"Hybrid Cooling With A Power Twist"

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Steam turbine generators (STGs) are being combined with steam absorbers to create hybrid plants that can offer innovative and environmentally-friendly cooling solutions. A unique vertical microturbine technology targets high pressure steam systems - including district steam systems - with an STG designed for applications under 500kw of electrical production, with a 4,000 to 20,000 lb per hour steam load. At a supplied pressure of 150psig and a flow rate of 12,000 lbs/hr, the package reduces the steam pressure to the load to15psig, and delivers 275kW electrical output in parallel operation with the utility grid, while operating at 85dBa with less than 1 mil of vibration.

The physical arrangement of the package consists of a top mounted high-speed, high efficiency, Euler dual-pressure turbine connected to a planetary gear, which in turn is connected to an induction generator. This system is best applied in manufacturing situations or in dense urban areas where district steam systems are more likely to be available. This is of particular benefit since district steam systems usually experience high summer demand on the local electrical grid. By utilizing an electric centrifugal chiller in series, a hybrid cooling plant can be designed to afford significant flexibility to the building owner when considering such things as capital costs, equipment lead time, ease of operation and demand response. Demand peaks can be avoided and system steam rates become competitive with double-effect machines.

The package design addresses the space limitations and reliability requirements of commercial applications; operational simplicity with single button startup and shutdown; the sound criteria of equipment rooms, and the performance requirements for a 2 to 5 year payback investment. With a compact 34 in. wide by 42 in. deep by 78 in. high footprint, the package accepts inlet steam pressures up to and including 200psig . Its performance translates to a 3 to 5 year payback depending on hours of operation and cost of electricity. The system is designed for a 15-year life and 8000 hours MTBF at 80% confidence.

Demonstration sites were the Barber Nicols plant in Arvada, Colorado, and the Rolex Building in New York City, New York. The first commercial application is installed in 7 World Trade Center in New York City. To analyze the benefits, a computer program was developed to simulate the operation and dispatch of plant components. It was based on chiller-log inputs and local utility tariffs for both steam and electric.

Key words: Steam; turbine; generator; STG, PRV

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In today's unpredictable and sometimes volatile world energy market, district energy operators are continually challenged to find new ways to contain their costs while maximizing their resources, all the while delivering reliable, economical, efficient and environmentally sound energy services. Forward-thinking facility operators of buildings that have steam boilers or steam services with pressure reduction valves (PRVs) are now realizing that they have a significant opportunity to generate their own electricity through the use of a new generation of steam turbine generator (STG.) This revolutionary microsteam turbine generates 275kW from an untapped steam pressure resource. Taking this technology one step further, hybrid plants can be designed for the purpose of providing facility air-conditioning. Not only does this utilize a heretofore little used "clean" resource, but it also contributes to the facility's electric power peak shaving efforts, improves energy security and implements a strategy that will help them meet their long-term energy needs.

The Big Chill

Hybrid cooling is the product of using two independent energy sources for the purpose of providing facility air conditioning. Having alternative energy sources available enables a facility to manage its costs around external market influences. Buildings in Manhattan have just such alternatives in electricity and steam. Constructing a central chiller plant designed with both electric and steam driven chillers allows a building manager the flexibility to select the energy sources employed to meet building loads. These are based on the cost benefits associated with the energy source coincident with the load requirements. Particularly during summer peak periods, when electricity costs are at their highest and electric systems are strained to perform under adverse temperature conditions, dispatching a facility's cooling load to a steam driven chiller takes advantage of the lower cost of steam energy at that time and lessens the strain on the building's internal electric grid. There is also the side benefit to the external utility grid. Carrying this one step further, it has been suggested that the incorporation of a microsteam turbine could enhance the benefits of hybrid cooling.

Consolidated Edison is the New York City utility company. In their vast steam network, steam is provided to its customers at no less than 125psi. Most facilities step this down to 15psi for internal use using pressure reducing valves. The microsteam turbine can replace the PRV to provide the required step down in pressure while simultaneously producing electricity on site with an increase in steam consumption of no more than 10 percent. A typical system design would direct the low pressure (LP) steam exhausted from the turbine to a low pressure steam absorption chiller. The electricity produced can be directed to a multitude of uses, including supplementing the facilities main electricity supply, providing power to a dedicated electric chiller, and providing power to essential chilled water equipment, in order to operate the cooling plant in a manner that is independent of utility electric power.

The microsteam turbine application is not a simple solution, however, designed properly it is a remarkably flexible solution. It takes one half of the alternative energy source solution - HP steam - and generates two (2) new alternative energy sources, LP steam and electricity. How that flexibility is managed is exemplified in the story of The Rolex Building.

The Logic Behind The Microsteam Turbine

As with most buildings in Manhattan, steam is supplied to the Rolex Building at 160-180 psig by New York City's utility, Consolidated Edison. The pressure is reduced through two pressure reduction valves to about 10 psig to operate a steam absorption chiller in the summer and heating loads in the winter. The turbine was installed in parallel to one of these pressure reduction valves and generated between 30-100 kWe during the operation of the chiller, dependant upon the steam load of the chiller. The power was fed into the Rolex building power panel, reducing the amount of purchased power and reducing the peak summer capacity requirements for Con Edison's electric distribution system.

For over two years, this Vertical Packaged STG has demonstrated a maximum turbine efficiency of 74% and a power generation of 120 kWe at the maximum steam flow rate of 7,500 lb/h (approximately 500 tons of downstream steam driven cooling.) Following an easy installation, its operation was automatic. Startup and shutdown were implemented daily with a single push button and the unit operated unattended.

Such vertical Packaged STGs make sound fiscal and operational sense in today's district energy environments. For one thing, the uncertainty and fluctuations of the purchase cost of electricity continue to plague district energy operators. Today's electricity generation is one of the largest and most capital-intensive sectors of our economy. Total asset value is estimated to exceed $800 billion, with approximately 60 percent invested in power plants, 30 percent in distribution facilities, and 10 percent in transmission facilities.[1] By establishing the ability to deliver electricity within one's own facilities using existing steam pressure, Microsteam turbines can help combat rising electricity costs.

As municipalities and their surrounding communities continue to expand, electric grid capacities — often stretched to their limit — are experiencing unplanned interruptions of service. Onsite hybrid Microsteam turbines are specifically engineered for commercial, industrial, institutional and municipal application and provide facility operators with an added level of peace of mind in the event of brownouts. For those organizations who are realizing the many benefits of certifying building projects through the U.S. Green Building Council's LEED (Leadership in Energy and Environmental Design) Green Building Rating System®, the application of steam generation may contribute to LEED credits based on its energy recovery and energy cost reduction.

Another contributing factor to the viability of using a Microsteam turbine is the abundance of steam within many private district energy facilities. Without steam turbine generators, this

1 Gridworks. U.S. Department of Energy. Office of Electricity Delivery & Energy Reliability. <http://www.energetics.com/gridworks/grid.html>

valuable resource is currently being lost through PRVs. Clearly, utilizing existing steam sources to generate electricity makes perfect fiscal, operational and environmental sense. The potential new use of this Microsteam turbine on a wider base of installations represents an important step towards a world that must view energy recovery as an integral and essential part of creating sustainable working and living environments for generations to come.

Buildings that use district steam now have many distinct advantages over traditional generation units such as diesel backup generators, microturbines or fuel cells. Using existing steam means there's no on-site combustion; so there are no requirements for emission permits, exhaust stacks, fuel delivery or storage, or additional fire safety systems. Additionally, new technologies are now making this option much more economically viable, creating an opportunity for energy cost cutting through steam-driven on-site power generation.

Figure 1 shows a typical installation of an STG to generate electricity from an existing steam system utilizing a PRV. Connected in parallel with a PRV, a high-pressure steam source feeds both the PRV and the STG. Prior to the installation of an STG, the high-pressure steam is reduced in pressure (with a percentage being wasted) to make it usable to power a single effect absorption chiller and/or another low-pressure load. Introducing an STG to this scenario and decreasing steam consumption slightly, generates electricity, which can be fed back into the primary building grid while continuing to provide steam flow at the requisite reduced pressure for facility use. While these types of steam applications exist at commercial, institutional, and municipal type facilities, informal surveys show that very few STGs are currently installed.

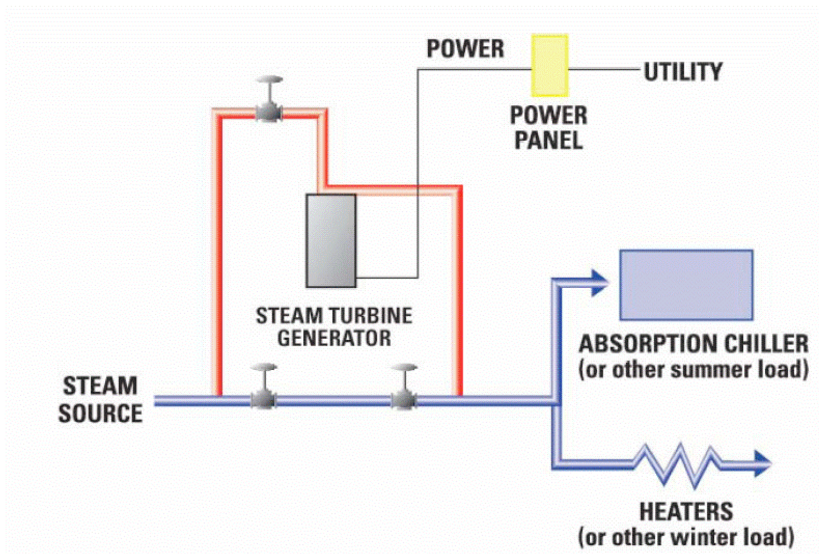

Figure 1 — Typical Installation of an STG

500kW Applications: Learning From the Past

As one of the oldest prime mover technologies still in production, traditional steam turbines have been generating most of the electricity in the U.S. for well over a century. Steam turbine capacities can range from 50kW to several thousand MWs[2], however, the new generation of STGs has been designed to meet the electrical needs of the commercial segment typically not serviced by steam turbine generation — the 500kW and under market.

2 Basics of CHP. Combined Heat and Power for the Northeast. University of Massachusetts Amherst. <http://www.northeastchp.org/nac/CHP/basics.htm>

Until recently, choosing a steam turbine generator for electrical applications of 500kW and under had significant drawbacks. Although the earlier generator “sets” represented the latest steam turbine generation technology of the day, the primary barrier to their application was a marginal payback. Commercially available steam turbines for these applications had efficiencies in the 35-50 percent range. This low efficiency resulted in low power production for a given steam load which resulted in a high installed cost per kilowatt produced and low electricity cost savings.

These units required architects and engineers to design large areas for their physical location, in addition to solving rigging and routing aspects, as well as steam piping and electrical connection challenges. Finding enough space in a mechanical equipment room to engineer an extremely heavy and large-footprint unit into a permanent position often proved difficult. Installing and calibrating these cumbersome horizontally configured units required extensive field wiring and installation labor, specialized mounting equipment and materials. Due to their design complexity, their operational characteristics required constant daily attention in addition to costly annual shutdown and overhaul procedures.

In many cases these devices were located close to the load and away from the central steam production plant, so there was a concern that the level of expertise required to run them was beyond the capabilities of a local operator. While running, these machines were also prone to maintenance events as the result of excessive vibration, which also generated high decibels of ambient noise, requiring additional sound attenuation strategies to be employed.

The quality of the steam used to drive steam turbines often proved to have a damaging effect on many of the components, requiring costly downtime and maintenance. Their susceptibility to corrosion, corrosion fatigue, minerals and non-ionic deposits are well documented. Until now, the combination of all these drawbacks has led many within the industry to think that the 500kW and under market couldn’t be efficiently serviced with steam turbine generating technology.

The New Generation of Hybrids: A Perfect Fit

The revolutionary and innovative technologies found within the leading edge STGs are a direct response to the ever-increasing power demands of today’s energy climate and illustrate why they should become an integral part of an overall energy delivery strategy. As shown in Figure 1, an STG is installed in parallel to an existing PRV. When started, the turbine automatically takes over the steam flow control from the PRV. Whenever the turbine is shut down, the PRV automatically resumes steam control. The STG recovers energy by reducing the inlet steam pressure through a high efficiency, radial outflow steam turbine to drive an electric generator. Electricity generated from the turbine is fed directly to the building’s power panel with utility-approved protective relays, thus reducing purchased power and saving energy costs for building owners. For the system to operate most efficiently, a low pressure application downstream of the turbine is required. This is ideally a LP steam absorption chiller for summer AC use and heat exchangers for winter heating use. The optimum combination is dependant on the intended design parameters of the “hybrid” system.

Today, an advanced compact power system engineered to meet all the electricity generation needs of the 500kW and under market is the culmination of years of research, development and testing. This fully packaged, vertically configured steam turbine generator meets all of the criteria necessary to seamlessly and efficiently integrate into any existing system to provide steam-driven on-site power generation.

The beta test site for the initial prototype, the 11-story 130,000 square foot Rolex building in New York City, met a majority of the issues raised by facility managers.

Based on a thorough analysis of the performance data from the beta site, the United Technologies Research Center was contracted to improve the prototype by developing a Design and Reliability document that more closely answered the needs of a commercial facility. The D&R included lower noise criteria, smaller footprint, simplified operation, increased efficiency and a more robust component design. Following this process, the next turbine was installed in the cutting- edge 7 World Trade Center building in New York City. The unit will produce 200 kWe from the otherwise wasted steam letdown energy. This building contains 42 tenant floors with a rentable area of approximately 1,700,000 square feet.[3]

MICROSTEAM TURBINES - UP CLOSE AND PERSONAL

To fully appreciate the long-term potential of today's Microsteam turbines, one must take a closer look at the specific components and the latest technologies employed in their creation.

Designed for optimal efficiency and performance on all levels, the unit's basic parts, as shown in Figure 2, consist of:

1. Steam Inlet
2. Steam Outlet
3. Turbine
4. Epicyclical Gear
5. Generator
6. Lubrication Oil Pump
7. Lubrication Oil Cooler

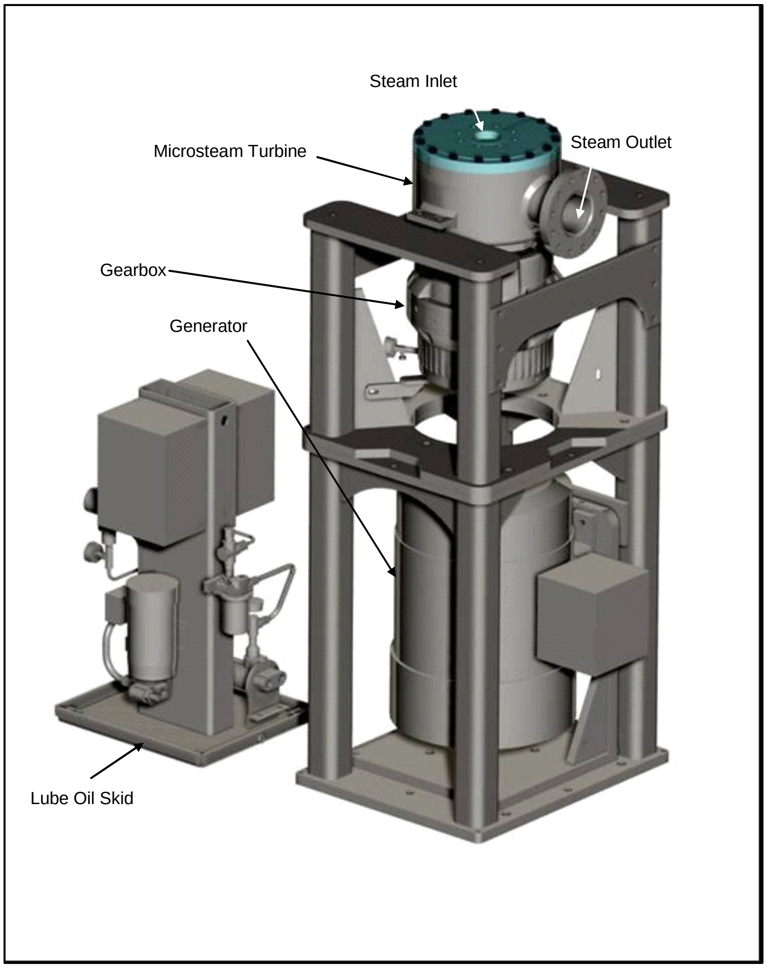

Figure 2 — Vertical Packaged STG

3 *EMPORIS, Buildings, http://www.emporis.com/en/wm/bu/?id=170407*

Microsteam Turbine

At the heart of the unit is its high efficiency Radial Outflow Turbine Rotor (Figure 3a & 3b) that was developed under a grant from the U.S. Department of Energy[4] and the State of California[5] and is unique in several aspects. Its operating principles are simple — energy that is normally dissipated by reducing steam pressure in a PRV is now converted to power by reducing that same pressure through the turbine.

The steam flow is radially outward (Figure 3b). Two power producing pressure letdowns are enabled with a single rotor resulting in a high efficiency. As a result, the turbine can efficiently perform the function of two PRVs in series. In addition to having the highest efficiency, the rugged turbine rotor is constructed from corrosion and erosion resistant titanium alloy and clears most particulates or contamination often found in poor quality steam by centrifugal force. The lightweight rotor enables a top mounted unit with a vertical shaft. To facilitate easy connection to typical overhead steam lines, both the inlet and outlet ports are located at the top of the unit.

Figure 3a

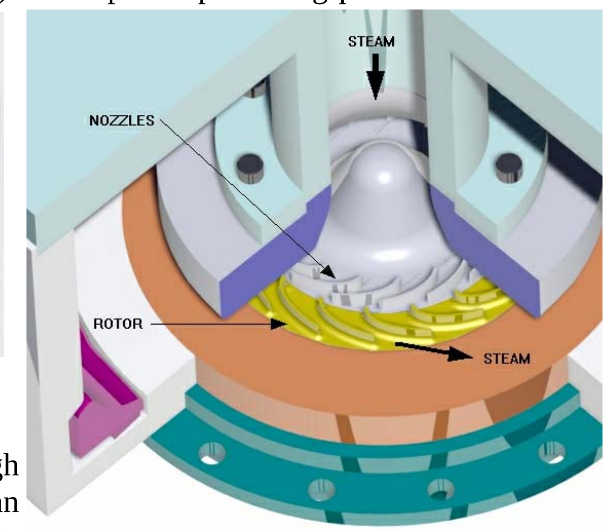

Figure 3b

This patented turbine technology is based on the principles of an Euler turbine design.[6] In independent tests conducted at the United Technologies Research Laboratory, efficiency levels of greater than 80 percent were achieved.

Gearbox

To transfer the energy recovered by the turbine and reduce its high rotating speed, an epicyclical (planetary) gearbox is utilized. This gearbox is a single stage reduction unit with a ratio of 7.78:1. The high-speed shaft supports the turbine and gear on rugged tilting pad bearings. The gearbox is directly mounted on a C-face flange of the generator with a rigid shaft connection. Field alignment is never required. The gearbox efficiency is high, greater than 97 percent, and the unit is quiet, less than 85dBA.

4 California Energy Commission Grant No. NIC-01K-001, administered for the U.S. DOE
5 California State Grant No. C01-00894
6 Hays, L., Dual Pressure Euler Turbine

Generator

The Vertical Packaged STG's generator utilizes a high efficiency Induction Generator, sometimes referred to as an asynchronous generator. Simply, it's a machine built as an induction motor and driven above synchronous speed, thus acting as an alternating-current generator. Below synchronism the machine takes in electrical energy and acts as an induction motor. However, at synchronism, the power component of current becomes zero and changes sign, so that above synchronism the machine (driven here by existing steam) gives out electrical energy as a generator.

It has a D-face flange mounted directly to the base of the frame. The generator frame, gearbox casing and turbine housing are bolted together, providing a self-supporting assembly. This generator operates at 95.4 percent efficiency at 275kWe.

Controls

The programmable controls for the Microsteam turbine are Programmable Logic Controller, or PLC-based, with a full color, easy-to-read display. The PLC was selected for its real-time programming capabilities and reliability within rugged industrial environments and is completely pre-tested at the factory.

Startup is initiated by a single push button. The speed ramp is programmed into a Proportional-Integral-Derivative, or PID loop to provide a gradual opening of the inlet trip and throttle valve until near synchronous speed is reached. At that point, the breaker closes automatically and the generator produces power at the grid frequency. The PLC transfers control to another PID loop which is programmed to maintain the load steam pressure at a value that is slightly above the PRV settings. The valve opens until the required load pressure and steam flow are reached. At this point the PRV has closed and all of the steam flow is through the turbine. As the load requirements change, the valve is opened or closed and the output power follows the steam flow.

The control system has a digital multipoint protective relay and hardwired trips to protect the turbine and power system in the event of faults. If the unit is tripped, the inlet valve closes, the outlet pressure drops and the PRV automatically opens to maintain the original pressure setting. A touch screen displays all key operating parameters, alarms and trips. When the cause of a trip is determined and cleared, the unit can be started again with a single push button.

Atmospheric Lubrication System

The Atmospheric Lubrication System consists of two separate Oil Pumps and an Oil Cooler. Delivering the lowest possible maintenance costs for ease of access and maintenance, this forced-lube system also ensures that no contaminants enter the lubrication cycle. The Vertical Packaged STG's robust frame supports the lubrication package and other ancillary items. An AC motor drives the primary lubrication pump. A DC motor fed by onboard batteries in the event of a power failure drives an auxiliary pump. The lubrication oil is cooled by plant water.

Compact Footprint

Although engineered by utilizing the most advanced steam turbine technologies available today, one of the most striking and universally appealing aspects of the Microsteam turbine is its physical size — or perhaps more accurately — the lack thereof.

Vertically mounted and extremely compact, the entire 275kW power package measures in at a mere 34" width x 42" length x 78" height, allowing it to easily fit through a standard door and maneuver through congested equipment rooms.

To keep installation time and costs at an absolute minimum, a plug-and-play strategy was implemented. As a result, all instrumentation wiring and skid ancillary power connections are pre-wired and pre-tested at the factory. Once in position, installation consists essentially of steam, power and plant utility connections.

To ensure that the Vertical Packaged STG would meet strict safety and reliability standards to qualify it for commercial service, rigorous and exhaustive testing was conducted at the United Technologies Research Center (Figure 4). This photograph shows the unit at the UTRC test laboratory being analyzed for safety, reliability and performance. During testing, the maximum efficiency measured was 80 percent. Laboratory test simulations have demonstrated that a 15-year life cycle can be anticipated.

Figure 4 — STG During Operation at UTRC

PERFORMANCE, EFFICIENCY AND PAYBACK

Performance Testing at The Rolex Building

Short-term operating performance of the turbine at Rolex was measured and Table 1 shows the periodic, remote access and reduced data obtained from the PLC. The weather was very mild during September, limiting the chiller operation and steam flow to levels below which the turbine could not generate appreciable power. However a maximum power of 100 kWe was recorded. The results of these performance tests validated the performance code to be used for commercial applications. The code is based on a mean line analysis with documented steam loss coefficients.

The turbine system was automatically started by the operator each week day morning and shutdown at night. A total of over 50 automated startups and shutdowns were performed with

TABLE 1 - MICROSTEAM TURBINE DATA FOR STEAM TESTING

Date	Time	Test Number	Upstream Pressure	Steam Flow rate	Steam Flow rate	Inlet Pressure	Exit Pressure	Turbine Speed	Measured Power	Shaft Power	Calculated power	meas/calc power	Flow % of Design	Net Shaft Efficiency	Electrical Efficiency
			Psig	acfs	lb/h	Psig	psig	Rpm	kWe	kWs	kWs			%	%
15-May	20:12	11	114	2.34	2,372	7.8	1	27,999	0	15.2	15.2	1	26%		
16-May	19:22	3	124	2.25	2,452	8	1	27,825	4.5						
	19:30	4	128	2.66	2,979	12	1	27,836	5.5	23.8	24.4	0.975	32%	56%	13%
	19:46	5	122	3.24	3,482	16	1.25	27,836	18	36.8	34.1	1.079	38%	64%	32%
	19:56	6	133	3.46	4,007	20	1.5	27,845	28	47.2	47.5	0.994	44%	63%	37%
	20:09	7	113	4.66	4,687	26	1.5	27,863	45	65.7	68.1	0.965	51%	62%	43%
	20:27	8	112	5.26	5,251	30	1.5	27,867	58	79.2	86	0.921	57%	62%	45%
	20:36	9	132	5.57	6,408	40	3	27,889	87	110	116.3	0.946	70%	64%	51%
	20:49	10	115	6.83	6,973	42	3.75	27,903	98-101	124	126.7	0.979	76%	67%	55%
17-May	8:39								55-60						
	11:00	1	136	4.34	5,126	30	1.5	27,881	56	78	83	0.940	56%	62%	45%
	12:00	2	132	4.34		30	1.6	27,852	55						
	13:00	3	135	4.36		30	1.5	27,843	57						
	14:00	4	128	4.38		30	1.5	27,817	50						
	15:00	5	130	4.4		30.5	1.7	27,815	56						
	16:00	6	130	4.4		28.5	1.25	27,825	54						
	17:00	7	130	4.42		28.5	1.5	27,803	54						
	18:00	8	128	4.45		30	1.6	27,793	54						
	19:00	9	131	4.45		29	1.5	27,817	53						
	20:00	10	130	4.46		30	1.5	27,808	51						
	21:00	11	134	4.48		29	1.5	27,812	59						
	22:00	12	134	4.49		31	1.5	27,830	58						
	23:00	13	133	4.52		31	1.5	27,843	59						

no malfunctions. The measured efficiency of the turbine was 67 percent, close to the predicted efficiency for the part load steam conditions encountered. This is significantly greater than conventional industrial steam turbines, which have efficiencies in the 30-45 percent range. The performance code predicted a turbine efficiency of 78 percent for a single stage rotor and greater than 80 percent for a two-stage rotor for commercial applications of interest.

Long Term Operation at Rolex

The unit experienced an additional 250 hours of operation at Rolex during the next summer, with the generation of 8500 kWh. During peak summer days, the Rolex Building manager experienced a 10-15 percent decrease in power bills due to the offset power generated by the turbine. The operation included shutdown every evening and startup the following morning. Initial startup required opening the manual block valves to warm up the turbine followed by pressing the "Start" button. The operation from that point was automatic. During the week the block valves were left open overnight to maintain the turbine in the warm condition. Then, startup in the morning only required pushing the "Start" button. In the evening the unit was shutdown by pressing the "Stop" button.

During the day the system operated unattended. Steam flow was automatically regulated by the control system in response to the chiller demands. During a period when the chiller was malfunctioning, the turbine system automatically tripped and remained in a safe condition until the chiller was fixed and the turbine restarted.

Post operation inspection of the turbine after both demonstrations revealed no erosion or corrosion, despite the significant particulate and liquid waste contamination found in New York City steam. The non-contact shaft seal was particularly effective in minimizing steam leakage with no gland steam condensing system and was found to be in perfect condition, even after the abnormally high number of starts and stops.

Based on testing results, the Microsteam turbine rotor was modified to produce more power at the lower than anticipated steam loads of the Rolex Building. The blade height was trimmed and an abradable tip seal was provided to increase the power output to 65-125 kWe for the range of typical summer steam loads.

Commercialization

As a result of its success at The Rolex Building, the Microsteam turbine is being sold commercially. With minor modifications, the manufacturing and assembly of the Microsteam turbine power system was completed with no problems or rework requirements. The design resulted in a cost effective turbine which can be produced in quantity for a cost which is competitive with, or less than, more mature steam turbine technologies.

Figure 5
Typical Vertical Packaged STG installation

The commercial Microsteam turbines have been designed with improved blade profiles and decreased internal steam leakage and will have a maximum efficiency of 78 percent at design flow rates. The commercial systems are designed as an integrated system to minimize installation costs. They have an improved gearbox and generator which results in a close coupled assembly with no field alignment requirements. The turnkey installation price will be less than $1000/kW for normal site conditions at the full power rating. The improved gearbox and generator efficiency will result in a heat rate of 3600 Btu/kWh at full power, the lowest of any commercial distributed power system.

TIMELY TECHNOLOGY FOR ONSITE ELECTRIC GENERATION

The technology behind the Microsteam turbine can be described as revolutionary, innovative., and pioneering. Years of research, development and testing have culminated in a unit that is simple in its operation with a fail-safe design. The patented Microsteam Turbine is highly efficient and highly resistant to the corrosion potential based on steam quality. The epicyclical gearbox and induction generator are both highly efficient and robust in design.

With a compact package configuration that occupies a footprint of only 34" width x 42" length x 78" height, the Vertical Packaged STG package fits through any standard doorway (as seen in figure 5). Once easily installed and running, the noise level for the unit is 85dBA and the vibration characteristics are less than 1 mil. The 275kW maximum output can be achieved for a wide range of steam conditions. The unit is economical even for lower steam flows with a correspondingly lower power output. The application example shows a payback of 2 years, which is well within range of most financial criteria for such a project.

Clearly, with the advent of the new generation of microsteam turbines, district energy operators no longer have the physical restrictions, economic shortfalls and unacceptable performance associated with earlier versions of this technology. Now, the 500 kW and under market can benefit from an impressive list of advantages. Energy conversion with these new Vertical Packaged STGs will reduce the amount of electricity purchased, saving energy costs. Now all buildings with steam service and PRVs must be viewed as potential candidates to economically generate their own electric power from this dynamic technology.

In the final analysis, these units represent a significant opportunity to progressive minded facility managers who want to reuse an existing energy resource, improve energy security, contain energy costs and take an important step towards a sustainable future.

Author’s Note

The Microsteam system was introduced by Carrier Commercial Service in July 2006. Carrier Commercial Service provides heating, cooling, building controls and energy solutions to customers in the U.S. and Canada through 100 branch locations. Carrier Corporation is a subsidiary of United Technologies Corp. (UTX), a diversified company that provides a broad range of high technology products and services to the aerospace and commercial building industries worldwide. Many thanks to Lance Hays of Mafi-Trench and Benoit Olsommer, Ph.D. Project Leader, Energy Systems, United Technologies Research Center for supplying technical information and data used during the research and writing of this paper.

Bibliography

Print Media Tredinnick, Steve, P.E. “STGs as PRVs?” District Energy Third Quarter, 2005: 47-48.

Websites

Basics of CHP, Combined Heat and Power for the Northeast. University of Massachusetts Amherst. 20 December 2005. http://www.northeastchp.org/nac/CHP/basics.htm
EMPORIS, Buildings. 23 December 2005. http://www.emporis.com/en/wm/bu/?id=170407
Gridworks, U.S. Department of Energy. Office of Electricity Delivery & Energy Reliability. 20 December 2005. http://www.energetics.com/gridworks/grid.html
U.S. Green Building Council. 5 January 2006. http://www.usgbc.org