# Removing 99.99998% of Oil Aerosols From Compressed Air and Other Gases

DON W. BENNER, Vice President, Wilkerson Corporation, Englewood, Colorado 80110


## Abstract

The oil and water particulates in compressed air and other gases are present as sprays, mists, fogs, smoke, fumes and vapors. The best method found to date for removing the oil and water contaminants from compressed air is a combination of direct impaction, inertial compaction, diffusion (Brownian motion) and coalescence, the latter being the main method of removing them. Baffles, centrifugal flow and flow directional changes of the air stream are helpful in causing coalescence and impingement. Flowing the air through porous media also is effective. The best way to coalesce liquid particulates from compressed air is to control the air flow and velocity as it passes through a fibrous bed that has predetermined porosity and which has minute strands and permanent electrostatic charges. An element designed with a prefilter with tiny pores in a cloth-like layer such as silicon-treated borosilicate enhances coalescing of the liquids. The air passageway between the random microfibers of inert strands located in the next layer through which air travels, and at right angles to the air stream, is very small. he strands must also be very fine (0.5 μ mean diameter). Because of the smaller open area and the smaller diameter of the fibers, this material is more effective as a coalescer of liquid droplets from 5 μ in size down to 0.01 μ in size. This structure also removes small solid particulates by diffusion (Brownian motion) and direct or inertial impaction. As long as air is flowing this design results in an almost continuous film of liquid on the outer layer. Ordinarily excessive air velocities in an element of this kind will cause subdivision of coalesced droplets. An outer cover of a material like a soft plastic, porous foam traps the coalesced film of liquid something like a sponge sleeve would "soak" liquids off a wetted outer cylinder wall. By gravity the liquids migrate down within the foam cover, dropping off the bottom of it and into the sump, out of the gas system.


The oil and water particulates in compressed air and other gases are usually present in the following forms: (a) sprays—droplets 500 μ in size and larger; (b) mists—droplets ca. 50–500 μ in size; (c) fogs—droplets from 1.0–50 μ; (d) smoke—0.1–0.5 μ; (e) fumes—0.001–1.0 μ; (f) vapors—0.001–1.0 μ liquid molecules.

The source of the water of course is the relative humidity present in atmospheric air, placed there by nature, that is drawn into every air compressor via its intake.

Much of the hydrocarbon particulates also enters the gas stream in the same manner, being added to atmospheric air by unecologically-minded man and the emissions from his lubricated internal combustion engines, the oil escaping from exhaust ports of air valves and other lubricated pneumatic controllers, and the excess lubricants that come from automatic lubrication systems. These hydrocarbons are even present when oilless compressors are used to compress air. When an oil-lubricated compressor is used, the shearing action of the piston rings against the cylinder walls and the high heat of compression converts much of the crankcase oil into aerosols and vapors which bypass the compression rings and enter the air stream.

Solid particulates also come into any compressor, oiled or not, via the intake strainer, which cannot be a strainer fine enough to keep out anything but the larger particles in order to permit high volumes of atmospheric air to be drawn into the cylinders without restriction.

The best method found to date for removing the oil and water contaminants from compressed air is a combination of direct impaction, inertial compaction, diffusion (Brownian motion) and coalescence. The first three arts actually enhance the last one, the coalescing of the liquid particulates being the main method of removing them.

Where solid particles are present with liquid particles, there will always be a film of the dirt particles around the liquid particles. This dust film reduces coalescing action even when the liquid particles agglomerate. During air flow the air system will either make the liquid particles further subdivide, or will make them grow in size as they run into each other. Which action will take place depends upon the air's pressure and velocity, the oil and water surface tensions, viscosity, dirt condition, density and temperature.

The most coalescing action takes place at lower air pressures and lower air velocities, with those liquids having highest surface tension, biggest difference in densities between oil and water, greatest cleanliness and room temperatures. These perfect coalescing conditions rarely all exist at the same time with compressed air systems, so coalescence must be induced by mechanical means. If only one liquid is present, that liquid's own surface tension value would be the biggest influence on its coalescence from air. Where oil and water are both present, then the interfacial tension value between the two liquids determines their ability to coalesce. The higher the surface tension and interfacial tensions, the more readily they will coalesce. Baffles, centrifugal flow and flow directional changes of the air stream are helpful in causing coalescence and impingement. Flowing the air through porous media also is effective. In many cases where the particulates are invisible in the air stream, the action seems to change miraculously part of the air itself into a liquid emulsion.

Years of experience have proven that the best way to coalesce liquid particulates from compressed air is to control the air flow and velocity as it passes through a fibrous bed that has predetermined porosity, minute strands and permanent electrostatic charges. To keep the size of the element small and prolong its useful life (in other words, to allow the air to flow without undue restriction while the particles are loading on its surface), a medium that has the highest possible ratio of air passages (pores) to medium material (strands) is most desirable. Also, one must use a material that has great strength so it will not crumble and migrate downstream, and one that is inert to chemicals, acids and other possible attackers in air; a material which will be nonwettable and which is itself austinetic, nontoxic and unable to contribute undesirable elements to the compressed air. A material such as borosilicate glass strands with a mean diameter of 0.5 μ fulfills this need perfectly. With an element using laminations of materials to prefilter the air before it enters the borosilicate or comparable inert medium, the medium itself—an after-filter layer fine enough to prevent any migration of the medium, all held in place by very strong cylinders that will not only sufficiently support the delicate strands in their intended position but will also keep the medium compacted between the prefilter layer and postfilter layers so that the air stream cannot move even one strand out of place even under pulsating shock conditions of air flow, and allow air channeling—will achieve the depth-type maximum coalescing of aerosols.

Effective coalescing can be accomplished by using a porous bed of very open mesh, such as a knitted wire mesh material of an inch or more in depth, which looks like a pad of steel wool called "through-flow depth-type coalescing." Mainly it is the pad's thickness and diameter

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# First Food Engineering Award Established

Nominations for the first DFISA-ASAE Food Engineering Award, created to honor outstanding original contributions in the food industry, are now being accepted. All candidates who have made noteworthy efforts in research, development, design or management of food processing equipment or processes which have been of significant economic value to the food industry and the consuming public will be considered.

The Award, cosponsored by Dairy and Food Industries Supply Association (DFISA) and American Society of Agricultural Engineers (ASAE), consists of a gold medal, presentation certificate and cash stipend of $2,000.

Recipient of the honor will be announced in August of 1972. Initial presentation will be made at the Food Engineering Forum, a highlight of the DFISA-sponsored Food & Dairy Expo. Expo '72, the most comprehensive exhibition of food and dairy processing equipment, is scheduled for Oct. 1–5 in Atlantic City Convention Hall.

Food Engineering Forum, part of Expo Week activities since 1964, is designed to update management and give them a perceptive and technical analysis of major food industry problems. The first Food Engineering Award winner will be part of the Forum program and will be required to deliver an address on the subject of his Award-winning work. At that time, the medal and check will be bestowed; the Award will be re-presented at the ASAE national meeting later in the year.

Nominations will be accepted until March 1, 1972, by the Executive Secretary of ASAE, James L. Butt, American Society of Agricultural Engineers, 2950 Niles Road, St. Joseph, Mich. 49085. Nomination forms are available on request from that office, or letters of nomination may be sent directly to the society.

Selection of a recipient will be made by an awards jury, which will include: president of DFISA or his designated representative; chairman of the Food Engineering Division of ASAE; chairman of an agricultural engineering department; chairman of a food science department; administrator, senior scientist or engineer from Agricultural Research Service, U.S. Dept. of Agriculture; administrator or senior scientist from the U.S. Public Health Service; and a professor of food engineering. Announcement of jury members will be forthcoming.

Nominees will be evaluated by the following criteria: (1) Degree to which human performance and progress in the application of engineering and technology has been significantly advanced; (2) Development of machines, processes or methods for the food industry; (3) Leadership shown in the professional development of the food industry; (4) Inspirational example of the individual's activities in the food industry.

In addition to background information—full name, address, business affiliation, date and place of birth, name of parents and immediate family—nominations should include: (1) Education, schools and degrees; (2) Memberships and activities in scientific, honorary, civic, fraternal, social or religious organizations; (3) Other honors or awards received; (4) Occupational history; (5) Listing of published works, especially those most pertinent to the Award; (6) 500-word statement describing the scope and nature of achievements on which the resommendation is based, and the personal character of the candidate, his influence on the profession and recognition in the food industry; (7) Statement should also show how the candidate meets the criteria on which nominations are to be evaluated.

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which determine the velocity at which the air will flow. Very low velocities must be maintained, such as 3–20 fps. As the air enters the pad of wire mesh, the liquid particles come in contact with the random wire strands and collect on them. As this continues the liquid on the wires accumulates, making it easier for additional oil to contact it. This method is heavily dependent on the high surface tension of the liquid, which many liquids do not have. Also it is dependent on the wire mesh being highly wettable. The droplets spread on the wires and cling there only through adhesion, making an interface between a solid (wire) and a liquid (oil or water, or both). Because oil usually is spreadable and has an affinity for wire, a straight, head-on contact angle will trap the oil by direct impaction, and oil will readily adhere to the wire strands until by gravity they drop or are blown off as the coating gets thicker. Many oils have a low surface tension, so the droplets do not adhere to each other but do adhere to the wire, making the desired "wettable" condition on the wires.

However because the oil droplets have low surface tension to each other but the oil-to-air interface has a higher attraction, that interface is broken when the oil droplet collides with the wire. This causes the oil to "splatter" and subdivide into smaller droplets, thus defeating coalescence in a portion of the oil, especially if the oil has a low surface tension. Another deterrent to good coalescence is the interjection of a second liquid into this process—moisture. Remember from our previous discussion that there is also a liquid-to-liquid interface involved when oil and water are present in the gas together. Also if the dirt is not prefiltered first with a large surface area layer before the medium, entrained dust interferes with coalescence. Moderate coalescing therefore results in such a unit.

In a discussion on this subject York and Poppele (1) state that, as the gas velocity increases and the oil builds up on the strands (restricting the air passages between the strands and increasing the air's velocity), both pressure drop and depth of liquid activity will also increase. According to these authors, under carefully controlled air velocities and the liquid load in the wire mesh (also dependent on the wire mesh pattern), the best than can be expected after much experimenting with scientific apparatus is a separation efficiency of only 99% of all droplets 5 $\mu$ in size and larger.

An element designed with a prefilter with tiny pores in a cloth-like layer such as silicon-treated borosilicate, that will remove very small solid particulates, enhances coalescing of the liquids. The distance between the random microfibers of inert strands located in the next layer through which the air travels, and at right angles to the air stream, is very small. The strands must also be very fine (0.5 $\mu$ mean diameter). Because of the smaller open areas, and the smaller diameter of the fibers, this material is more effective as a coalescer of liquid droplets from 5 $\mu$ in size down to 0.01 $\mu$ in size. This structure also removes small solid particulates by diffusion (Brownian motion) and direct or inertial inpaction.

As long as air is flowing, this design results in an almost continuous film of liquid on the outer cloth-like barrier that holds in place the densely packed layer of random microfibers. Ordinarily excessive air velocities in an elment of this kind will cause subdivision of coalesced droplets. However if the element is equipped with yet another layer of the medium, this possibility is totally eliminated. An outer cover of a material like a soft plastic, porous foam traps the coalesced film of liquid forming on the cloth-like barrier, something like a sponge sleeve would "soak" liquids off a wetted outer cylinder wall. By gravity the liquids migrate down within the foam cover, dropping off the bottom of it and into the sump, out of the gas system.

REFERENCE

1. York, O.H., and E.W. Poppele, Chem. Eng. Prog. 59(6):45 (1963).

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