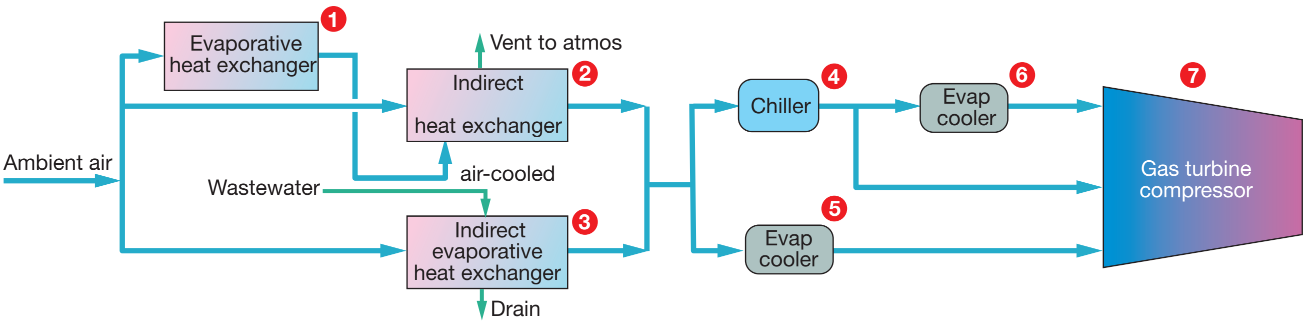
Make it right!



ECOCool™ 1→2→5→7   ECOChill™ 1→2→4→7 or 1→2→4→6→7   Hydro-FlexCool™ 3→4→7, 3→4→6→7, or 3→5→7

21. Options for cooling turbine inlet air on GTs rated less than about 25 MW offered by Everest Sciences may increase net generation and improve net heat rate compared to traditional solutions

The section on optimizing turbine inlet cooling immediately below, offers new options for owner/operators of small GTs, which may involve chilling—or not. It illustrates the value of combining multiple heat-transfer devices into an integrated TIC system to maximize performance and return on investment.

Optimizing TIC

In the minds of most power professionals, GT inlet cooling can be accomplished in one of three ways: evap cooler, fogging system, or chiller. Selection often is made based on the lowest-cost alternative given the plant's ambient environment and power-supply contract.

In general, not much engineering time is expended on this phase of major power projects. Example: For a given plant, fogging may be nixed at the get-go by owners worried about the potential for water-droplet impingement on compressor blades, and chillers may be thought of simply as "too expensive." That would leave a wetted-media evaporative cooler as the "best fit" by default.

Perhaps there's not much an owner would gain by investing in more engineering on TIC, particularly in the merchant power sector where plants are "flipped" regularly. In such situations, low capital cost is critical to return on investment. Also, off-takers and contracts change over time which can alter the value proposition of inlet cooling. Chillers may make perfect sense if your plant qualifies for capacity payments, but what if you just sell energy?

Investment criteria when the GTs are installed to serve onsite load, such as at process plants and institutions. Low life-cycle cost, achieved through top performance and high capacity factor, typically is the goal in this segment of the generation business. Gas turbines for all but the largest refineries, chemical plants, and paper mills typically are rated less than about 25 MW, which opens up another option for TIC: Everest Sciences Corp's (Tulsa, Okla) highly engineered air inlet systems.

The company's factory-assembled and -tested modules incorporate filtration, cooling, and inlet noise control elements configured for specific site conditions. They can be installed over a weekend, or in less time, depending on the degree of preparation—for example, having electrical, water, and sewer connections available.

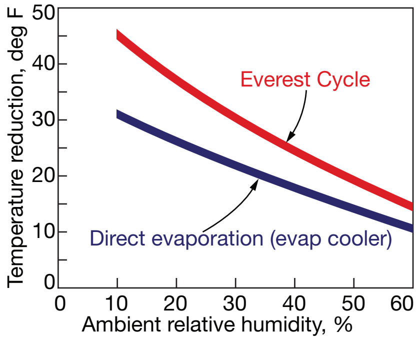
Two packaged TIC systems supplied by Everest have been operating successfully since early 2007, two more are scheduled for operation by early fall. The gas turbines at these installations all are A501K engines (manufactured by Allison and now part of the Rolls-Royce GT portfolio). The company's first LM2500 application is planned for early 2011.

You can look under the hood of an Everest TIC solution but you can't see the guts of the company's proprietary heat-transfer equipment. There's no smoke and mirrors here, the thermodynamics is "textbook." The company's engineers have integrated several components in a manner that significantly improves turbine performance through more effective heat transfer while reducing the amount of power required for TIC.

To understand what Everest has done in principle, follow the processes described in Fig 21. The company offers three general solutions: ECOCool™, ECOChill™, and Hydro-FlexCool™. Each begins with ambient air and ends with conditioned air being injected into the GT compressor.

In the ECOCool process, ambient air is cooled by evaporation in a high-tech crossflow heat exchanger (1 in the flow chart)—an entirely different device than the wetted-media evap coolers you are most familiar with (Fig 22). Air from (1) is used to cool ambient air for combustion in an air-cooled heat exchanger (2).

Key point: Combustion air flowing through (2) is cooled, and its density is increased, without adding moisture. Thus, for a given temperature reduction, mass flow is higher. More specifically, ECOCool reduces the enthalpy of the combustion air (removes heat energy), unlike conventional evaporative methods which cool air, but cannot change its enthalpy. This sensible cooling pro



22. Everest cooling process is increasingly more attractive than direct evaporation as ambient relative humidity drops

cess resembles a chilling cycle but it uses fans and pumps rather than large compressors.

Cool air leaving (2) next passes through a wetted-media evap cooler (5) before entering the compressor (7). Important to keep in mind when you dig into the company's literature at www.everestsciences.com is that the two-stage hybrid cooling process incorporating steps (1) and (2) is referred to as the Everest Cycle™. ECOCool is the name for the Everest Cycle coupled with the air-wash cooling step in (5).

Everest's Marcus Bastianen, PE/SE, sums up the benefits of ECOCool this way: "The hybrid process supplies air to the compressor at *less* than the ambient wet bulb using about the same amount of power required for conventional evaporative methods. It provides turbine inlet air at higher density than any competing evaporative technique."

ECOChill flow path is (1), (2), and (4), where the last is the chiller package. A final evap cooling step (5) may be added to optimize the offering for certain ambient conditions. ECOChill reaches target turbine inlet air temperatures with a chiller that is substantially smaller than one for a conventional refrigeration package because former is less directly affected by ambient conditions. Air entering the chiller (4) is at a temperature significantly lower than ambient, some cooling already having been done by the Everest Cycle.

The benefits, says Bastianen, are "lower chiller capital and operating costs, more *net* turbine power output, and higher net engine efficiency. ECOChill also offers users the flexibility to optimize their cooling processes as ambient and operating requirements change."

Once again, understanding the Everest lingo is important before dialing up the company's Website: h^3 is the name Everest uses for its supplemental mechanical chilling process. ECOChill incorporates both

Comparing alternative GT air-inlet cooling strategies at 95F, 30% RH, sea level

	Gross power increase, kW		Net power increase, kW		Gross heat rate improvement, Btu/kWh		Net heat rate improvement, Btu/kWh	
Inlet cooling	**GT1**	**GT2**	**GT1**	**GT2**	**GT1**	**GT2**	**GT1**	**GT2**
None	Base case		Base case		Base case		Base case	
Evap cooler	7.4%	13.2%	7.3%	13.0%	1.1%	4.5%	1.1%	4.4%
ECOCool	9.9%	18.9%	9.8%	18.5%	1.4%	6.2%	1.3%	5.9%
Chiller	14.1%	29.5%	10.5%	23.9%	1.9%	8.8%	-1.3%	4.7%
ECOChill	14.2%	29.7%	12.0%	26.7%	1.9%	8.9%	Base	6.7%

Source: Everest Sciences Corp GT1=LM2500PC GT2=A501KH-7S
Assumptions: Direct evap is 85% effective; all parasitic loads (delta p, compressors, cooling towers, pumps, etc) are accounted for; analysis of GT1 performed using GE APPS Performance Prediction Program, analysis of GT2 performed using the Rolls-Royce Engine and Performance Prediction Program

the Everest Cycle and h^3

Note that a separate cooling tower is not required to support chiller operation. Air discharged to atmosphere from the indirect heat exchanger (2) is sufficiently cool to condense the refrigerant. An induced-draft fan is integrated into the Everest package to drive the condensing process.

Hydro-FlexCool is a variant of the Everest Cycle. Its indirect evaporative heat exchanger (3) uses brackish or reclaimed water and air as the first step in TIC. A similar heat-transfer device has been used on large chiller-equipped frame GTs for condensing refrigerant rather than for cooling combustion air.

The Hydro-FlexCool option is ideally suited for gas turbines in arid, remote areas. Units in pipeline service come to mind because locally available brackish well water can be used as the cooling medium.

Advantages of water-to-air heat transfer over air-to-air include the following: simpler TIC system; less heat-transfer surface for a given duty; and evaporation of some plant wastewater (if this is the water source), thereby reducing the amount of wastewater that may have to be treated prior to discharge or stored in onsite evaporation ponds.

The density of combustion air leaving (3) can be increased by using a chiller (4), with or without the final evaporative cooling step, or by simply following the evap cooler route through heat exchanger (5).

Performance improvement offered by ECOChill (Everest Cycle + h^3) for LM2500 and A501KH-7S GTs is compared in the table to a conventional chiller, ECOCool, evap cooler, and base case with no TIC. Data show the significant improvement in net power and net heat rate offered by the Everest Sciences solution over a standard chiller for both engine types.

Reason is that the reduction in ambient air temperature achieved by the Everest Cycle becomes the starting point for the h^3 cycle. This means substantially less refrigeration is required to reach a target turbine air inlet temperature than for the chiller-only case. The Everest solution's much lower parasitic load means added revenue at lower cost for the plant owner.

If you want to see the results graphically, visit the Everest website and review the psychrometric charts. If your thermodynamics has gotten rusty over the years, you might want to review how to use psych charts before logging on. The bottom line, as the two case histories that follow attest, is that the Everest solutions deliver on their promise. All you really have to figure out is if the economics work for your plant.

Case history 1. The utilities manager for a food processing plant located in the California desert told the editors the facility's A501K was installed in 1986 and provided all the power required onsite. Engine operation is controlled to match plant demand. The unit operates in parallel with the grid, so if it is forced out of service, continuity of electrical supply is preserved. The cogeneration facility also has a single-pressure heat-recovery steam generator (HRSG).

The electrical generator is capable of 6 MW, but even with a Cheng Cycle upgrade, which uses steam injection for NO_x control and power boost, the GT wasn't capable of doing more than about 5.7 MW on a typical day. On hot days, when summertime temperatures often hit 110F-115F, the engine couldn't do better than about 5.2-5.3 MW.

The utilities manager the editors spoke with hired on nearly seven years ago. It didn't take him long to tire of the poor performance from the single-stage conventional evap cooler. By then, the cooler had been operating for almost 20 years and had seen better days; the plant runs about 8500 hours annually. Further deterioration in swamp-cooler performance and the GT might not be able to meet in-house demand on some days.

He investigated the conventional alternatives—new evap cooler, fogging chiller—and what would later become Everest's ECOCool offering. Performance of the Everest TIC system installed was significantly better than the single-stage cooler with only a marginal increase in power consumption (Fig 23).

With the Everest upgrade, the engine can produce 5.6 MW on very hot days, an increase of 300 to 400 KW over that possible with the old evap cooler. Thus less steam is needed for power-boost service, saving on the cost of high-quality makeup water. Addition of the h^3 package wasn't considered because this plant already is producing all the power it needs with just the Everest Cycle front end.

Well water high in calcium and magnesium is used in the evaporative heat exchanger module (component 1 in Fig 21). The design is tolerant of bad water, the utilities manager said. Cycles of concentration are controlled by automatic blowdown based on water conductivity. Only real maintenance is to clean and flush the sump at the bottom of the TIC package quarterly.

The utilities manager told the editors that the Everest equipment has met expectations and that the company always has shared improvements it has made to the equipment installed.

Case history 2. Chief Engineer Tom Peltsch, Sonoco Canada, Brantford, Ont, also shared his experience with the Everest Sciences equipment Different climate and different operating paradigm, but the same positive results. Peltsch's powerplant provides all utilities to an ageless mill which now blends a variety of recycled cardboards to make the spiral wound paper used in the manufacture of containers for potato chips and other products.

A new generating plant installed in 1993 is powered by a gas-only Allison KB501 GT capable of producing 4 MW; mill requires 3 MW. Facility has a single-pressure, supplementary-fired HRSG and a gas/oil-fired 40,000-lb/hr packaged boiler to assure continuity of steam supply. Peltsch stressed the need for high reliability to satisfy mill commitments and to export power to the grid when financially viable.

The gas turbine was installed with only media filters on the front end. No cooling of inlet air would be required in Canada, or so engineers thought. After a summer with temperatures and humidity in the 90s the plant retrofitted an Everest Cycle + h^3 solution. Peltsch, who was not at the plant when the purchase decision was made, said there was little institutional knowledge on the matter.

The way the plant operates today testifies to the operational flexibility of the TIC system. The chief engineer said the Everest Cycle is turned on about May 1 and off by the end of October. Plant personnel continuously monitor ambient and turbine inlet conditions and bid into the hour-ahead market when there's money to be made.

Grid and gas prices are displayed in the control room, and with the aid of a weather station installed on the plant site and software to run revenue calculations, plant personnel can exploit an opportunity simply by turning on the h^3 (chiller) portion of the Everest TIC system.

Peltsch said the plant can dispatch to the grid 24/7, but the actual time it does depends on price. Operators minimize export and burn less gas when the grid price is low. He thought the chiller ran about 30% of the time during the May to October period.

Peltsch

Operators are continually fine-tuning operations to squeeze top performance from the plant. Peltsch continued. There are times a fan may be turned off because it's not needed and a few more pennies drop into the revenue basket. The GT compressor is online washed weekly to assure maximum efficiency.

Water used in the Everest Cycle comes from the city main. It is monitored for conductivity and bacteria to guide the continuous blowdown system. Peltsch said that the system requires very little maintenance but because a lot of dust is generated in the handling of bales of cardboard, the sump must be washed out on a weekly basis.

23. Performance of the ECOCool TIC system installed at a food processing plant in the California desert was significantly better than a conventional evap cooler with only a small increase in power consumption