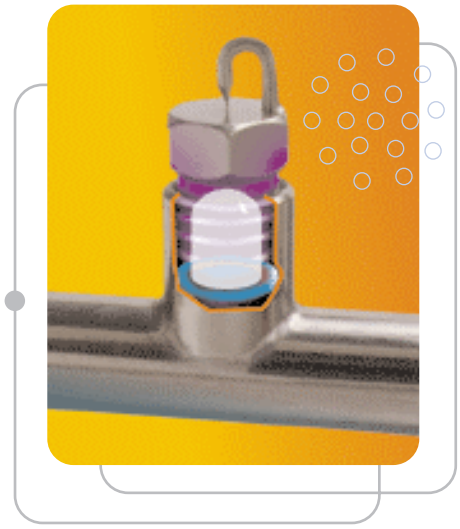
# Inlet Fog Cooling Nozzle Droplet Size Definition
# AN INTRODUCTION

Power boost from installed MeeFog™ systems
soon to exceed 2,900 Mega Watts of power.



MEE INDUSTRIES INC.
GAS TURBINE PRODUCTS DIVISION

# Comparison of Gas Turbine Inlet Fog Cooling Nozzle
## AN OVERVIEW

### How The Various Types of Fog Nozzles Work

With the growing popularity of gas turbine inlet air fogging, it is becoming increasingly important to have a standard for qualifying the characteristics of different spray nozzles. Fog system manufacturers make various claims based on different testing methods. The result is contradictory information that makes it impossible to evaluate the relative benefits of different systems.

Two types of fog nozzles are used for inlet air fogging, impaction-pin nozzles and swirl-jet nozzles. Both operate on the same general principle; water pressure is converted to velocity when the water is forced through a small orifice and an expanding conical sheet of water is formed. As the sheet of water travels away from the nozzle orifice, it is stretched ever thinner by virtue of the fact that the cone is expanding and the sheet of water has to cover an increasing surface area. Eventually, surface tension causes the thin sheet to separate first into fingers and then into small droplets.

Impaction-pin nozzles consist of a smooth, short, straight-through orifice with an impaction-pin located above the orifice such that the water jet impacts on it. When the water jet hits the impaction-pin, it is separated into a conical-shaped sheet. In the case of a swirl-jet type nozzle, an internal swirl chamber is used, which forces the water to exit the orifice tangentially to the axis of the orifice so that a hollow cone pattern is formed.

### How Droplets Form

The higher the velocity of the sheet of water, the thinner it can be stretched before surface tension causes it to break apart, and the thinner the sheet of water the smaller the droplet formed. Water velocity is a function of orifice diameter, operating pressure and internal losses in the nozzle flow passages. Given two nozzles with the same operating pressure and orifice diameter, the nozzle with less internal losses will generally make smaller droplets. The above description of the water atomization process is a simplification of what amounts to a very complex physical process but it serves our purposes here in that it shows the strong relationship between nozzle flow efficiency and droplet size.

The internal frictional losses associated with the swirl chamber in a swirl-jet nozzle are greater than those of an impaction-pin nozzle with a smooth, short straight-through orifice. In other words, a swirl-jet nozzle uses more energy to form the conical sheet of water so the sheet has less velocity and is not stretched as thin. The internal frictional losses associated with swirl-jet nozzles are demonstrated by the fact that swirl-jet nozzles have a lower flow rate than impaction-pin nozzles with the same orifice size and operating pressure.

Since they are inherently more efficient, impaction-pin fog nozzles always make smaller droplets than swirl-jet nozzles with the same orifice size. However, information published by suppliers of swirl-jet nozzles often indicates the opposite. This inconsistency is due to the fact that no standardized method for testing fog nozzles exists today.

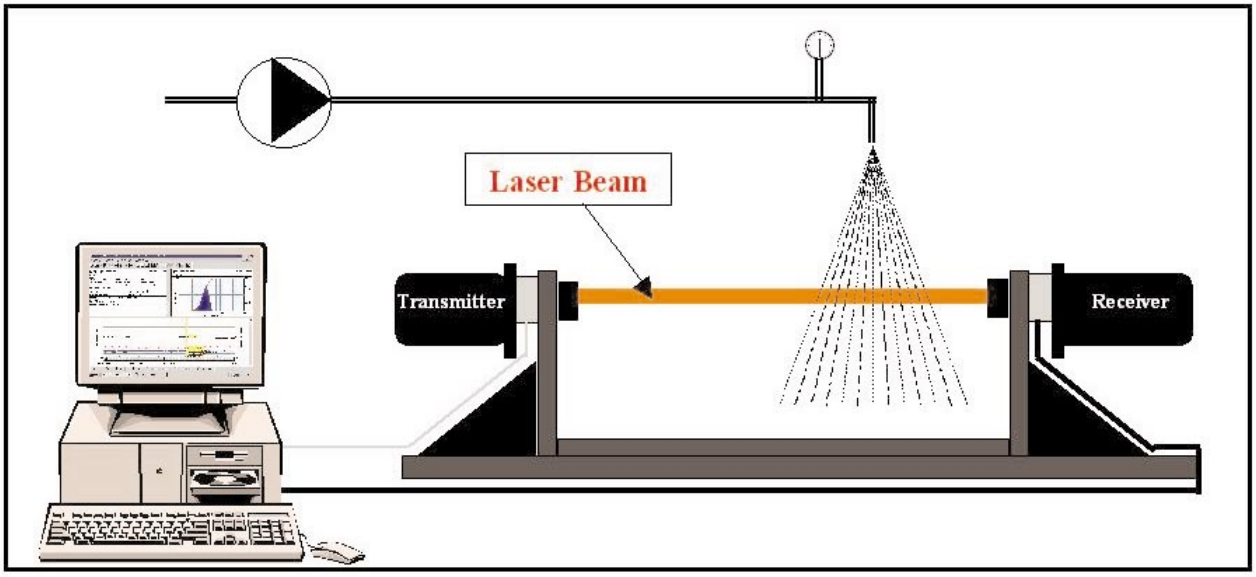
### Droplet Size Measurement Equipment

The advent of Laser Particle Analyzers makes it possible for qualified scientists to quickly and accurately measure droplets, but there is no industry standard for applying such devices. An example of how not to apply such instruments is one gas turbine OEM's specification which called for measuring droplets only at one point, three inches directly in front of the orifice. This technique measures only the smallest fog droplets produced by the nozzle at its center and fails to measure the droplet size of most of the mass flow of the water spray plume which occurs on the perimeter. In order to get meaningful numbers, it is necessary to measure droplet size at many points across the spray plume and to weight these numbers based on the mass flow of water at each point.

Results from tests run on impaction-pin and swirl-jet nozzles using this approach are shown below.

DROPLET SIZE

| NOZZLE TYPE | Center | Edge | Center | Edge |
|---|---|---|---|---|
| | D32 | D32 | DV90 | DV90 |
| Impaction-pin (2000 psi 0.006") | 6.5 | 8.0 | 14 | 24 |
| Swirl-jet (2000 psi) | 15 | 28 | 38 | 50 |




Laser Particle Analyzer

## Statistical Methods for Evaluating Droplet Size Distribution

High-pressure water atomization nozzles produce, by their very nature, a wide spectrum of droplet diameters. There are two generally accepted statistical methods used for quantifying (and qualifying) the characteristics of inlet fogging nozzles. The first of these, Sauter Mean Diameter (also called D32), quantifies a spray with a fictitious droplet whose diameter represents the average ratio of volume to surface area for all the droplets measured. D32 is commonly used for defining the spray from nozzles that are used for evaporation type processes because evaporation time for a given droplet is a strong function of the ratio of volume to surface area. With the short dwell times available in a turbine inlet duct, this is a very useful design parameter.

The other number commonly used to characterize inlet fogging sprays is DV90. This number defines a droplet diameter for which 90% of the mass flow of water is less than. DV90 is helpful when one wishes to look at the possibility of the fog spray collecting in the inlet ducts or impacting on compressor blading. As an example, DV90 = 20 microns means that 90% of the mass flow of water is in droplets that are 20 microns or less.

Armed with the above numbers, and assuming they represent the characteristics of the entire water mass flow of the fog nozzles being compared, not just a center section, a buyer can make an informed comparison of different fogging systems.

Mee Industries Inc.
Corporate Headquarters
204 W. Pomona Ave.
Monrovia, CA 91016

626.359.4550 • Phone
800.732.5364 • Toll Free
626.359.4660 • Fax

www.meefog.com

MEE INDUSTRIES INC.
GAS TURBINE PRODUCTS DIVISION