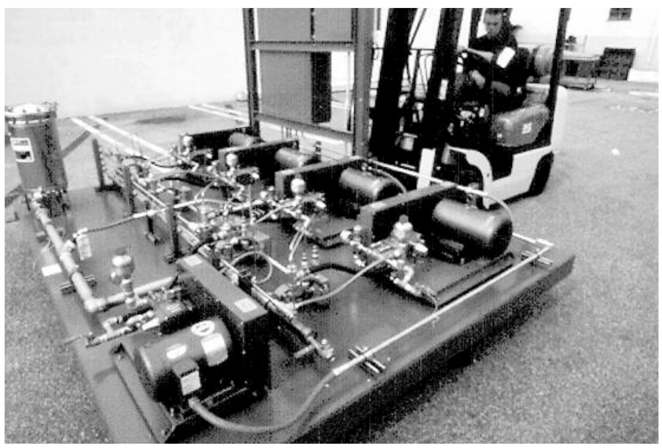
M E E   I N D U S T R I E S

Monrovia, CA

HIGH-PRESSURE FOG SYSTEM



FOG SYSTEM SELECTION: IT'S ALL IN THE SPECS

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Land-based turbines run at constant speed due to electrical requirements, creating significant problems over a yearly cycle. At the height of summer heat when electrical demand is at its highest, the turbine's power output is at its lowest. Since electrons cannot be stored, this creates high spot prices for electrical power as much as ten times the regular rate.

Further, since rapidly rising electricity demand is straining existing capacity, a backlog of 2 years or more has developed on new power equipment. This has led to a strong interest in retrofitting power generating equipment with inlet air fogging to augment power in the hotter months.

In the past decade, many different designs have been tried in gas turbine inlet air fogging. Some have been conservative, others offered a more adventurous approach to maximize turbine power output; some opted for the highest quality, others for the most economical model. Based on the accumulated knowledge and requirements of the electrical utility industry, certain practices have evolved that utilities and IPP's may find useful in the selection and specification of fog systems.

1. Power Augmentation Goals

While a complete component and design specification is essential, utilities are also advised to direct their planning efforts towards their power augmentation and return on investment goals. The degree of power augmentation available is fixed by the physical location of the turbine and the associated climatic variables. As a rule of thumb, 40 percent of the difference between dry bulb and wet bulb temperatures represents the maximum percentage of turbine power increase that is achievable with inlet fogging. Thus for a 100 MW turbine installation, with 20Á F of cooling possible in the summer months, a power increase of 8 MW can be achieved, using fog cooling.

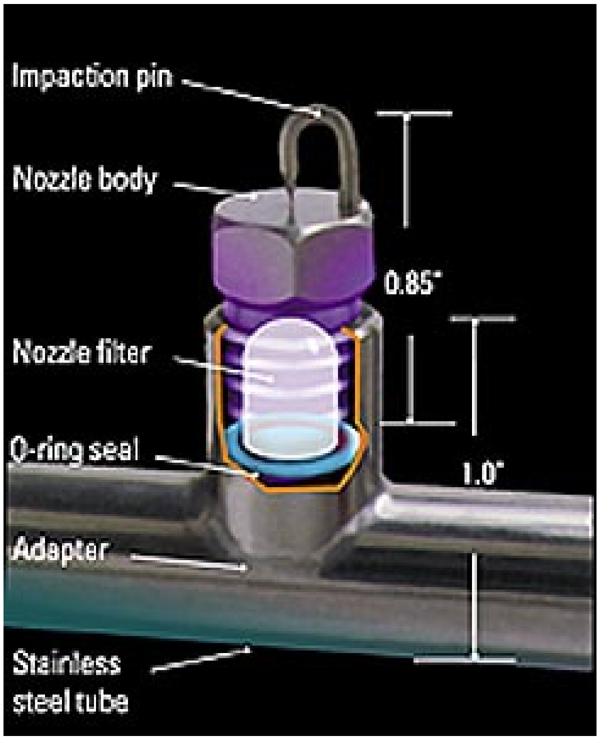
2. Turnkey Systems

Some utilities may prefer to procure individual fog systems components, tying them into existing plant equipment. Where the requisite expertise and equipment exists, this approach works well. There are, however, several companies who specialize in turnkey fog systems. These pre-engineered units come in a skid-mounted package, including high-pressure pumps, weather stations, PLCs and controls that can greatly speed up and simplify the installation process. Additionally, the turnkey installation package is fully covered under the manufacturer's warranty.

From a budgetary perspective, small facilities may wish to trim costs by omitting the PLC and manually operate the fog system. In these instances, however, maximum evaporative cooling efficiency is unlikely to be attained, with either too much or too little fog being applied. For small utilities, the price of the PLC may outstrip the amount lost due to inefficiency. But on larger turbine units, either the standard PLC or one selected for compatibility with the utilities control system can be supplied.

3. Design Specifications As with most equipment purchases, corners can be cut in fog system design specifications. To ensure adequate performance, the materials required for the manifold and skid equipment/components, base skid paint coatings and types of alloys should be clearly specified.

One of the key elements in the fog system design is the atomizing nozzles used to produce the fine fog droplets. The best quality nozzle is the impaction pin type which has become the industry standard. To avoid the possibility of compressor blade erosion, water droplets must be less than 30 microns. A typical distribution curve for fog droplets produced by an impaction pin nozzle is shown in Figure 1, Fog Droplet Size Chart. For optimum results, droplets should have an average mass median diameter of less than seventeen microns (This means that half the mass of the water is 17 microns or smaller).



4. High-Pressure Pump Speed

Pump speed is another area to specify. To lower costs, some vendors suggest fewer or smaller pumps, which then have to be operated at higher speeds. While this recommended speed may comply with the pump manufacturer's rating, with reciprocating pumps it is always best to run at lower speeds for better service life. As well as reducing pump wear, running pumps well below their manufacturerÍs rating prevents excessive vibration and increases the reliability of the pumps. By specifying larger pumps operating at lower speeds, fog system service performance is maximized.

5. Installation Choices

Should fog nozzles be placed upstream of air filters or downstream of the silencers? Should any fog droplets be allowed to enter the compressor or not? Should fog droplet filters be deployed or not? Unfortunately, there is no 'one size fits all' in fog installation. In most cases, fog systems should be installed just downstream of the air filters. This permits maximum evaporation time before entering the compressor, is relatively simple to accomplish and takes the turbines offline for no more than a couple of days. For optimum results, about 1 second of dwell time in the duct is required for the fog droplets to fully evaporate and cool the inlet air close to the wet bulb before it enters the compressor.

A growing number of utilities are requesting fog intercooling (overspray). In this case, more fog is supplied than is needed to cool the air to wet the bulb and the extra fog is drawn into the compressor resulting in interstage cooling, which further augments output power. When intercooling is specified, it is typically better to move the fog system downstream of the silencers otherwise the excess fog may soak the silencer materials. In some sites, evaporative cooling manifolds are best located upstream of the silencers with fog intercooling nozzle manifolds placed downstream of the silencers.

6. Ordering and Scheduling

More than half the fog systems ordered are assembled and installed between Jan 1st and June 1st each year. As there may already be delays due to such factors as budget approval or permitting, slow delivery of skid systems can mean large opportunity losses in terms of plant output. Yet due to the accelerated demand for fog cooling in combustion turbines, the production lines of most fog vendors are often strained to capacity in the early spring months and underutilized the rest of the year. Utilities, therefore, are advised to place orders early for delivery of fog systems prior to that peak period.

8. Experience

Just as many Johnny.com Lately's have recently sprung up offering Web-based services, so many new outfits are advertising themselves as inlet cooling fog suppliers. Like anything else, there is a learning curve involved in fog technology. And as there have only been around 300 installations of fog on gas turbines completed to date, the number of companies with experience can be counted on one hand. As poorly designed fog systems and installations can result in high maintenance requirements or even damage to turbine components, it is best to deal only with reputable, experienced vendors who can supply examples of fog installations similar to yours that were successfully completed.

Case Study - Florida Power Corp.

Florida Power Corp, based in St. Petersburg, Florida is the second largest investor-owned utility in Florida, serving 1.3 million customers. Its Intercession City plant recently installed a Mee Fog system in each of its Four GE Frame 7EA's in order to boost power during the hot Florida summers. Each turbine has an output of 83.5 MW and an air flow of 2,128,000 lbs/hr @ 59ÁF and 60%Rh.

The fog system itself consists of 630 nozzles and runs at an operating pres-sure of 2,000 psi. The fog is divided into a total of nine stages of cooling that are controlled remotely. Five pumps per skid (a maximum of 45 hp per turbine) are used to deliver up to 28 gpm (3 gpm per stage) of fog to the inlet air. The project manager at Florida Power Corp reports that the fog system gives a power boost of 6 to 8 MW per turbine. As a result, the facility plans to install fog on as many additional turbines as possible in order to maximize output.

Case Study - Tennessee Valley Authority

High-pressure fog is installed on 12 GE Frame 7-Bs at TVA's Allen and Colbert plants in Tennessee. These turbines each have an output of 49MW. A total of 504 nozzles per turbine, at 2000 psi are configured to provide four discrete stages of cooling. Four 10 hp pumps supply a fog water droplet flow rate of 22.7 gpm. This arrangement brings TVA about 26ÁF of fog cooling.

These are peaking turbines with no inlet air filters, and the fog nozzle manifolds are installed downstream of the silencers and upstream of the trash screens. TVA chose this position to avoid any possibility of wetting the silencer panels. TVA also installed water drains under the nozzle manifolds to drain unevaporated water from the ducts.

The Mee Fog systems used by TVA include a PLC to measure ambient temperature and humidity, and compute the ambient wet bulb temperature. It then computes the ambient wet bulb depression (the difference between wet bulb and dry bulb, expressed in degrees). The wet bulb depression factor quantifies the potential for evaporative cooling. The PLC also allows the user to input the amount of overcooling (over saturation in the air stream) or under cooling (below saturation in the inlet air stream).

Additionally, TVA uses its specially designed fog systems to cool the Lube Oil Heat Exchangers on its turbines. Three fog nozzle lines are installed on the face of each heat exchanger. This allows for operation of the turbine at high ambient temperatures, with increased output due to fogging, without overheating the lube oil. In total, TVA has installed fog on its entire fleet of 48 turbines, providing an estimated 150 to 200 MW of additional peaking power.