Automotive Air/Oil Separator (Catch Can) Efficiency - Beyond the Basics

Overview: While my "PCV Line Oil Removal 102" outlined Positive Crankcase Ventilation system function, as well as many types of catch cans/filter designs and their design attributes and flaws, this "white paper" of sorts will delve deeper into engine dynamics relating to blow-by gasses along with air/oil separation filter specifics, advantages and disadvantages.

Let's start with a quick recap. Engine piston movement produces high gas velocities inside the crankcase. This movement not only causes periodic volume changes within the crankcase, but also "encourages" oil droplets of varying diameter to become airborne and sail past internal baffles and common catch can filter media. Now, we know that full load operation (high blow-by quantity) and low pressure drop at the throttle valve often causes flow reversal back into the air filter box (but not through the air filter); however, normal throttle actuations still allow those hard-to catch oil droplets to flow through most catch cans in high enough quantity to be of concern.

What else produces oil consumption? The crankcase ventilation system is actually only one path through which oil consumption movement occurs. The other two are the cylinder/piston rings and valve stem seals.

How much oil is consumed through a crankcase ventilation system (CVS)? According to manufacturers' data, a typical 6 liter engine flows .035 gallons per hour of crankcase blowby-produced oil, constituting 5% of total oil consumption. As you can see, the CVS represents a rather small percentage of overall oil consumption. However...........

Deposits: Studies have shown that carbon deposits from CVS are often found on inlet valves. Of course, deposit buildup over time results in degradation of volumetric efficiency. Other areas of deposit accumulation include piston grooves, causing increased blow-by and subsequent oil consumption. Turbo and super-charged engines' intercoolers may experience impaired heat transfer due to resinous deposits of high temperature-withstanding polymer constituents (viscosity index improvers) and inorganic additives (Ca, Zn, P, and Mg).

While not as common in today's oils, phosphorous, in the form of zinc dithiophosphate (anti-oxidant or anti-abrasive) can cause chemical destruction of a catalytic converter's surface, reducing its effectiveness.

Oil droplet(particle) size: Oil carried through the CVS can range in droplet size from sub-micron to well over 20 microns. Each engine type produces its own droplet size distribution, although most automotive engineers who are knowledgeable about vehicle emissions would agree that the majority of oil droplets are smaller than 3 microns. In fact, many droplets are smaller than even 1 micron. **Note:** 1 micron = .000039 inch

Common catch can filter media: A common approach to trap oil droplets in crankcase ventilation systems is to pack "course" (grade 4 or higher) steel wool, a plastic-derived abrasive pad, or air filter media into a fairly large diameter tube or counterbore. Provided that the air flow is directed through the filter media just before exiting the assembly, the basic concept is sound. Please note that some catch cans are designed to route blow-by gasses in the exact opposite direction (not recommended). Assuming the routing of gasses is correct, however, there are at least three problems with this design (listed by highest significance, first):

1. The filter media fiber's cross sectional diameter is large enough so as to allow smaller oil droplets to float through the air spaces within the filter bundle. See figures 1 and 2.

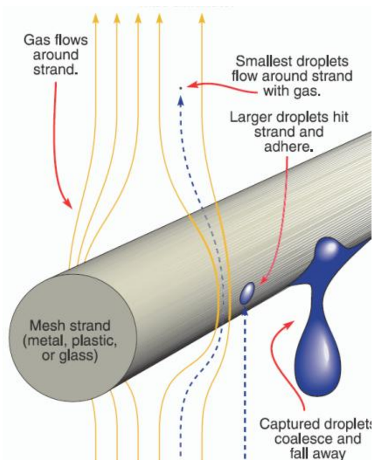


Figure 1: The effect of media large strand size

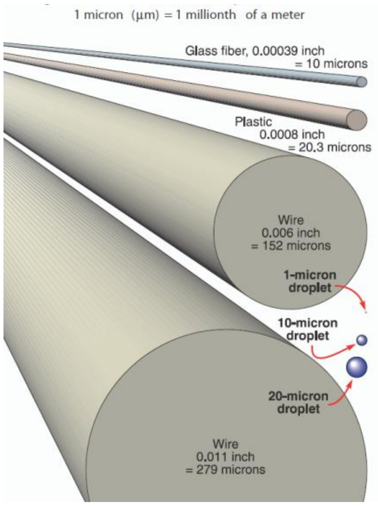


Figure 2: Filter media strand size comparison

There are generally two reasons for the common selection of .005" - .011" diameter fibers.
The <u>first</u> is that this grade of media is readily available and the <u>second</u> because finer media is most often so dense that vacuum pressure drop would be too high.

2. Based upon the cross-sectional area of the filter media (and its enclosure), the velocity of the blow-by gasses passing through the filter is not high enough to encourage an optimized rate of "inertial capture", the result of which is shown in blue (figure 1). The faster a droplet approaches a strand, the greater its momentum and the more likely it is to collide with the filter media strands. By comparison, smaller, lighter droplets have a much easier time floating past the large diameter media strands that are very common in many catch cans. And since gas velocity is simply the flow of gasses divided by the cross-sectional area of the filter media, larger media enclosures shown in "PCV Line Oil Removal 102", (pages 5-8) keep gas velocity at a capture efficiency disadvantage. Add to this design inadequacy the relatively large diameter filter media strands and it's no wonder plenty of oil works its way into the engine's intake, valves and pistons.

3. Most catch cans' filter media is packed against a much smaller diameter exit or entry hole. Because of this configuration, gasses are at their highest velocity through a comparatively small center section of the filter media. The velocity gradient across the media cross sectional area, then, varies in that it decreases radially toward the outer circumference of the media. Insufficient "gap space" designed into the internal catch can geometry is the cause; the result is less than optimum filtration performance.

In addition to what is listed above, many catch can manufacturers recommend and supply hardware for bolting their products directly to the engine. It is generally well known among those involved with compressed air systems that when it comes to catching oil, heat is the enemy. Let's look at the fundamental reason why this is true:

Oil droplets deviate from gas path variations not just because of their momentum but also because of the difference between the droplet's momentum and that of the gas surrounding it. When the gas is nearly as dense as the liquid, the gas has a tendency to "sweep" the oil droplets around the "obstacle" more easily. The more viscous the gas, the greater the drag it exerts on the airborne oil droplets as they flow around filter media strands. **The viscosity of gas generally increases as temperature increases.** Thus, keeping the filter media and its enclosure in as cool a place as possible is preferable when trying to maximize oil capture efficiency.

So, based upon the aforementioned design considerations, the following attributes contribute to the making of the ideal (highly efficient) catch can. Its design:

1. must route blow-by gasses through the filter media immediately before exiting the catch can. In other words, the best filter media should be the last thing the gasses "see" before entering the tubing which carries it to the engine's intake.

2. should contain one or more components that cause blow-by gas to abruptly change direction when entering the catch can. These design features encourage the largest oil droplets to drop out of suspension.

3. must contain a primary filter to trap medium-to-large sized oil and water droplets (3-20 microns). This filter media can be similar to what is now commonly used in premium catch cans. It can also be what is known as a particulate filter. **This filter media must be free-flowing (low pressure drop) and must have excellent drainage characteristics.** As with all other components of this catch can, the filter must be capable of withstanding temperatures of 200 degrees F. If stainless steel wire is used, it must not be a continuously-would coil, as coalescing oil drops tend to disengage more easily from the wire if it is formed using non-continuous lengths.

4. should contain a secondary filter that is capable of trapping sub-micron to 3 micron oil and water droplets. This filter media must <u>not</u> create a large (>3"Hg) vacuum pressure drop, dry or wet. This filter should last a reasonable length of time before requiring cleaning or replacement.

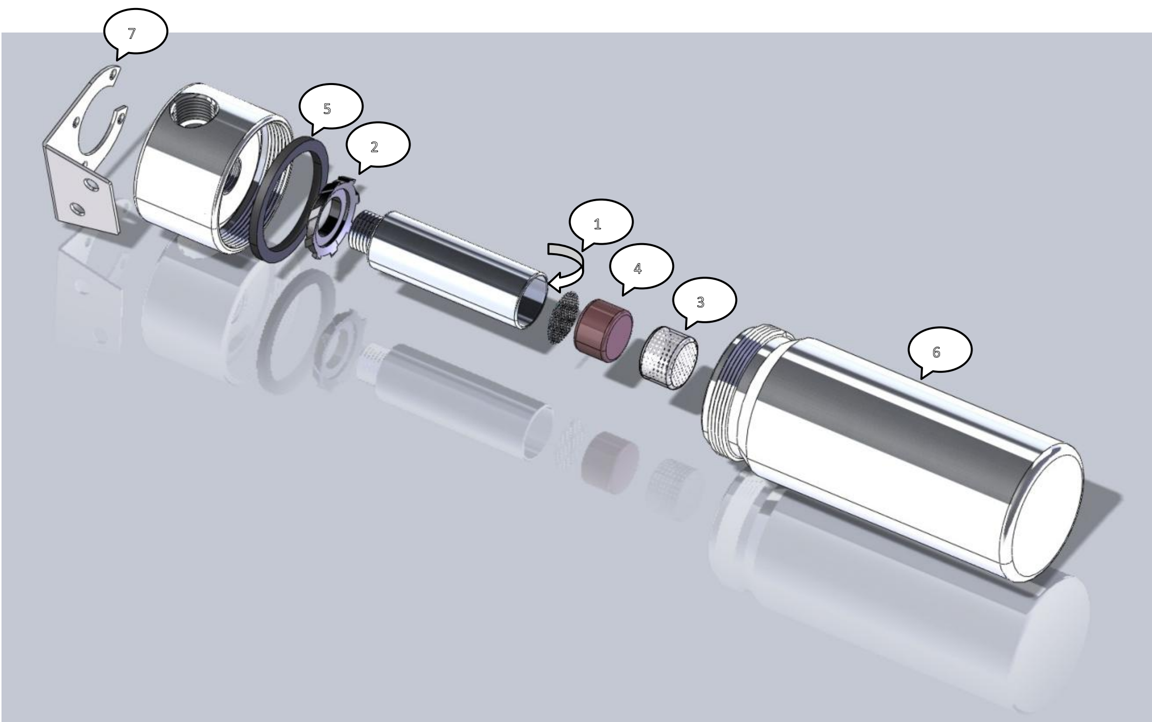
5. should feature a sizeable (face) gasket to ensure a leak-proof vacuum and positive pressure seal. Small cross-section (bore) o-ring seals are not recommended when sealing vacuum pressure.

6. should be available in multiple sizes and materials (aluminum, zinc, and glass) to accommodate owners of various types of vehicles and those who wish to see oil/water accumulation without removing the reservoir or other level detection device.

7. should contain a universal/reversible orientation mounting bracket.

8. should be available at reasonable starting prices, yet be effective at all levels.

Just what would this automotive air/oil separator look like? Perhaps something like this:



Dave