<u>Evaporative Cooling & Wet Compression Technologies</u>

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It is well known that as ambient temperatures rise, the output of combustion turbine (CT) generating facilities decrease. For every 10°F rise in temperature, the output decrease by 3-4% and heat rate increases up to 1%. Combustion turbine Inlet air-cooling (CTIAC) systems minimize these affects. There are several CTIAC technologies available for this purpose and the focus of this article will be ***Evaporative Cooling*** and ***Wet Compression Technology***.

Evaporative cooling technology is the oldest technology available for CTIAC. It utilizes the principle of latent heat of vaporization of water to cool the air prior to entering the combustion turbine. The maximum amount of cooling possible is dependent upon the difference between dry bulb and wet bulb temperature, thus the performance benefit is dependent upon ambient conditions.

Evaporative cooling systems are classified into two methods: "***Evap Media***" and "***Fogging***" systems. They work off the same thermodynamic principle, however each has distinct advantages and disadvantages. Both are mature technologies and widely used across the world.

A recently proven technology, which takes the evaporative cooling principle a step further, is "***Wet Compression***", also referred to as "overspray" and "high-fogging". This patented process intentionally and systematically injects water directly into the airstream with the intent of carrying water into the compressor of the CT. As the water evaporates in the compressor stages, it cools the air, allowing the compressor to run more efficiently. Wet compression systems are complimentary to other CTIAC technologies and are typically installed in conjunction with evaporative cooling systems (media or fog). The typical locations of these systems are illustrated in *Figure 1*.

Evap Media

Evap media systems typically utilize a wetted media (fabric) and adiabatically cools the inlet air. Air is cooled as it passes through the media and excess water is taken out by a mist eliminator to reduce the possibility of water carryover into the CT.

Media systems utilize potable water at low pressure, eliminating the need for demineralized water and high-pressure pumps. However, the water is typically treated with biocide and the media and mist eliminator increase the pressure drop for the inlet system reducing the cooling benefit.

Fogging

Fogging systems have become quite common in the industry over the past ten years. In fact, in addition to the primary developers and suppliers of this technology, several CT OEM's now offer this technology.

Fogging systems achieve the evaporative cooling effect by systematically spraying high-pressure demineralized water through nozzles distributed across the inlet. Fogging systems produce micro-fine droplets that evaporate before impacting structures in the plenum or entering the combustion turbine. When properly designed, these systems offer the maximum evaporative cooling possible with compressor inlet temperature approaching wet bulb temperatures, without an increase in pressure drop. Controls and nozzle technology have advanced significantly over the past two years to enhance system performance, component life and reliability.

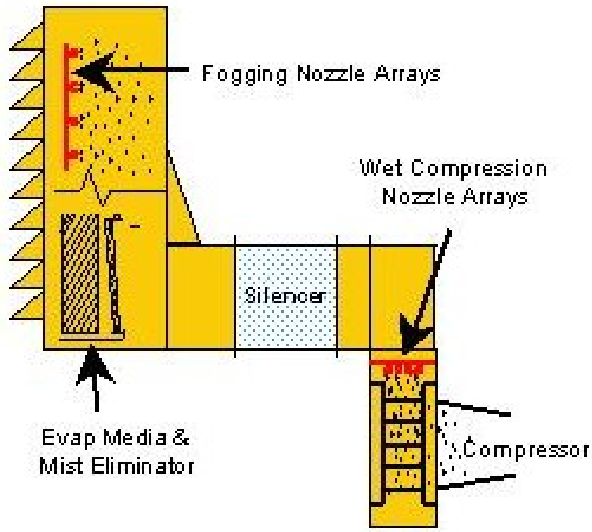

Figure 1: Technology Locations in Ductwork

Wet Compression Technology
Wet compression is a relatively new technology that has now been installed and proven on aeroderivative, mature frame and advanced frame CTs. When properly designed and implemented, this technology produces power gains upwards of 25%, independent of the ambient temperature conditions, reducing the fluctuations experienced with traditional evaporative cooling systems.

Wet compression takes the evaporative cooling effect into the compressor. The water not only increases the overall mass flow, but also improves compressor efficiency due to the intercooling effect, increasing the power output and improving the heat rate. One of the biggest challenges with this technology has been the potential for blade erosion. It has now been proven that this risk can be managed with proper design and safeguards to ensure reliable CT performance. The lead unit has well over 40,000 hours of wet compression without blade replacement.

The technology of wet compression is often confused with that of fogging, however in reality they are significantly different. A typical fogging system may inject 20-25 gpm to cool the air, whereas a wet compression system may inject over 100 gpm into the CT. A properly designed and installed wet compression system is integrated into the cooling and controls systems of the CT. Wet compression changes the load profile of the compressor, affects the cooling circuitry of the CT hot-section and safety control requirements for the machine. Merely spraying water into the compressor without designing and safeguarding the CT could be disastrous.

Cost and Benefit
Power generation plant costs are depicted as dollars per kW of power generation ($/kW). To apply this same philosophy to power augmentation technology is misleading, as most CTIAC systems are highly ambient dependent and have significant swings in instantaneous $/kW. The following analysis was completed for a 120 MW CT utilizing historical weather data.

Referencing *Figure 2*, on a hot day design point, evaporative cooling (evap media and fogging) systems will cost $30/kw and the wet compression costs $50/kW. This "design point" is only a brief period of time and in actuality, may never occur. Considering this, if hourly costs are averaged over the entire day, the evap cooling cost becomes $98/kW and wet compression is $63/kW.   This significant difference is due to the varying spread between dry and wet bulb temperature throughout the day. Referencing *Figure 4*, the energy gains for the same 24-hour hot day, the evaporative cooling system yields 235 MW-hrs of additional energy and the wet compression system yield an additional 854 MW-hrs.

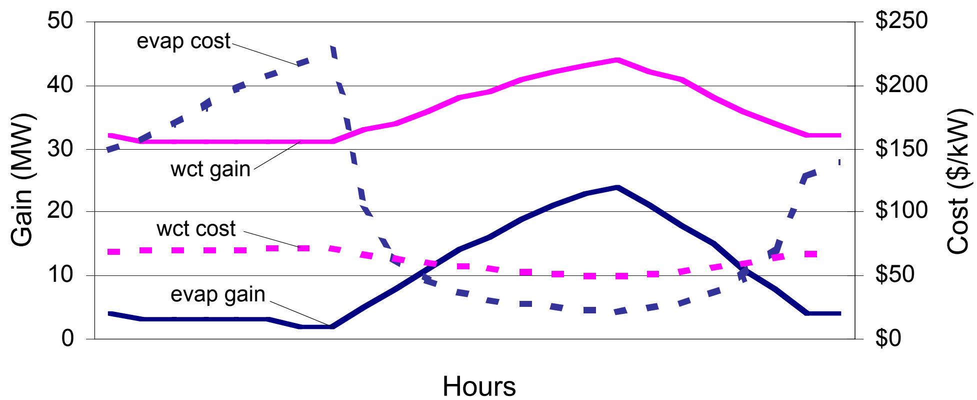

Figure 2: Hot Day (90°F wb/60°F db) Performance and Cost

For a typical humid day, reference *Figure 3*, the cost of evaporative cooling is greater than $500/kW, as there is very little cooling potential in the air. However the wet compression system cost remains under $80/kW. This illistrates that wet compression systems performance gains are not as ambient dependent as evaporative cooling. For the energy gain, referencing *Figure 4*, the evaporative cooling system yields 8 MW-hrs of additional energy and the wet compression system yields an additional 681 MW-hrs.

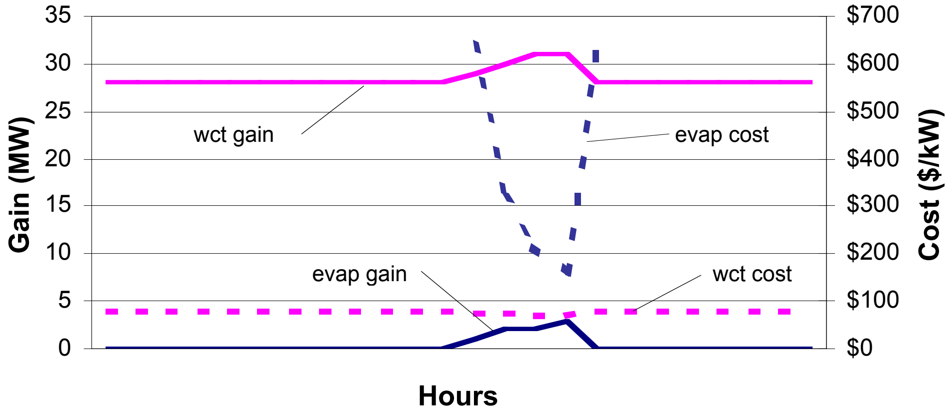

Figure 3: Humid Day (72°F db/64°F wb) Performance and Cost

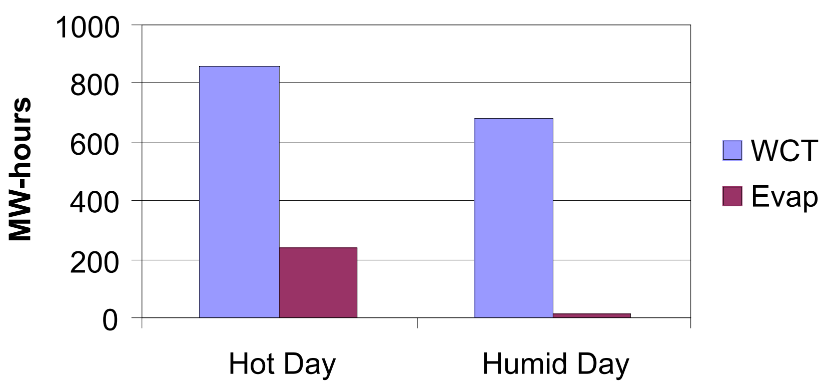

Figure 4: Energy Gains from Wet Compression and Evap Cooling

Summary

When properly applied, evap media, fogging and wet compression systems are all safe and proven technologies that recover the lost power due to fluctuating ambient conditions and optimize/maximize the output and efficiency of CT plants. Pay careful attention to the integration of these systems into the inlet, auxiliary and safety systems of the CT plant to reliably achieve the expected performance gains with minimal risk. When evaluating CTIAC technologies, be diligent to evaluate the operations of your plant over a period of time (day, month, year) and not just what may be considered to be your "design point" in order to truly maximize potential benefit.