

# **The Why and How of Coalescing Type Oil Removal Filters**

By:

Thomas P. Colcombe  
Director of Engineering  
Filtration Technologies

## **Why Use a Coalescing Filter**

The increasing complexity of pneumatic applications often requires higher air quality levels. The major contaminants influencing air quality are water, oil and solid particles. Of these, oil is typically the most difficult to remove.

In applications such as pneumatic control systems, where there are many close tolerances, oil is extremely harmful. A single drop of oil can alter orifice characteristics and cause an entire automated process to malfunction. In some cases oil can cause seals in pneumatic valves and cylinders to swell causing sluggish operation or, in severe cases, complete seizure. Oil can also affect product quality causing defects in blow molded parts or surface blemishes in air applied finishes. Problems such as these show the need to remove unwanted oil from compressed air systems.

The largest source of oil contamination is the oil-lubricated compressor used in most compressed air systems. These compressors introduce oil as aerosols (tiny liquid droplets also called mist, fumes, fog, or smoke) and vapor. Aerosols are formed in two ways. The shearing action of the compressor's piston, screw or vane creates "dispersion aerosols" ranging from 1 to 50 microns in diameter (1 micron = 0.00004 in.). The heat of compression vaporizes oil which, when cooled, forms "condensation aerosols" generally less than 1 micron in diameter. Condensation aerosols typically represent over 50% by weight and more than 99% by actual particle count of all the oil present. The remaining "non-condensed" oil vapor is not a problem in most applications and is easily removed, if required, by an activated carbon filter.

The oil normally present on a per unit basis, while typically small, becomes quite significant on a cumulative basis. For example, an air flow of 100 scfm (standard cubic feet per minute) containing 50 ppm w/w (parts per million by weight) of oil would introduce 7.5 liters of oil into a system every month. Quantities as small as 1 ppm w/w of oil would introduce 150 mL monthly.

One way to reduce the amount of oil introduced into the system is by using oil free compressors. This however, will not completely eliminate the possibility of oil contamination. Light industrial areas may have as much as 0.5 ppm w/w of hydrocarbon vapor in the atmosphere. After compression some of this vapor condenses introducing as much as 15 mL/100 scfm/month of oil aerosols into the air system.

To eliminate oil from a system, a filter capable of reducing the oil content from 50 ppm w/w or more to below 0.01 ppm w/w is necessary. These filters must also operate for extended periods of time and with minimum pressure loss. Filters not specifically designed to remove oil seldom produce an outlet concentration of less than 5 ppm w/w. Even those filters claiming outlet concentrations of 1 ppm w/w would allow unacceptable amounts of oil downstream.

There are several types of oil removal filters available today. Filters using adsorptive materials which operate by surface attraction forces (i.e. activated carbon) have a limited life and lose their adsorptive properties when fouled by oil. Absorbent filter materials such as wool, felt and cotton, which take liquids into their interior, lose their structural integrity and quickly become ineffective after becoming saturated with liquids. Mechanical separators and screening type air line filters (usually rated at 5, 10, 20, or 40 microns) are not effective on the smaller particles which make up the bulk of oil aerosols. Today, for high efficiency oil aerosol removal, filters utilizing media composed of glass microfibers are generally considered the most effective.

Glass microfiber media are able to remove oil aerosols in the + 50 micron to less than 0.01 micron size at high efficiencies. They are neither liquid adsorbent or absorbent and, consequently, are superior in retaining their original properties. In fact, when removing liquids, glass microfiber media have an indefinite life.

## How They Work

Glass microfiber media are made of in-depth layers of fibers laid down in a random fashion. As aerosols move through the media, they are captured on the microfibers. There are several mechanisms that explain how this happens.

**Gravitational settling** When velocities within the filter element are very low, the larger aerosols, usually 20 to 50 microns in diameter, may fall out of the air stream before reaching the media. If they do reach the media they will continue to fall as they pass through the media. This vertical motion increases the likelihood that they will bump into a fiber and be captured.

**Inertial impaction** Airborne aerosols usually larger than 1 micron develop enough momentum that they do not conform to the air flow path and impact on fibers in the media. See Figure 1, particle path A.

**Direct interception** Particles usually in the range of 0.3 to 1 micron in diameter follow the air stream. This increases the likelihood that they will intercept a fiber (come to within 1/2 of their diameter of a fiber) and be captured. See Figure 1, particle path B.

**Diffusion** Particles smaller than 0.3 microns do not possess properties normally associated with a liquid. Their mass is so small that they do not conform to the conventional laws governing moving bodies. They instead travel in random directions without conforming to the path of the air stream. This phenomenon is called Brownian motion. The random motion increases the likelihood that they will come into close contact with a fiber and be captured. See Figure 1, particle path C.

The capture rate caused by Brownian motion increases as the particle size is reduced. The smaller the particle, the greater its motion and the greater its chance of being captured. The capture rate caused by impaction and interception, however, decreases as the particle size is reduced. This leaves a range of around 0.3 micron where neither mechanism is as efficient and particles are the most difficult to capture. The efficiency of a filter is largely determined by its ability to capture particles in this range.

While the capture mechanisms described here are most effective on particles in a certain size range, an increase or decrease in air velocity causes this effectiveness to vary. For example, as velocity increases, gravitational settling is less of a factor on larger particles (larger particles remain suspended in the air stream) but inertial impaction becomes more of a factor.

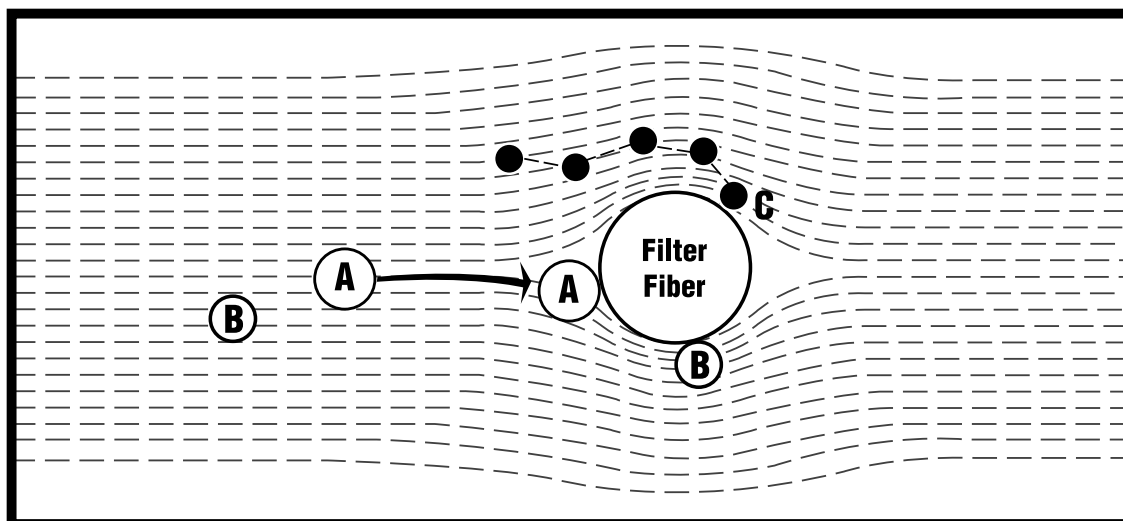


FIGURE 1

After oil aerosols are captured on the media fibers, they must be removed from the compressed air system. To remove these small aerosols they must first be caused to coalesce or grow together. This occurs as small oil aerosols unite to form large oil droplets. The large oil droplets then have enough mass to gravitate to the bottom of the media and into the filter sump. A manual or automatic drain discharges the collected oil from the system.

Coalescence is a physical process that occurs provided favorable conditions exist. Pressure, temperature, fluid velocity, humidity and the physical properties of the aerosol (density, viscosity, surface tension) all influence the degree to which coalescence occurs. The filter designer, however, has control of only the fluid velocity and the physical environment (filter media). The configuration, arrangement, size and type of filter media material selected are therefore critical.

As mentioned, glass microfibers are the best media available for coalescing liquid aerosols. Glass microfibers are hydrophobic (water repellent). This causes captured water aerosols to form as droplets rather than as a film, a condition favorable for maintaining filtration efficiency. Glass microfibers are not, however, oleophobic (oil repellent). Oil will form as a film on the fiber surface. The oil film moves along the fibers as oil wets the media. Coalescence occurs where the fibers are close enough together for the films to converge.

The oil film also tends to increase the functional diameter of the fibers. To maintain filtration efficiency as this growth in fiber diameter occurs, the designer must choose a media with smaller fibers than would otherwise be necessary if an oleophobic material were available.

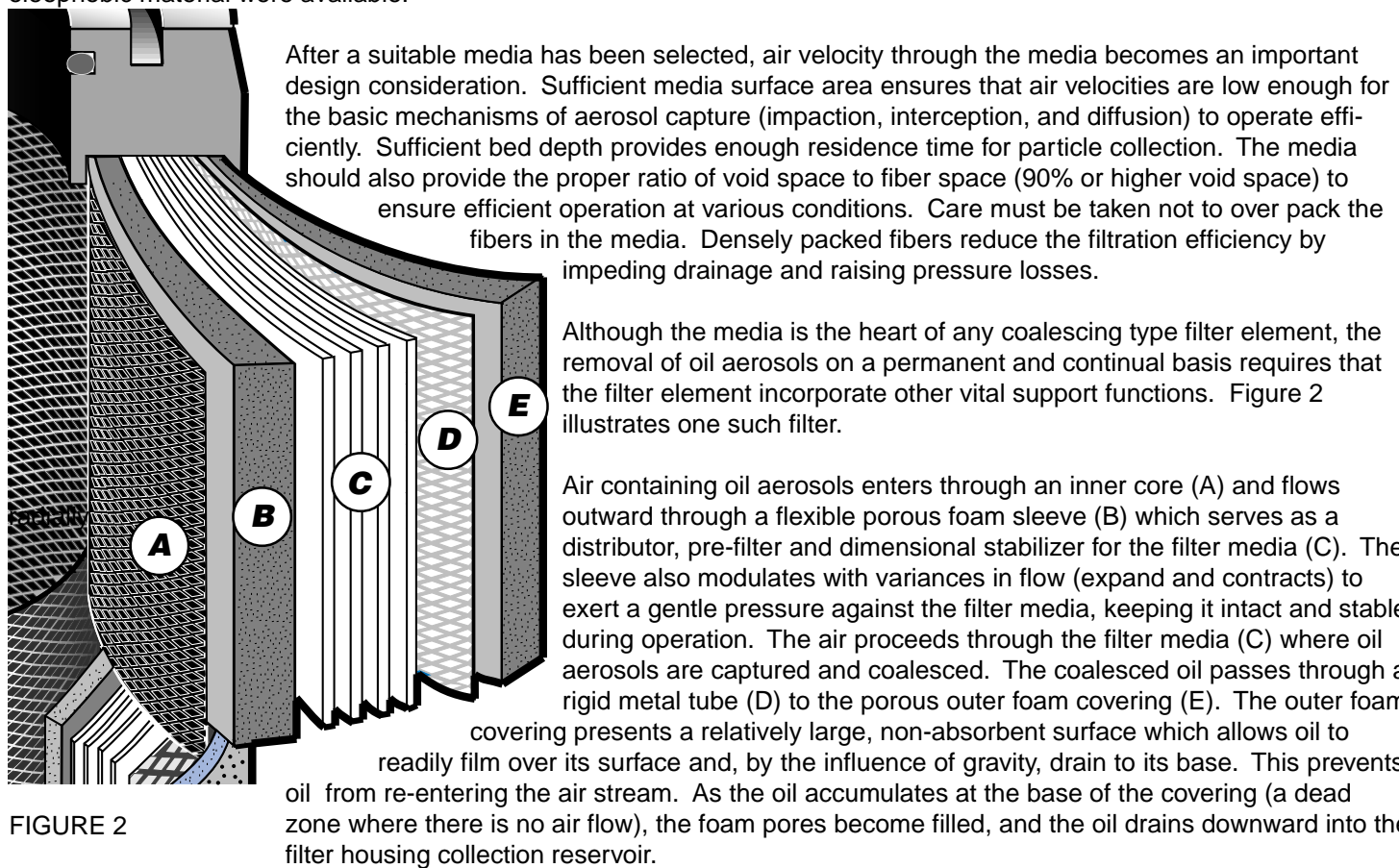


FIGURE 2

The filter element described here has an infinite life when removing liquids since filtration efficiency is virtually constant and the coalesced oil continuously drains away. However, the collection of solid particulate matter within the media and the resulting increase in pressure drop eventually ends the effective life of the element.

Coalescing filters are capable of producing outlet oil aerosol concentrations as small as 0.001 ppm w/w to meet the most stringent requirements of pneumatic systems. This is a level that approaches the purity of air containing only oil vapor. A well designed coalescing filter is the solution to the growing need for oil-free compressed air.



Division of Hansen Inc.  
Canonsburg, PA 15317-1700 U.S.A.  
Tel 724-745-1555 Fax 724-745-6040  
E-mail- [inquiry@hankisonintl.com](mailto:inquiry@hankisonintl.com)