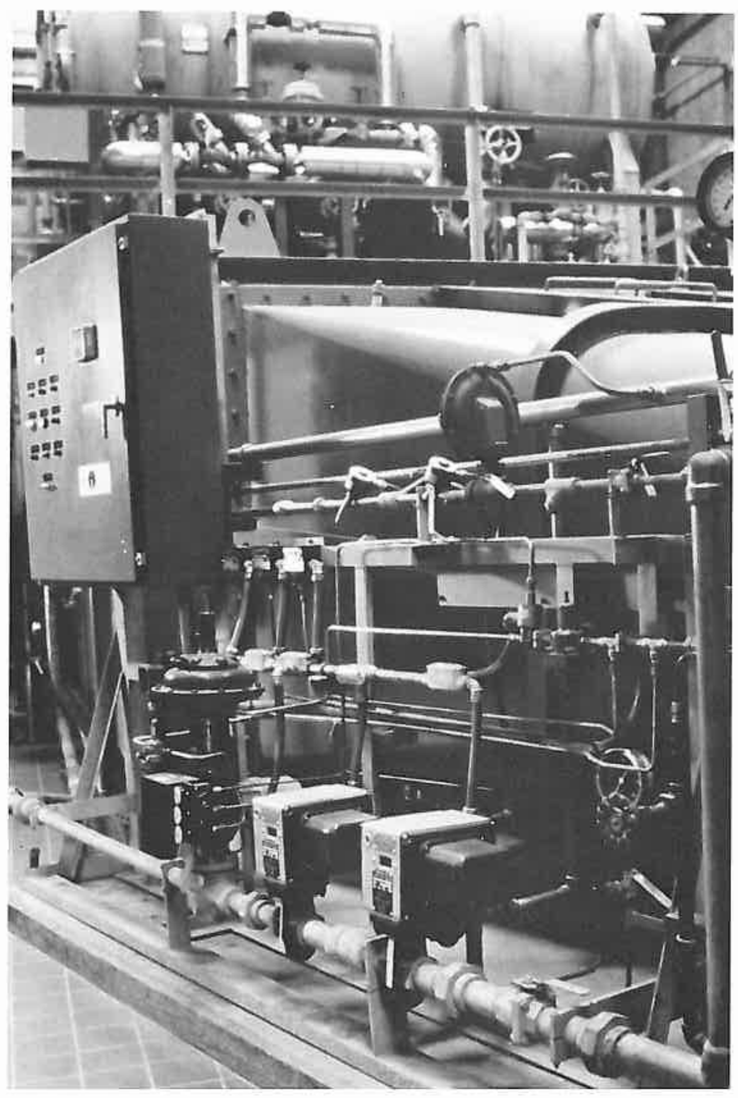
A console centralizes control of the cogeneration system at San Jose State University in California. It provides all the essential information and energy management to achieve effective steam utilization and electricity generation. Console (foreground) provides color graphics.

The horizontal tank (background) is the deaerator in the compact installation. Turbine transition duct and secondary combustion fuel train are in the foreground. The system was third-party financed so installation and operation were not the University's responsibility.





UNDER THE AUSPICES of the State of California Department of General Services, a program identified 10 state facilities where cogeneration appeared technically and economically feasible. The facilities were a combination of hospitals, correctional institutions and universities. One of the universities was San Jose State University.

On June 6, 1982, a Request for Proposal (RFP) was issued soliciting financial and technical proposals from interested developers.

The State was interested in developers who could arrange third-party financing, engineering and construction of the cogeneration systems. The site would benefit from reduced energy costs and, in addition, the State and the institution would benefit from surplus power sold to the local utility. Up front facility development was another feature in the program which the developer would finance.

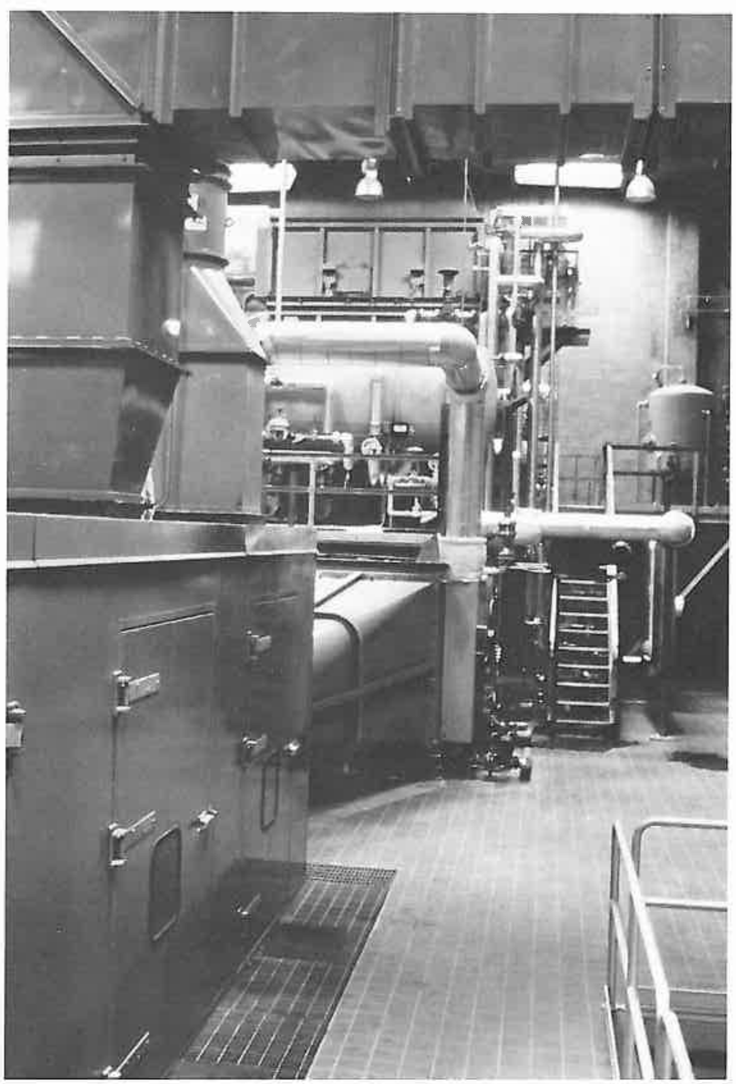
San Jose State University, centered in an agricultural community, has grown from a small teachers' college to a large regional university.

The University's eight schools — Applied Arts & Sciences, Business, Education, Engineering, Humanities and the Arts, Science, Social Science and Social Work — enroll more than 25,000 graduate and undergraduate students. In addition, there are more than 2,000 full- and part-time faculty. The total facility also includes seven on-campus residence halls that accommodate approximately 1,800 students.

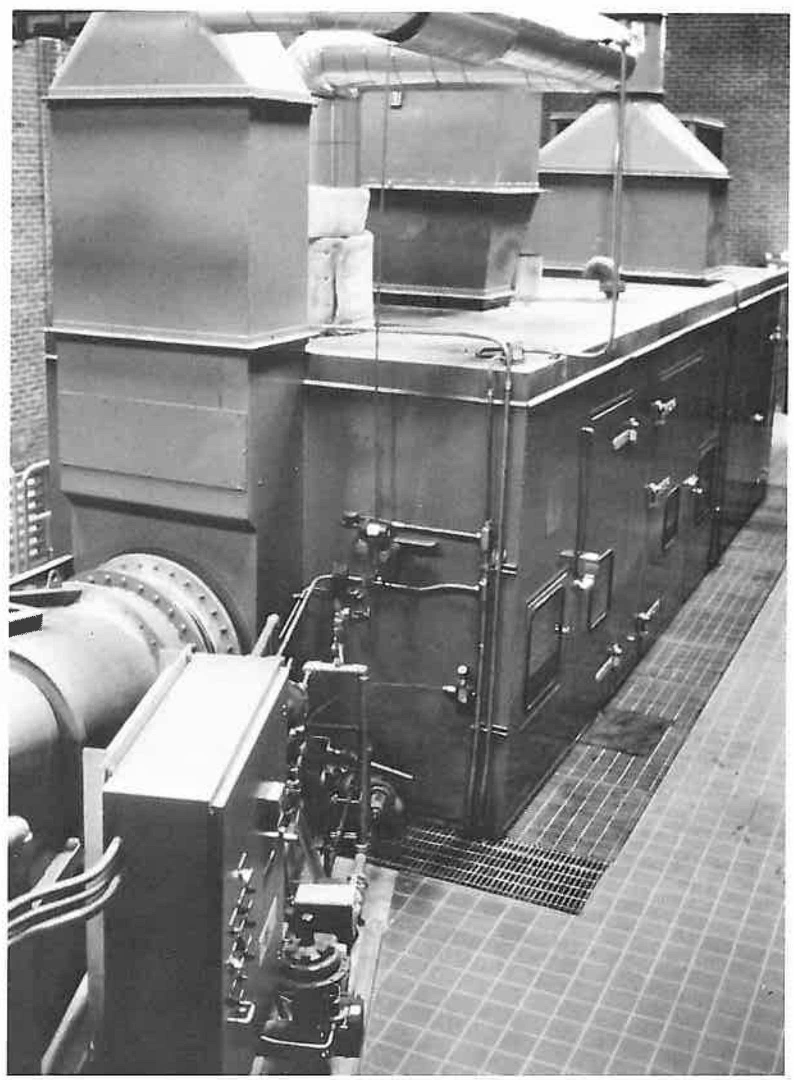
The climate in the San Jose area is mild. The year-round mean temperature is 59.4 F with winter averaging 49.2 F and summer 68.2 F. Rainfall reaches 13.11 in/yr and annual average humidity is 58 percent. Annual temperature patterns are shown in *Figure 1*.

Campus energy requirements are electricity and steam. Prior to installation of a cogeneration system, electricity was supplied by Pacific Gas & Electric (PG&E) through a 115 kv substation located adjacent to the central power house facility.

The power plant includes four 65,000 lb/hr capacity boilers, which in normal operation produced up to 50,000 lb/hr (total) of 110 psi steam. This steam is used to provide heating to 4.5 million sq ft of administrative and classroom buildings. In addition,



Located on the main cogeneration operating floor are the turbine/generator skid, turbine transition duct, superheater and heat recovery steam generator. The ribbed ductwork (foreground) carries combustion air to the gas turbine skid from air filters.



The complete cogeneration skid is mounted two feet below floor level allowing ready access to all equipment. On the skid are the turbine/generator with injection steam piping and ducting for combustion air and skid cooling air.

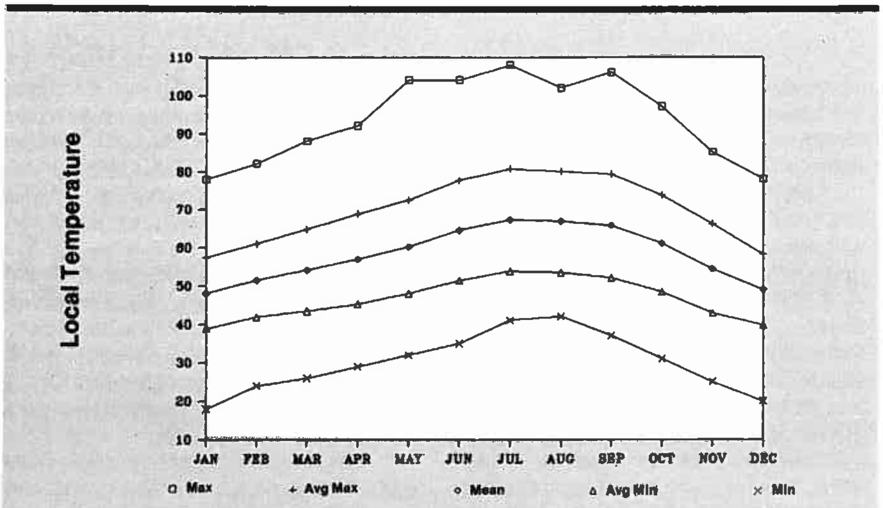


Figure 1

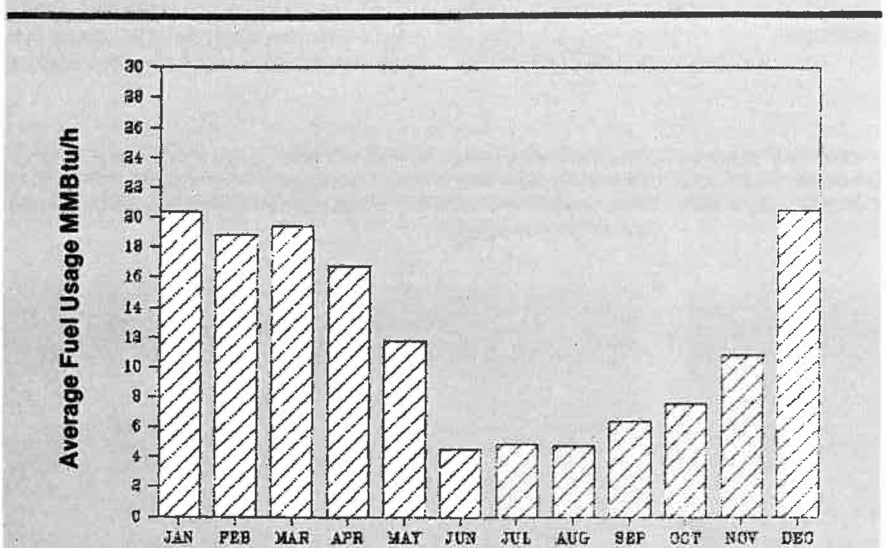


Figure 2a

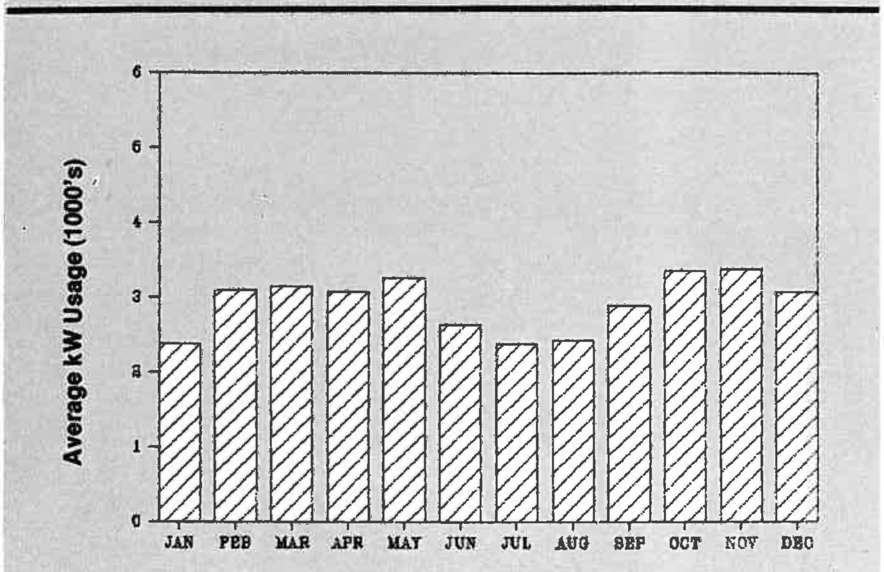


Figure 2b

1.1 million sq ft of administrative and classroom buildings are air conditioned by means of absorption chillers located in the central plant. The seven residence halls have independent heating/cooling sources. The central heating and cooling distribution system serves 64 buildings and facilities.

Original sizing of the campus steam requirements anticipated a much larger campus population in 1985. As a result, the boiler plant is considerably oversized for the current and projected needs.

In addition, space was originally reserved within the walls of the plant for a second cooling tower which is no longer in the University's plans. This space was made available for the installation of a cogeneration plant.

The considerations

Among the major obstacles that the developer and engineer had to consider were the limited space available both for the physical installation and the construction of laydown areas.

A concern was the close proximity of the campus environment to the plant. The access around the plant is a student corridor with fraternity and sorority houses on two sides. The School of Business Administration and the Medical Center buildings are on the other two sides.

However, the most prominent consideration was the erratic steam load. Daily and yearly steam fluctuations occur as a result of the daily and seasonal ambient temperature changes as well as variations in the level of campus activity. Unfortunately, conventional cogeneration works best with a steady steam load.

Evaluation of alternatives

In order to determine the most appropriate technology for the site, extensive data were compiled on energy usage, with both steam and electric loads profiled over a day's time, over a week, and throughout the year. Several years historical records (*Figures 2a and 2b*) were compared to ensure representative patterns.

Though steam turbines and reciprocating engines were considered for the San Jose State project, the steam and electrical load characteristics resulted in a focus on gas-turbine based systems.

Factors considered were availability, size, load flexibility, start/load/unload/stop response time and maintenance requirements.

To gain a better understanding of

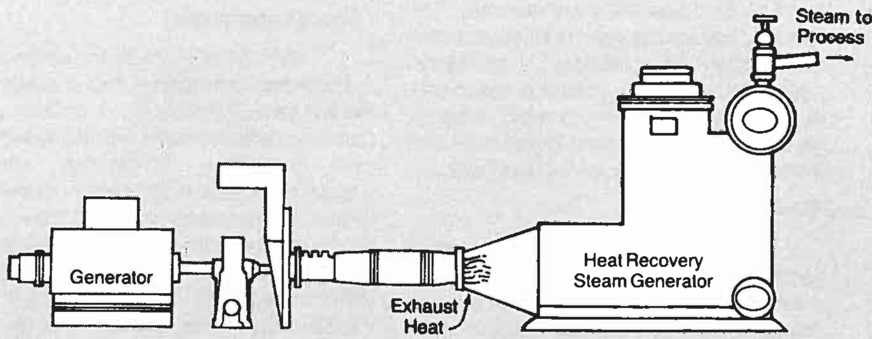


Figure 3

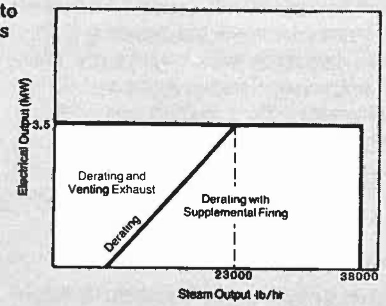


Figure 4

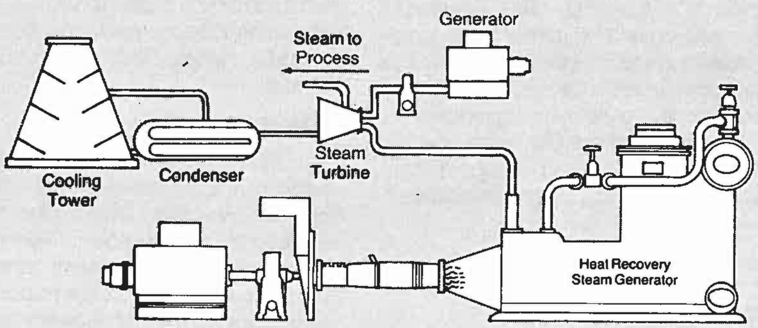


Figure 5

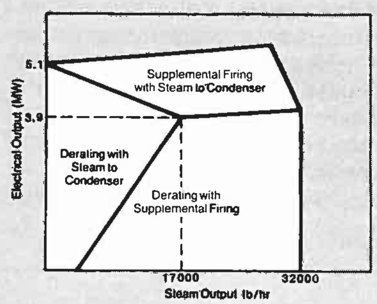


Figure 6

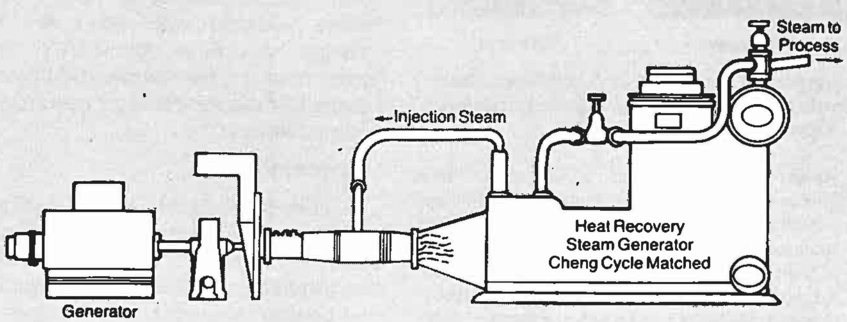


Figure 7

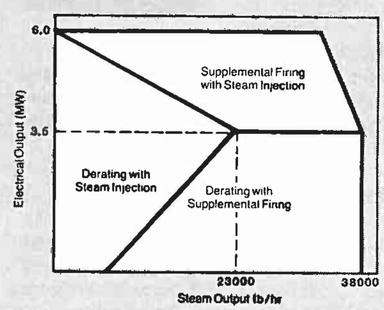


Figure 8

how various gas-turbine based systems would perform, several possible equipment designers were configured and their operations were modeled with respect to the load profiles. Particular arrangements of interest were two commonly used systems: (1) a simple-cycle gas turbine and (2) a combined-cycle system and (3) a Cheng-cycle system. The Cheng system is a comparatively new technology.

The simple cycle

The simple cycle system (*Figure 3*) consists of a gas turbine exhausting into a waste heat steam generator. It is a simple, efficient and economic system for applications with constant thermal loads. However, as thermal load drops below the rated design point, the system loses efficiency rapidly, depressing the operating economics.

When loads do fluctuate below the rated output, two options are available: bypass exhaust around the boiler to reduce steam output, or derate the gas turbine and reduce both steam and electrical output (*Figure 4*). Depending on the fuel and electric rates one or the other options might be less onerous. In either case, when the steam dropped too far, the best strategy would be to shut down the cogeneration plant and use the campus boilers for steam needs.

At San Jose State University, the electric rates changed with time of day sufficiently to change the best operating strategy. Steam load patterns caused the modeled simple-cycle system to spend a good deal of its time at reduced-output conditions.

Combined cycle

The combined-cycle system provides an economic alternative for the problem of variable loads. The system considerations of a gas turbine exhausting into a high-pressure steam generator, and a steam turbine connected to a condenser (*Figure 5*).

With the addition of the steam turbine and condenser, the cogeneration plant can deal with reduced loads without bypassing the exhaust or derating. Steam not needed for campus use is expanded through the turbine and condensed, producing more electricity (*Figure 6*). The combined cycle alternative would increase the University project economic returns substantially over the simple cycle. However, the system is significantly more complex than the simple cycle system, and results in higher investment and operating costs. In addition, the increased size of the plant would have severely taxed the limited space available at the University.

The Cheng cycle

The Cheng cycle is similar in mechanical simplicity to a simple cycle system (*Figure 7*). It consists of a gas turbine modified for the Cheng cycle operation, exhausting into a specially matched steam generator with superheater, and a steam line feeding back through the superheater into the engine. Steam not needed for the campus is directed through the superheater directly into the gas turbine combustion chamber where a carefully controlled mixing with the combustion gases takes place. The increased volume expands the turbine, generating additional power.

There is more flexibility than a simple cycle and greater electrical and steaming capacity than for the equivalent combined cycle (*Figure 8*).

An analysis showed that under the University's loads and rate structure, the Cheng cycle could provide realistic sizing and good financial returns.

Selection

On the basis of the analyses, a review of the relatively new Cheng cycle was initiated. Ultimately, it was selected for installation. Financial and contractual issues were completed and the completed cogeneration system produced its first steam and electricity in December 1984.

The cogeneration plant is capable of meeting the total campus steam and electric requirements. When the cogeneration plant is down for routine maintenance, backup is supplied by the existing boiler plant and the local electrical utility.

Power generated above the University's requirement is sold to the utility at avoided cost rates. When these avoided cost rates are high enough, as during the utility's daily peak hours, cogeneration plant power output is maximized to capture additional revenue.

Financing

The San Jose State University project was financed on a third-party basis. This means that the University and the State of California contributed no capital to the project, but are sharing in the profits. In addition, the University increases energy system reliability by having redundant sources of both steam and electricity. Operations and maintenance for the plant are the responsibility of the developer. ■

About the authors

Kosla

Shepherd

Orbach

L.A. "Lee" Kosla joined International Power Technology, Palo Alto, California, as vice president, sales. He had been with Econics Corp. as national sales manager. Kosla joined Econics during its start-up period in 1979 and was instrumental in developing its sales and marketing strategy and staff. He received his B.S. in Business Administration from Pepperdine University.

Stan H. Shepherd joined International Power Technology in 1983 as product manager for the firm's Series 7-Cogen product. He provides technical support for the marketing and sales activities as well as project management assistance. He too had been with Econics before joining IPT. Shepherd was senior control engineer and product manager for Econics. He holds a patent on a control system for optimizing operation of industrial boilers. Shepherd received his B.S., Engineering, from Cal Tech in 1971 and is a registered professional engineer in California and a senior member of the Instrument Society of America.

Henry Orbach came to San Jose State University in 1982 as associate executive vice president for facilities development and plant operations. He has been a registered architect in the U.S. since 1959 and is a member of the Royal Institute of British Architects. Orbach came to San Jose from Wayne County Community College, Michigan, where he had been Dean of Administration and previously director of capital outlay. Previously, he had been with Chrysler as manager of architectural planning and services.