

INLET COOLING OPTIONS

SELECTING THE RIGHT TECHNOLOGY FOR A SPECIFIC APPLICATION

Summer afternoons are a great time for hitting the water, cooling off and recovering a bit of the energy sapped by the blistering heat. We are talking, of course about combustion turbines, though that strategy also works for humans. And both humans and turbines have options. Instead of choosing between the pool, lake or ocean, turbine operators can select their water in the form of ice, fog or humidity from an evaporative cooler.

There is no doubt that cooling inlet air is an economical action. Since a combustion turbine's output is dependent on the mass of air moved through its compressor, and since the volume per revolution is fixed by the turbine design, bringing down the air temperature increases the air density and raises power output. In addition, cooler air is easier to compress, lowering the parasitic load of the compressor.

For many environments, therefore, the question is not whether to use an inlet cooling system, but which one best meets the requirements. Factors to consider include local temperature patterns, humidity, availability of water, operation and maintenance costs, initial equipment costs, and the cost of using electricity to run a chiller instead of selling it to the grid. Here's how utilities deal with these factors.

Using media-type

Tourists to Las Vegas have the option of visiting Hoover Dam, about a half hour drive from the casinos on the Strip. The world's largest hydroelectric facility when it was built in the 1930s, the dam's 17 main turbines still furnish about 4,000 GWh hours of electricity annually. But little of that electricity goes to power the neon along the Las Vegas strip.

"We get very little of our power from the dam — about 3% — most of it goes to California," says Mark Severts, Project Communications Director for NV Energy Inc. "The vast majority of our generation comes from gas-fired turbines."

NV Energy, which provides power for 2.4 million people in Nevada and northeastern California, uses evaporative cooling at its main 1,139 MW Edward W. Clark Generating Station in Las Vegas, NV, as well as at its 530 MW Higgins and 150 MW Sunrise generating stations. The dry desert air — an average of just 11% relative humidity on June after-



Figure 1: Midland Cogeneration Venture in Michigan installed inlet fogging when its new owners demanded higher output

noons and 24% in the mornings — gives plenty of opportunity to lower the inlet air temperature.

"Evaporative coolers work well out here," says plant engineer Joe Cook. "The ones we have are designed for 108°F days

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at a 66°F wet bulb, and we can bring it down to 68° F at the turbine inlet."

The plant has four upgraded Westinghouse 501B-6 machines coupled to two Mitsubishi steam turbines generators, as well as a GE MS-7000 series genset. The original evaporative coolers were installed with these generators starting in the 70s, but by the 1990s, the plant was looking for replacements. The Ecodyne Corporation units used high carbon steel and these were starting to erode.

Cook paid a visit to a plant in Nebraska that was using chillers, but decided that the technology was not a good match for his needs.

Chillers had to have a certain amount of time to make the ice, says Cook. "We could turn the evaporative coolers on and off instantly whenever we needed, and they was more cost-efficient."

He put the job out to bid and picked a design from Premier Industries in Phoenix, AZ. One of the factors in making the decision was that the plant had limited spaces because of overhead cranes and other equipment right next to the turbines. Premier's design was on the ground level, and was able to fit the same footprint as the original coolers, and also had a good efficiency rating. The units were made of stainless steel rather than carbon steel, so they do not have the same corrosion issues as the originals.

A test was run on Unit 7, one of the 501B-6s, using four modules. The overall cooler effectiveness was found to be 97.92%, exceeding the 95% design criterion

Cook says the evaporative coolers are run whenever the temperature is above 60°F degrees, and produce about a 2% -



Figure 2: A Mee fog skid at Midland Cogeneration

3% increase in output. They use water blown down from a cooling tower after it is processed through a brine concentrator at an onsite water treatment plant. If the water plant is out of service, they can use potable water, but this rarely occurs.

The plant is right next to the Interstate, so there is a lot of exhaust from the cars and trucks, as well as the dust blowing across the desert. To keep this out of the turbine, the coolers are placed before the filters, which remove 80% of the airborne particles before they hit the filters. This extends the life of the filters; the fabric prefilters can be cleaned once a year, and the main fiberglass filters are changed every four years.

The cooling efficiency is about 95% on these units, says Cook. "We are pretty satisfied with how they work."

An evaporative cooler, then, is often an economical choice for low-humidity environments, such as the Nevada desert. But it is limited in the amount of cooling it can offer in other environments. Once 100% relative humidity is achieved, it becomes impossible to evaporate more water into the airstream. For that reason, in hot humid conditions, it is not possible to accomplish more than about 10°F of cooling. Another caveat — when planning to retrofit an evaporative cooler, adequate space should be provided otherwise costs can increase significantly.

Inlet Fogging

High-pressure fogging systems allow fine control of temperature over a wider range of temperature and humidity conditions than evaporative cooling. Even in high humidity conditions at 96°F, a plant in



Figure 3: Fog array at the gas turbine inlet

Houston, TX, can achieve up to 20°F of cooling. And fog is said to be the only solution with no parasitic load.

In addition, the power gain available from fog can be further boosted by what is known as overspray (also known as wet compression or intercooling). This technology enables the injection of water into the compressor, which decreases the

amount of energy used in compression. This can add perhaps 5°F or so of additional cooling.

Due to these benefits, fogging systems are sometimes preferred to evaporative coolers. Close to 1,000 turbines have been either retrofitted with fogging systems, or had them included in the initial design.

Midland Cogeneration Venture (MCV; Figure 1), one of the largest cogeneration projects in the U.S., has selected fogging as its method of inlet cooling. The site was originally slated to house two pressurized-water nuclear reactors. However, construction problems plagued the project — including poor soil compaction leading to sinking and cracking of buildings. Coupled with regulatory changes following the Three Mile Island incident in 1979, the plans for a nuclear facility were abandoned. Instead, twelve ABB 11N gas turbines were installed, with the first going commercial in 1991. These turbines use Heat Recovery Steam Generators (HRSGs)

with Coen duct burners. There are also Indeck package boilers, two GE steam turbines and one 15 MW ABB backpressure steam turbine.

Although there are two GE steam turbines, usually only one is run at a time, with the other serving as a backup. "We typically run all twelve gas turbines, but can only run one steam turbine," says Brian Vokal, performance engineer for MCV. "This is a converted nuclear plant that originally was going to have two units, but the gas turbines only produce enough steam to run one steam turbine."

MCV's main customer is the nearby Dow Chemical plant in Midland, MI. MCV provides 1.35 million pounds of steam per hour for Dow, and generates 1,560 MW of electricity, about 10% of the power needs for Michigan's Lower Peninsula. Dow is a primary electrical customer, and MCV also contracts with Consumers Energy, which distributes power to 1.8 million customers.

"We provide a baseload of 100% of Dow Chemical's electricity and steam," says Vokal. "We always keep units on to meet their demand, and also participate in the MISO (Midwest Independent Service Operator) market, where we are dispatched on electrical prices."

In 2009, the Swedish firm EQT Infrastructure and its American partner Fortistar purchased MCV for a reported \$1.1 billion. One of the first actions the

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new owners took was to boost production at the plant. "We have new owners and the focus is on generating cash flow through increased output and income," says Vokal.

The obvious way to increase output was to use inlet cooling. Vokal says they evaluated evaporative cooling, wet compression and mechanical chilling, but decided to go with inlet fogging. Inlet fogging was about half the price of wet compression, and was also much cheaper than mechanical chilling when taking into effect operating costs. They put the system out for bid and chose Mee Industries (Figure 2).

The vendor calculated the increase in efficiency and output that could be expected in that climate based on the number of operating hours, and how much income that would result. In the summer of 2009, a test fogging skid was set up on one of the units (Figure 3). These real world results validated the initial projections: the fogging system produced enough additional revenue to

finance the installation of more such units on the other gas turbines.

“We are going to buy six more units and then use the cash generated from that to buy five more, so by the summer of 2011, we will have skids installed on all 12 gas turbines,” says Vokal. “They are simple, easy to install and operate.”

Better than a new turbine

Even with overspray, fog cannot quite match the amount of cooling provided by a chiller. Also, chillers can induce any amount of cooling even in the highest humidity environments. On the other side

of the coin, mechanical chillers have much higher initial and operating costs. But this can be offset if certain conditions prevail. The presence of abundant waste heat as an energy source for chilling, or an available chilled water source, can cut costs dramatically. Further, engineering chilling into the initial design is a good way to reduce the price tag.

The Imperial Irrigation District, the sixth largest utility in California, installed a chiller at its new Niland Gas Turbine Plant, which was completed in time for the 2008 summer season. The 90 MW simple cycle-plant uses two GE

LM6000s and an A-50 system from Turbine Air Systems that provides 4,450 tons of chiller output.

“We compared the economics of various output-increasing technologies for the LM6000 to adding another LM6000,” says Henryk Olstowski, PE, assistant manager of the energy production business unit at IID. “We added a chilling system and optional Sprint overspray technology to the LM6000s for about half of what it would cost for an additional turbine.”

John Andrepont, president of Cool Solutions, a turbine inlet cooling consulting firm, says that chillers make the most sense for new model aeroderivatives, such as the LM6000. “As we come up the evolutionary line, turbines have become more sensitive to inlet air temperature, thus there is more bang for your chilling buck,” he says, “and aeroderivatives are the most sensitive.”

Mixing and matching

Even when chilling is selected, it is often used together with both evaporative and spray systems, which have lower operating costs and faster startup. The Niland plant, for example also uses

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GE’s Sprint water injection technology. Las Vegas Cogen, which has four LM6000s, installed a Mee fogging up ahead of its chiller, and the systems can be used separately or in conjunction, depending on operating conditions. Fogging systems can also be installed after the chiller to provide overspray into the inlet.

Depending on the economics and local climate, such hybrid systems can give even finer temperature control, and better return, over a wider range of operating conditions. ■