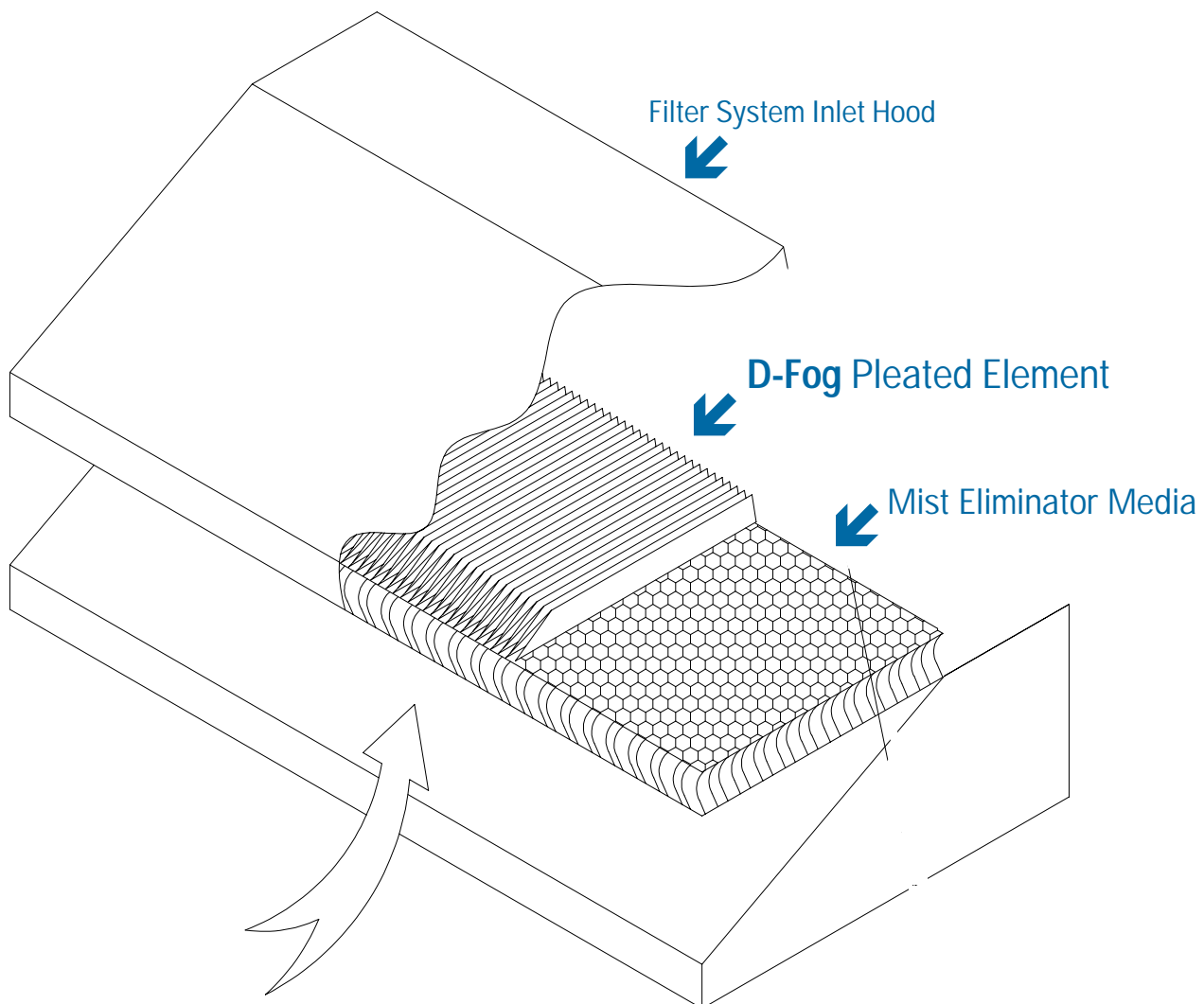




D-Fog™

Donaldson's solution
for the effective removal of dense fog
from gas turbine inlet air



Donaldson D-Fog™: Air Inlet Filtration Accessory and Operating Plan for Environments with Frequent Occurrences of Dense Fog

by Ben Nelson, PE, Product Development Engineer
Gas Turbine Systems, Donaldson Company, Inc.
bknelson@mail.donaldson.com

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Donaldson D-Fog™

I. Introduction

Gas turbine inlet air filtration systems have historically had difficulty maintaining a low operating restriction during periods of heavy fog. Typically, a filter system exposed to fog will experience a rise in restriction that exceeds one or more of its alarm setpoints. The turbine then shuts down by the air filter alarm control signal; alternatively, operators experienced in managing the phenomena may reduce the power output as a means to maintain continued operation.

Since the occurrences happen primarily when the air is saturated with visible fog, it has been assumed that this excess moisture wets the filter media and causes the fibers to swell. However, an extensive test program completed by Donaldson Company, Inc. has identified the contaminant collected on the filter media — not the media itself — as the cause of the excessive restriction. Many environmental contaminants captured on air filter media will expand or swell when exposed to water droplets or high humidity. The swelling of these contaminants reduces the free area available for the air to pass through. Additionally, the fog particles themselves block passages that are normally open for airflow. This reduced permeability, in turn, increases the restriction that an air filter imposes on a given airflow. The test results were consistent for Donaldson moisture resistant filter media.

As a result of this research, Donaldson has developed the D-Fog coalescing filter to control the ingestion of fog, combined with a filter element maintenance program to limit the effects of those contaminants prone to swell in the presence of high humidity or water droplets. Successful incorporation of this program will ensure that the inlet air filtration system will be able to perform adequately during periods of heavy fog exposure.

II. Background

A. Physical Characteristics of Fog

The findings of the report, *Microphysical Properties of Fog at Otis AFB**, were used as a basis for structuring the test program and establishing the engineering parameters for the D-Fog accessory filter system and operating plan. The report details an extensive analysis of droplet size and concentration with respect to elevation, wind direction (i.e. source of condensation nuclei), and lapsed time in the life cycle of a fog event.

In addition to this report, it has been assumed that the relative humidity coincident with fog approaches 100%. This assumes the fog is formed when the ambient temperature falls below the dewpoint temperature and the excess water vapor condenses on the condensation nuclei present in the surrounding air.

* *Microphysical Properties of Fog at Otis AFB*, Bruce Kunkel, 26 January 1982.

The following excerpts from the *Microphysical Properties of Fog at Otis AFB* report are relevant to the parameters used in the D-Fog program:

“Describing a typical droplet spectrum for (advection) fogs is difficult since no two droplet spectra are alike. Droplet size spectra vary not only from one fog episode to another, but also during the life of a particular fog and with height above the ground.”

“The common feature of...samples taken, is, without exception, the high concentration of particles below 2.5 μm : that is, apparently, the result of inactive or haze nuclei.”

“...a typical or mean spectrum of the data collected. It is characterized by a primary mode between 0.5 and 2.0 μm , a secondary mode or plateau between 5 and 10 μm , and a plateau between 15 and 30 μm .”

“The distribution of liquid water...is bimodal with peaks at about 10 μm and 30 μm .”

Since Donaldson's standard mist eliminator efficiency is very high on droplets 55 μm and larger, the D-Fog accessory and operating plan is designed to address the effects of droplets smaller than 55 μm .

B. Influence of Humidity and Moisture on Filtration Media

All of Donaldson's moisture resistant filter media used for gas turbine air inlet filtration are very resistant to both high humidity and water droplets. The synthetic media has a strong resistance to water by virtue of the fibers being non-absorbent. The Duratek™ media undergoes a resin treatment that enhances its resistance to water. The Spider-Web® fine fiber treatment is also a material that does not absorb moisture.

Laboratory tests on clean filter elements indicate only a negligible increase in restriction (0.1" to 0.2") by introducing high humidity to Donaldson elements, even after several hours of operation. A measureable, but tolerable, rise in restriction was achieved by feeding an artificially excessive concentration of fog -- up to 2" after an extended operating time (7 hours.) This gain in restriction is due to particulate loading of the fog droplets. The restriction on the elements decreases promptly when the fog challenge is removed.

C. Influence of Humidity and Moisture on Contaminant

Contaminants have varying degrees of sensitivity with respect to moisture. As they are pieces of their bulk parent components, it is believed that their behavior with respect to humidity and moisture will be characteristic of their bulk parent forms, i.e. clay and cement dusts will bind when mixed with water, salts will deliquesce in the presence of humidity, etc. The exact behavior of contaminants becomes very complex to predict when they combine with materials of other families such as in the case of the dust cake on an air filter.

Many of these environmental contaminants will expand, or swell when exposed to moisture. When they are present in the dust cake on a filter element, the swelling of these contaminants reduces the free area available for air to pass

through. This reduced permeability, in turn, increases the restriction that an air filter imposes on the turbine airflow.

The introduction of fog presents a unique challenge in that very small water droplets (0.5 to 30 μm in size) are suspended in air that is typically at 100% relative humidity. This makes it very difficult to determine if a rise in restriction is caused by high humidity or by water droplets. The addition of fog to an established dust cake on a filter element can swell the contaminant from either its high humidity or its water droplet content.

Successful turbine operation in locations with frequent occurrences of fog and moisture-sensitive contaminant will involve a two-part program consisting of a Donaldson D-Fog coalescing filter accessory combined with a main filter replacement schedule that limits the amount of contaminant present.

D. When to Pulse-Clean

A gas turbine air inlet filtration system is better able to manage a fog event when there is the least amount of contaminant on the filters.

The performance of a Donaldson GD_X pulse-clean air inlet filtration system can be optimized by daily pulse-cleaning the elements via manual operation of the pulse-clean system. The pulse-clean should be placed in manual mode (the "on" position on the control panel) for the length of time required to make one complete cycle through the elements. For sites that do not run 24 hours a day, it is preferable to do this while the turbine is off-line if a source of compressed air is available.

At the onset of a fog event, the system should be manually pulsed continuously until the restriction has returned to the conditions prior to the fog.

Although pulse-cleaning is beneficial in maintaining a lower pressure drop during periods of high humidity, it may not be as effective on removing contaminant during these periods, depending on the nature of the contaminant. A daily pulse cleaning will facilitate more efficient removal of contaminant while it is in a dry state. The daily pulse-clean regimen is a proactive method of controlling contaminant build-up during a time when most contaminants will more readily shed themselves from the elements.

III. Product Description and Operating Plan

A. D-Fog Product Description

The D-Fog filter accessory is a pleated coalescer element and retention frame that retrofits standard Donaldson gas turbine hood assemblies. The retention frame is a one-time modification installed into the hood assemblies.

The D-Fog coalescer element is a flexible, expandable, polymer media pack that is packaged with the pleats compressed. Upon installation, the media pack expands inside the hood and is placed in a horizontal orientation on top of the mist eliminators. Element pleats are self-spacing by means of the pre-attached spacing ribbons. The unit is held in place by means of a clamping fixture at each



D-Fog is a pleated coalescer element that fits into Donaldson inlet hoods.



Ribbons on the backside of the D-Fog makes the pleats self-spacing.

side of the hood and a series of retention rods spaced across the width of the element. The coalescer element is serviceable by either replacement or cleaning. The cleaning can be done with the elements in place if the turbine is not operating.

B. D-Fog Operating Principle

During a fog or rain event, water is filtered from the inlet air via increasing stages of moisture removal efficiency. The **first stage** of separation occurs at the hoods themselves. The larger rain and coalesced water droplets cascade down the front of the hood panels and fall to the ground. Smaller water droplets entrained in the airstream strike the **second stage** mist eliminators and are removed by means of inertial separation. These droplets coalesce and fall to the hood panels, then run off to the ground.

In the **third stage**, the finer fog droplets that have traversed the tortuous path through the mist eliminators impinge upon the D-Fog coalescing element. The impinged droplets grow in size by coalescing with other droplets. Once the coalesced droplets reach a size that is too large for them to remain in suspension, they fall back through the airstream and mix with the droplets captured by the mist eliminators.

The air leaving the D-Fog element is free of visible fog.

C. Applications

Gas turbine sites that historically experience a restriction rise during fog events will behave differently depending on the contaminants to which they are exposed. Their behavior with the D-Fog accessory and the recommended operating plan can be characterized as follows:

1. Contaminants that swell when exposed to humidity. This is the most difficult condition to remedy. Although the D-Fog coalescing filter will remove the fog droplets from the air, it will not remove the 100% relative humidity condition that is coincident with the fog. These events are often perceived as being caused by the fog because of their coincidence in time, when, in reality, the restriction rise accrues from the 100% humidity condition alone. This type of site condition must be addressed by replacement of the main filter elements with new and clean elements at the beginning of the fog season. To compliment this maintenance schedule, the D-Fog coalescing filter provides the following benefits to ensure that turbine operation is not interrupted:

- a. Fog droplets will be removed from the airflow to minimize their detrimental effects. The extent to which the contaminant swells will be limited to that caused by the humidity effects alone.
- b. The main filter elements will not be subjected to the additional particulate loading presented by the fog contaminant. Since fog is an aerosol, the entrained moisture droplets can add to the dust cake, filling in the voids previously traversed by the airstream. The D-Fog filter will remove visible droplets and their associated particulate loading effects.
- c. The D-Fog coalescing filter will serve as a prefilter to prevent a portion of the contaminant from reaching the main filter elements, extending the service life, and associated restriction rise, of the main filters.

2. Contaminants that swell when exposed to water droplets. The D-Fog coalescing filter accessory will remove virtually all of the water from the airstream that is in droplet form. This will minimize the exposure of liquid water droplets to any contaminant on the main filter elements. This type of site can follow a more conventional schedule for replacement of the main filter elements assuming the operational history shows that the contaminant is not affected by high humidity.

3. Contaminants that do not swell from either humidity or water droplets. The D-Fog coalescing filter will prevent the main filter elements from being overwhelmed by the fog's particulate loading effects if the operational history of the site deems this as a concern. The benefits of the D-Fog filter accessory will not be as pronounced for this application as they are for the other contaminant conditions.

The D-Fog filter accessory may also be considered for its merits as a prefilter if there is a particular problem contaminant at the site.

4. Contaminants that deliquesce with humidity, typically salts. Usually found in off-shore or coastal applications. Although the D-Fog filter accessory will not prevent the main elements from being exposed to high humidity and the subsequent bleed-through of salts from deliquescence, it will limit the amount of liquid water droplets that reach the main filter elements during fog events.

D. Installation

The specification of a D-Fog filter accessory requires an engineering review of the existing air filter assembly by Donaldson Gas Turbine Systems Design Engineering. The review will determine quantities for each of the D-Fog accessory components. After the design review, a retrofit kit can be detailed to meet the site requirements.

The erection at the gas turbine site will involve the installation of a retention hardware package for the D-Fog coalescing filter accessory. Once these components are in place, the D-Fog filter elements can be installed immediately or scheduled for the beginning of the next fog season.

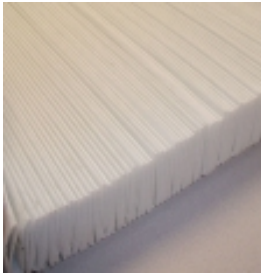
E. Maintenance

Since D-Fog is a fibrous coalescing element, it will capture contaminant and experience a restriction rise as it loads with dust. Donaldson recommends that the D-Fog elements be serviced when their restriction reaches 1" above the initial clean value.

The preferred method of cleaning is by using a portable pressure washer with the elements in place and the turbine off-line. Position the pressure spray to span one trough of the element pleats and move the wand from the near end of the hood to the far end of the hood. When the spray reaches the far end of the hood, it will deflect the pleats and direct any accumulated water out of the hood. Another method of cleaning is with compressed air from a nozzle. This also must be done with the turbine off. The success of this type of cleaning method will depend on the nature of the contaminant collected.



Donaldson **D-Fog**
fog removal solution



The D-Fog element is compressed when shipped to save on freight & storage space.



The full length of the D-Fog element spans the width of the inlet hood. Its construction makes it self-spacing.

Alternatively, the D-Fog media packs can be removed from the filter housing, cleaned with water or air, and reinstalled. Because of the additional labor required, it is likely that this method would only be used for a turbine that must remain on-line continuously. A spare set of D-Fog elements will ensure protection during the service period.

IV. Conclusions

Once fitted with the retention hardware, a Donaldson gas turbine air inlet filtration system can be fitted with D-Fog coalescing elements during the seasons that are known to be prevalent with fog. The D-Fog coalescing accessory will eliminate the introduction of fine fog droplets onto the main filter elements. This, along with a disciplined pulse-cleaning schedule and seasonal replacement of the main filter elements as required, will ensure that the inlet air filter system will remain operational when challenged with fog.

The D-Fog elements will capture a large portion of the contaminant that enters a filter system, thereby reducing the amount of contaminant that reaches the main filter elements. The loaded D-Fog elements can be replaced while the turbine is on-line, or washed in place while the turbine is off-line.

The maintenance requirements for the D-Fog operating plan are all measurable and predictable activities. The successful implementation of these will ensure that the turbine will remain operational during periods of dense fog.

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Where to Find Us:

website: www.donaldson.com
email: filterinfo@mail.donaldson.com
or gts-europe@mail.donaldson.com
or gts-asiapacific@donaldson.com.sg

Donaldson Company, Inc.
Gas Turbine Systems
P.O. Box 1299
Minneapolis, Minnesota 55440 USA
Phone 952-887-3543
Fax 952-887-3843
Parts/Elements 800-431-0555

Donaldson Europe N.V.
Research Park Zone 1
Interleuvenlaan, 1
B-3001 Leuven, Belgium
Phone 32-16-38-3940
Fax 32-16-38-3939

Donaldson Filtration Asia Pacific Pte Ltd
No. 9, Changi South Street 3, #07-01
Singapore 486361
Phone 65-6546-4400
Fax 65-6546-4325

Donaldson Far East Ltd.
Unit A, B & C, 21/F CDW Bld.
388 Castle Peak Road
Tsuen Wan, N.T. Hong Kong
Phone 852-2402-2830
Fax 852-2493-2928

Donaldson Shanghai
Unit F2, 6/F
Zhao Feng Universe Building
1800 Zhong Shan West Road
Shanghai 200233
Phone 86-21-6440-1808
Fax 86-21-6440-1639

DI Filter Systems Pvt. Ltd.
D-44, Gulmohar Park
New Delhi 110-049 India
Phone 91-124-633-7350/ 633-7351
Fax 91-11-6569534

Nippon Donaldson Ltd.
13-2, 5-chome, Imadera
Ome City, Tokyo 198 Japan
Phone 81-428-31-6399
Fax 81-428-31-7076

Donaldson Australasia Pty. Ltd.
Lucca Rd, Wyong, New South Wales
Australia 2259
Phone 61-02-4352-2022
Fax 61-02-4351-2036

