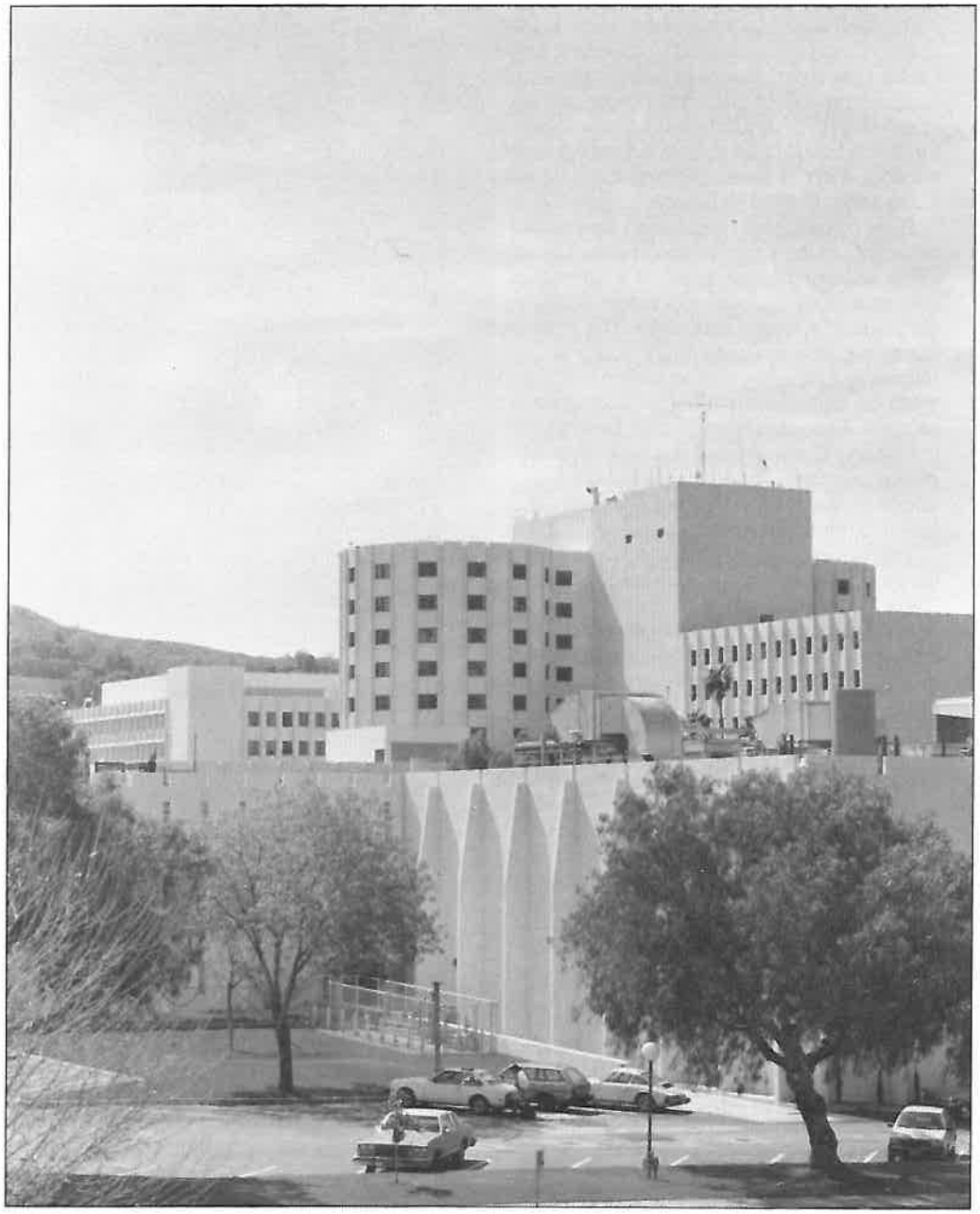
COGENERATION SYSTEM

Cheng Cycle Units Installed at Loma Linda

Loma Linda Hospital and University, Loma Linda, California, where expected energy cost savings with the Cheng Cycle are over $1 million per year.



For further information, contact:

International Power Technology
333 Twin Dolphin Drive,
Suite 725
Redwood City, CA 94065
Tel: 415-592-9020
FAX: 415-592-9028

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International Power Technology (IPT) of Redwood City, California, announced recently that two Cheng Cycle cogeneration systems have completed acceptance and emission testing at Loma Linda Hospital and University, Loma Linda, California. The plant will supply up to 11.2 megawatts of electrical power and as much as 86,000 pounds per hour of steam to the institution for use in space heating and cooling. Surplus electrical output will be sold to Southern California Edison.

By simultaneously producing steam and electricity in the cogeneration plant, Loma Linda will significantly lower its total energy bills as well as become much more self-sufficient in energy production. The institution chose the Cheng Cycle for its ability to efficiently follow fluctuating steam loads and produce high electrical output during peak periods. Expected energy cost savings with the Cheng Cycle are substantially over $1 million per year. The facility was built to accommodate a third Series 7 unit as the facility's need develops.

The system was supplied to Loma Linda by the North American licensee for the Cheng Cycle 501-KH Cogen, U.S. Turbine Corporation of Maineville, Ohio. The plant is a gas turbine-based, modular cogeneration plant, each unit of which can produce up to 5.6 MW of electricity and up to 43,000 pounds per hour of process steam.

"Loma Linda is the first Cheng Cycle plant to be completed by U.S. Turbine," said Scott Baker, IPT president and CEO. "By providing reliable and economical cogeneration service to the hospital and university, it will prove to be an outstanding example of the technical advantages of the Cheng Cycle delivered through the superior engineering and packaging skills of U.S. Turbine."

International Power Technology is a supplier of cogeneration systems based on its patented Cheng Cycle technology. The Cheng Cycle is licensed to U.S. Turbine for marketing, manufacturing and installation in the Western Hemisphere. SGP-VA of Vienna, Austria performs that role in Europe while Hitachi Zosen of Osaka, Japan covers Asia and the Pacific. Kawasaki Heavy Industries is also a licensee with worldwide rights to Cheng Cycle technology.

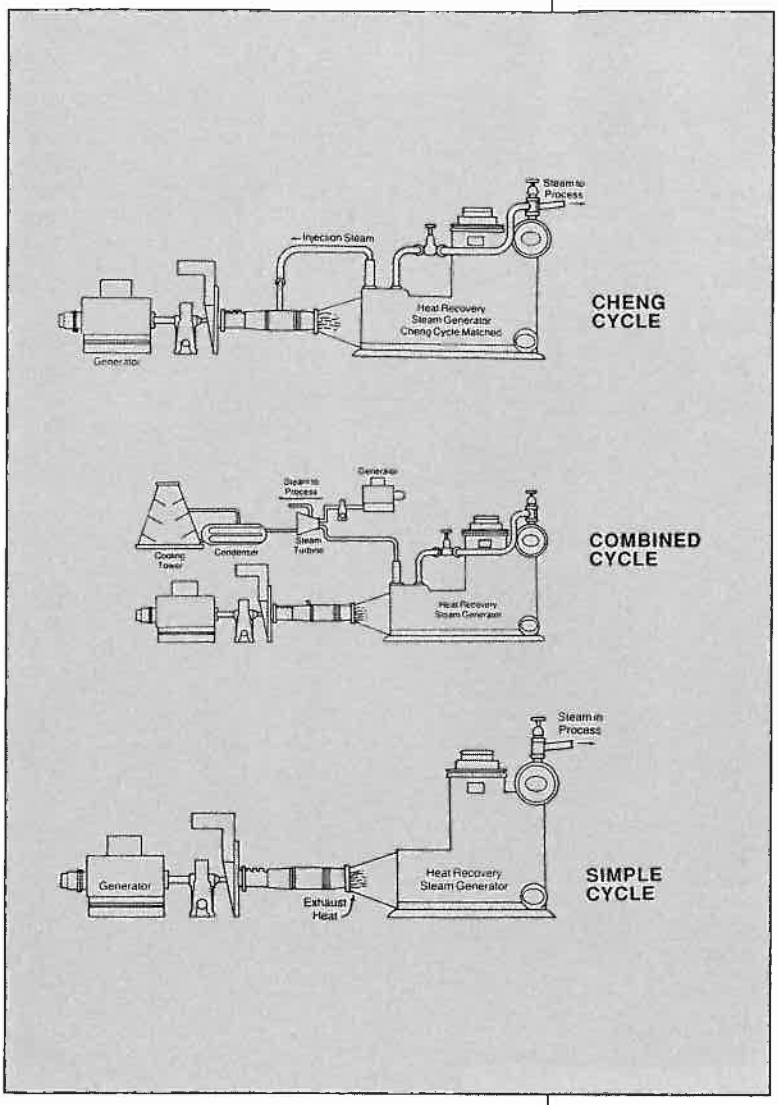
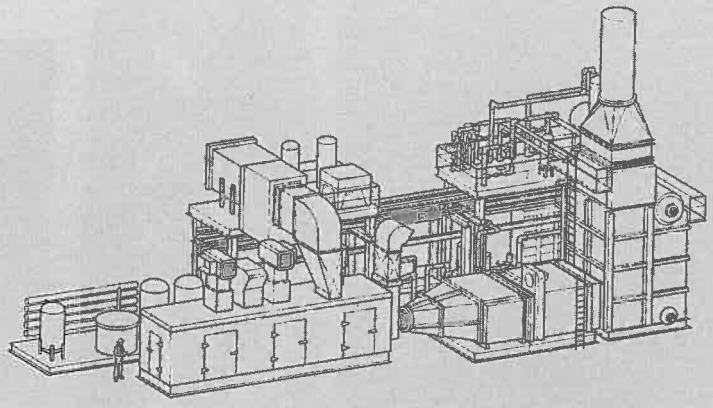


Figure 1. *Cogeneration System Diagrams: Cheng Cycle, Combined Cycle and Simple Cycle.*

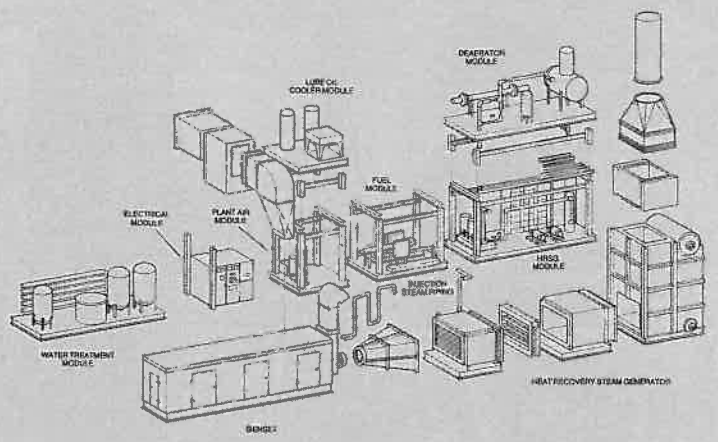
Cheng Cycle Explained

Background

The concept of gas turbine steam injection is not new; experiments have been performed



Cheng Cycle Series 7 Power Island can be completely installed and operational in less than 12 months from date of order.



Exploded view of Cheng Cycle Series 7 Cogen Plant. Pre-packaged modular systems maximize reliability and minimize installation and start-up costs.

since 1905. Until recently, however, use of steam injection has been limited to NOx control or simple power augmentation. The critical relationships between steam-to-air ratios, steam-to-fuel ratios, and other cycle parameters in optimizing the efficiency of the steam injected gas turbine cycle were first identified by Dr. Dah Yu Cheng, a professor at the University of Santa Clara. In 1974, Dr. Cheng formed International Power Technology to develop and commercialize what is now called the Cheng Cycle. Since that time IPT has been granted over 60 U.S. and international patents on the concept and associated hardware.

Unique Combination of Cycles

The Cheng Cycle combines the Brayton (gas turbine) and Rankine (steam turbine) cycles in a unique manner. Traditionally, the Brayton and Rankine cycles have been used in series, as in the well-known "combined cycle." In both combined cycle and Cheng Cycle, engine exhaust heat is used to generate steam in a waste heat boiler. In the combined cycle, steam is passed through a steam turbine to produce additional work. In the Cheng Cycle, steam is further heated and injected into the gas turbine along with the Brayton cycle air and expands through the turbine, producing additional work. The injected steam generates power in parallel with air in the gas turbine, combining the Brayton and Rankine cycles. The boiler captures otherwise wasted energy from both the steam and the air in the gas turbine's exhaust. Power output and generating efficiency are improved by 50% and 37% respectively for the Cheng Cycle Series 7 system.

Cheng Cycle achieves the parallel combining of the Brayton and Rankine cycles without requiring a steam turbine, additional generator, condenser, cooling tower, and auxiliary equipment. For gas turbines in sizes greater than 10-15,000 horsepower, both Cheng Cycle and combined cycle improve the power output and heat rate by a comparable amount. For smaller engines, combined cycle applications suffer from poor steam turbine efficiencies and the disproportionate complexity of added equipment.

Dr. Cheng discovered that peak cycle efficiency occurs at a unique mass flow of superheated steam to the gas turbine. Insufficient flow of steam to the gas turbine results in excess energy exhausted to the atmosphere in the form of sensible heat. Too much steam flow to the gas turbine results in excess energy exhausted in the form of latent heat of vaporization. The Cheng Cycle patents describe in detail how the waste heat boiler design is intrinsically tied to the compressor pressure ratio and turbine inlet temperature of the gas turbine.

An important benefit of the Cheng Cycle is greatly reduced NOx emissions. Steam injection greatly reduces nitrogen oxides (NOx) production — from 100-130 to 10-20 ppmv (dry @ 15% 0_2). Two mechanisms are involved: (1) the large specific heat of water serves to buffer the peak flame temperature and (2) the large volume of steam involved suppresses the partial pressure of oxygen.

Cheng Cycle Cogeneration Application

In a pure electrical power generating application of the Cheng Cycle, all the steam produced by waste heat is recycled through the gas turbine. The single form of useful output from the cycle is electricity. The Cheng Cycle concept can also be readily applied to cogeneration applications wherein there are two useful forms of energy output from the cycle: shaft power and/or electricity as well as thermal output (generally steam or hot water).

In cogeneration applications of the Cheng Cycle steam may be used either for process needs and/or injected into the gas turbine. (See Figure 1.) A duct burner is added between the gas turbine and the waste heat boiler to increase the total steam-producing capability of the system. The added steam

may be used to match increased process loads and/or to increased injection to the gas turbine for higher power output. When tracking process thermal loads, the cogeneration system varies the mass flow through the turbine and/or the duct burner firing rate, rather than cycling turbine firing temperature. In addition, the system can vary both steam and electricity outputs independently of each other. Thus Cheng Cycle provides operating flexibility with mechanical simplicity comparable to a simple cycle system.

In cogeneration, an IPT-developed procedure called "staged steam injection" works to enhance NOx suppression at intermediate steam injection rates. Steam is preferentially diverted to the area where it can have the greatest effect on the primary and secondary combustion zones. In some applications, water injection is used in addition to steam injection for coordinated NOx reduction. This is typically used when regulations require continuous NOx control and when periodically little or no steam is available for injection due to process demands or economic considerations.

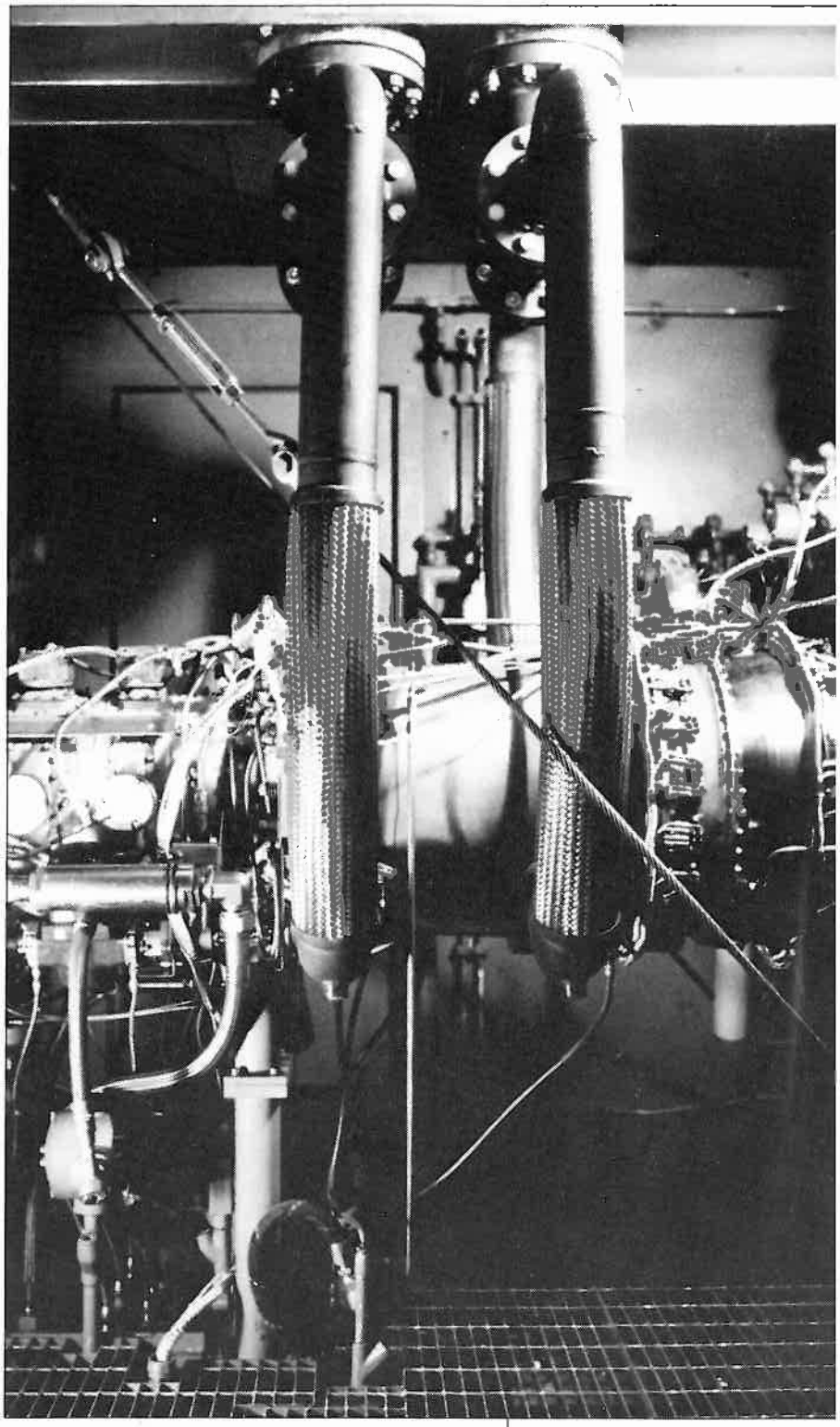
In cogeneration, Cheng Cycle offers numerous advantages over conventional simple or combined cycle systems:

- Operating flexibility. Cheng Cycle systems follow process steam load fluctuations very economically. Steam not needed for process is used for injection into the gas turbine, thus increasing efficiency, electrical output and revenues.
- Peaking electrical capacity. Steam injection, coupled with duct burner firing, allows electrical output to be increased significantly when economics or operating requirements dictate. Process steam production can be maintained simultaneously with maximum electrical production.
- Mechanical simplicity. Cheng Cycle achieves flexibility and high capacity without the steam turbine and associated systems (cooling tower, condenser, etc.) required by a combined cycle cogeneration plant. The result is less complexity and higher reliability.
- Design standardization. The operating flexibility described above means that a single Cheng Cycle system is suitable for a wide variety of applications. This allows design standardization and the accompanying benefits of lower cost and less risk.
- NOx control. Cheng Cycle systems have been permitted in some of the most stringent air quality control districts in the United States. These units have been permitted without the use of expensive selective catalytic reduction.

Cheng Cycle Series 7-Cogen

The first commercial application of the Cheng Cycle is called the Cheng Cycle Series 7-Cogen. It is based on the 501-K industrial gas turbine, modified and manufactured for Cheng Cycle operation by the Allison Gas Turbine Division of General Motors.

The six cogen units already in operation have logged over 180,000 operating hours. The first was installed at San Jose State University, San Jose, California in December 1984. In early 1985, two Series 7-Cogen systems began operation at the Sunkist Growers' facility in Ontario, California. Three Series 7-Cogen 5.6MW systems were installed in 1986 and 1987: a unit at the Frito-Lay plant in Kern County, California; one at SRI International, Menlo Park, California, and a third at the Hershey Chocolate Company Western Plant in Oakdale, California. □



Steam injection lines into 501-KH engines.