Development And Operating History Of Cheng Cycle Series 7

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The first three units of International Power Technologies' innovative Cheng Cycle Series 7 cogeneration systems (*D&GTW,* April '84) have demonstrated a major step forward in reliability in the two and one-half years these steam-injected gas turbine units have been in service. For the ten month period ending April 1987, IPT says these three Allison 501KS-based systems have averaged better than 95% availability, which the company considers very satisfactory for the new technology. Three other Series 7 units have been installed within the last year and these, too, are also said to be providing reliable service.

Development of the Cheng Cycle technology began in 1974, when Dr. Dah Yu Cheng, a mechanical engineering professor at the University of Santa Clara obtained the first patent on the basic steam-injected gas turbine technology and its application. Dr. Cheng incorporated IPT that same year to actively pursue development and commercialization of his idea.

For several years thereafter, Dr. Cheng and his associates conducted research and development work using small gas turbines. In 1980 a major step occurred towards development of a commercial product when the company began working with the Allison Gas Turbine Div. of General Motors to develop a steam injected version of the 501 industrial gas turbine. Testing of the modified turbine occurred in 1982. Allison designated the production version of this steam-injected turbine the "501KH."

In 1983, the State of California, U.S.A. selected IPT to develop a Series 7 cogeneration project at San Jose State University (SJSU), using the Allison turbine. Also in 1983, IPT reached an agreement with Sunkist Growers, in Ontario, California, U.S.A., to develop a cogeneration project which would employ two Series 7 systems.

IPT has installed three additional Series 7's since the San Jose and Sunkist projects were completed. The following is a summary of all projects to date:

Project	# of Units	Startup Date
SJSU, San Jose, California, U.S.A.	1	December, 1984
Sunkist, Ontario, California, U.S.A	2	January, 1985
Frito-Lay, Bakersfield, California, U.S.A.	1	April, 1986
Hershey Chocolate, Oakdale, California, U.S.A.	1	February, 1987
SRI Int'l, Menlo Park, California, U.S.A.	1	April, 1987

Operating history showing cumulative availability of the IPT San Jose and Sunkist Cheng Cycle Series 7 cogeneration units, equipped with steam injected Allison 501 KH gas turbines. Note the dramatic increasing trend in availability over the past 18 months.

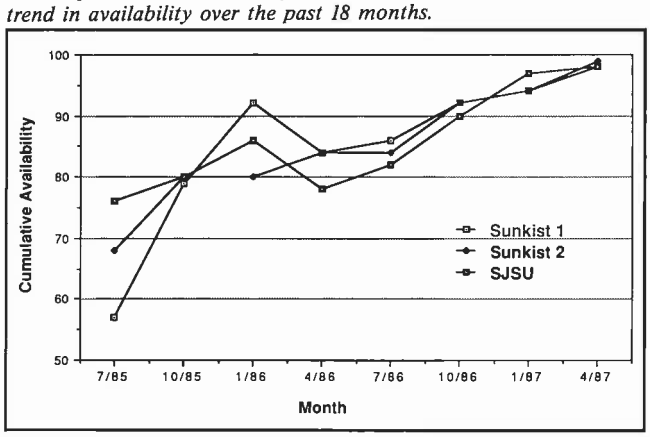
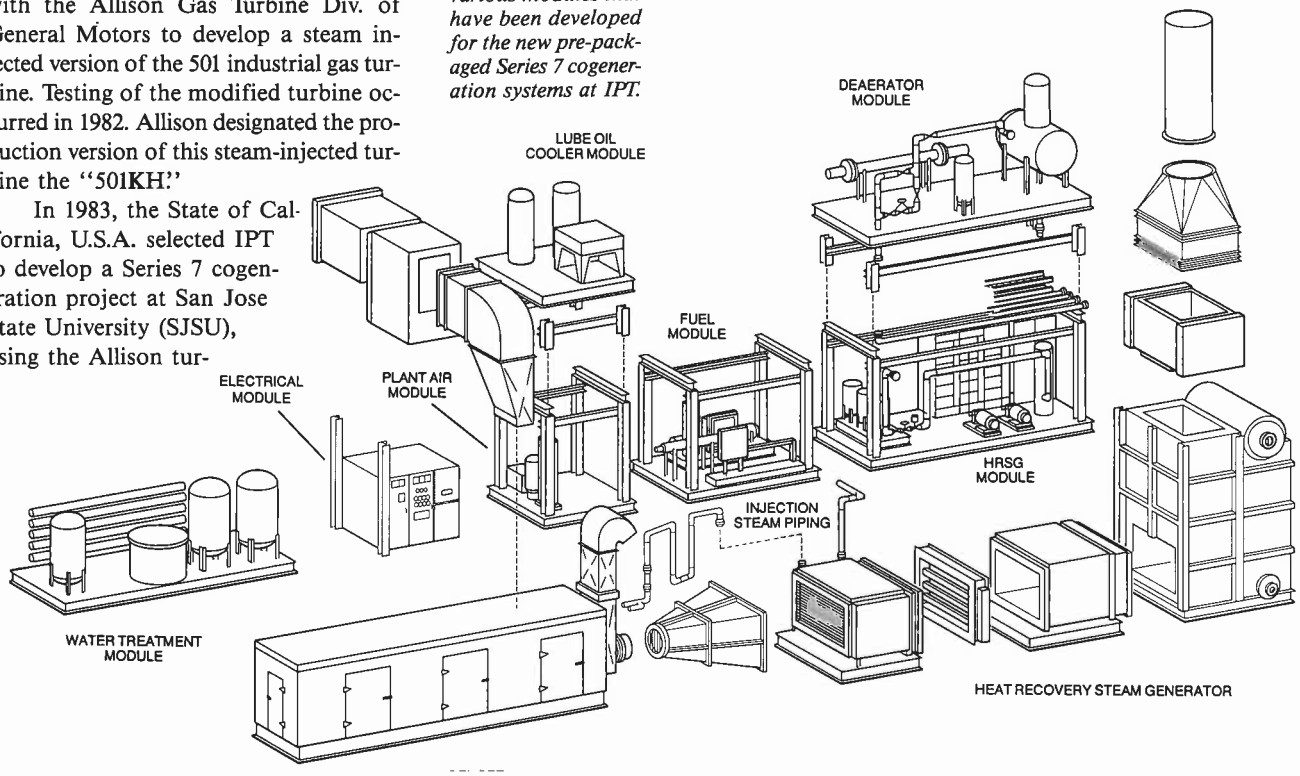
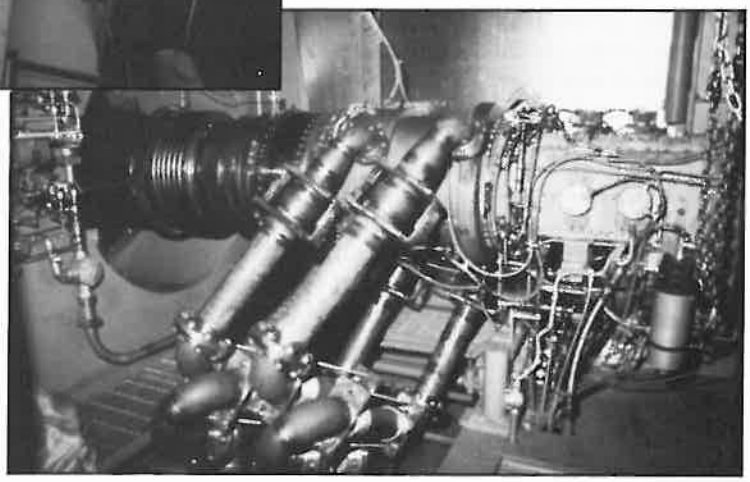


Diagram shows the various modules that have been developed for the new pre-packaged Series 7 cogeneration systems at IPT.



This Cheng Cycle Series 7 cogeneration plant at Sunkist Growers in Ontario, California, U.S.A., was the second of six current Cheng Cycle installations in California.



The new injection steam line design on this Cheng Cycle Allison 501 kH gas turbine is evident in this recent Hershey chocolate installation in Oakdale, California, U.S.A. This design change, along with some other design improvements, have eliminated outer combustor case cracking problems, according to IPT engineers.

The Series 7 has undergone a number of design refinements as a result of IPT's operating experience with the SJSU and Sunkist units. In addition to optimizing the steam injection-related systems, IPT has recently concluded a development effort to enhance the overall reliability and operability of the plant and lower its cost. Modularity and pre-packaging are employed to the optimal level in this new design, and the Series 7 scope has been expanded to include critical balance of plant systems.

The operating histories of the San Jose and Sunkist installations are illustrative of the development process; more so than recent units, which have benefitted from design improvements developed at the first installations. Operating statistics have been provided by IPT's Operations and Maintenance Div. (OMD), which is responsibile for operating and maintaining the SJSU and Sunkist plants. OMD has kept detailed records of plant operations since startup.

A long term measure of a unit's availability, a recent six-month rolling average is illustrated. For each month this is the average of availabilities for that month and the five prior months. All three units have now achieved very good availibility. Six month rolling average availability is now at least 93% for all three units, with the average being 95%.

Although a number of development problems were identified during the first 15 months of operation, the OMD figures demonstrate that they have been addressed and that the Series 7 has matured into a reliable cogeneration system.

The following operating problem conditions were found to be related directly or indirectly to the injection of steam into the turbine: 1. Turbine internal vane and blade cooling passage sulfidation; 2. Compressor surge detector solenoid valve malfunction; 3. Engine over-temperature damage; 4. Turbine lube oil sludging; 5. Super-heater exfoliation; and 6. Turbine labyrinth seal failure.

Typical solutions to some of these problems are listed below to illustrate the extensive development program undertaken to assure good reliability.

In keeping with IPT's stated product development philosophy of incorporating redundant corrections, three remedies were implemented to eliminate sulfidation problems. Allison has added protective coatings to the internal turbine blade and vane passages. IPT has upgraded heat recovery steam generator (HRSG) drum internals to employ a two-stage external steam separator. Control system changes have been incorporated which promote smooth HRSG operation without drum upsets. Since the above improvements were implemented, no further sulfidation problems have been experienced, IPT engineers state.

A joint IPT/Allison review determined that the compressor surge detector solenoid valve, which is not used in other Allison 501 engines, was not necessary. Thus, the valve has been eliminated. No further problems of this nature have been experienced in any of the IPT operating plants.

On several occasions, combustor cans and turbine blades and vanes suffered damage from over-temperature operation. Now, combustor cans are inspected more frequently in order to reduce the possibility of operating with damaged cans. In addition, IPT is field testing a new combustor can design developed by Allison which will prolong operating life. Engine start sequencing logic and the starter system have also been revised so that light-off occurs consistently at the proper speed.

Upon identifying the lube oil sludging problem, IPT reverted to using the ester-based oil originally recommended for this service. Oil/water separation systems have been added to reduce the potential for breakdown of the oil and, based on oil analyses, these systems appear to be performing well. IPT, in conjunction with Allison and a major lube oil supplier, has developed an alternative oil that is not as sensitive to breakdown or sludging and

will be performing field tests soon.

In order to eliminate superheater exfoliation or rust-related problems, superheaters at San Jose and Sunkist were internally nickel plated on site. Superheaters at other installations employ either Alonized or stainless tubing. No further exfoliation problems have been experienced as a result.

Improved alignment procedures and engine mounts have been implemented to prevent turbine labyrinth seal failure, and steam injection piping has been redesigned to reduce lateral loads. IPT reports that no seal failures have occurred since these solutions were implemented.

Based on its experience with the SJSU and Sunkist installations, IPT's design, scope of supply, and manufacturing strategy have undergone significant refinements. IPT's current product design philosophy emphasizes five principles:

1. Systematic incorporation of operating feedback into plant design. In this respect, IPT is in the enviable position of being both a supplier and an operator of several Cheng Cycle plants. As a result, operating feedback is routine and can be incorporated into plant designs over a long period of time.

2. Product design standardization to the maximum extent feasible. This approach allows each new plant to rely on lessons learned from previous similar installations. Thus, increasing operability and reliability.

3. A design that is biased toward shop fabrication, rather than field fabrication, IPT says they have found that shop conditions allow for a higher-quality manufacturing/assembly job than can be performed at the construction site.

4. The designation of a single entity responsible for design and procurement of all major systems. In operating its first installations, IPT found that the use of a variety of unrelated vendors was a major source of cogeneration system design and construction problems. To surmount this problem, IPT's scope of supply includes balance of plant equipment normally supplied by others. Thus, the entire cogeneration plant is designed and delivered in an integrated fashion.

5. The development of close, consistent relationships with a limited number of high quality suppliers. In an effort to increase quality and lower costs, IPT has recognized that standardized purchasing, support agreements and designs are needed to deliver a consistently reliable and cost-effective product. Thus in developing its product, IPT says they have emphasized a close working relationship with its suppliers, established on a long-term, rather than just a project-by-project basis.

The SJSU and Sunkist plants represent the first model of the Series 7 commercial product. Later plants (Frito-Lay, Hershey, and SRI) incorporate all changes required to eliminate the development problems experienced at SJSU and Sunkist, plus they use more extensive pre-packaging.

In particular, the bulk of system controls have been integrated into the gen-set skid allowing factory packaging and testing. IPT has recently concluded an effort aimed at maximizing pre-packaging for all systems, and establishing standard designs for balance-of-plant systems such as water and fuel treatment. The new design incorporates all of the five design principles outlined above.

With the IPT's experience to date, they are convinced that the Cheng Cycle has evolved from a theoretical concept in 1974 to a successful, mature cogeneration product in 1987. The development process presented certain challenges which were successfully addressed using redundant solutions. The result is a reliable powerplant, as evidenced by availabilities which are quite satisfactory to IPT, and provide profitable and reliable cogeneration service for them. ★

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