

PCV Line Oil Removal 102: [The Sequel](#)

Note: For those who missed PCV Line Oil Removal 101, I am including a recap of PCV operation descriptions.

Having been involved the utilization of compressed air systems and related components for many years, I became interested in the proliferation of "Oil Catch Cans" in many different types of vehicles. Could there be a better way to trap oil than the tried and true methods I've grown to know all these years? Let's take a look at what is going on in that little PCV tube.

From Wikipedia, we learn that.....

"As an engine runs, the crankcase (containing the crankshaft and other parts) begins to collect combustion chamber gases that leak past the seals around the pistons. These combustion gases are sometimes referred to as "blow by" because the combustion pressure "blows" them "by" the pistons. These gases contain compounds harmful to an engine, particularly hydrocarbons, which are just unburned fuel. It also contains a significant amount of water vapor. If allowed to remain in the crankcase, or become too concentrated, the harmful compounds begin to condense out of the air within the crankcase and form sludge on the engine's interior surfaces. This can harm the engine as it tends to clog small inner passages, causing overheating, poor lubrication, and high emissions levels. To keep the crankcase air as clean as possible, some sort of ventilation system must be present.

The PCV valve is only one part of the **PCV system**, which is essentially a closed-loop calibrated air leak, whereby the engine returns its crankcase combustion gases. Instead of the gases being vented to the atmosphere, gases are fed back into the intake manifold, to re-enter the combustion chamber as part of a fresh charge of air and fuel. The PCV system is not a classical "vacuum leak." Remember that all the air collected by the air cleaner (and metered by the mass air flow sensor, on a fuel injected engine) goes through the intake manifold anyway. The PCV system just diverts a small percentage of this air via the breather to the crankcase before allowing it to be drawn back in to the intake tract again.

The system relies on the fact that the intake manifold's air pressure is usually less than crankcase air pressure. The lower pressure of the manifold forces air to flow towards it, pulling air from the breather, through the crankcase (where it dilutes and mixes with combustion gases), through the PCV valve, and into the intake manifold.

The PCV system consists of: **1) The *breather tube*** , and **2) The *PCV valve***. The *breather tube* connects the crankcase to a clean source of fresh air, such as the air cleaner body. Usually, clean air from the air cleaner flows in to this tube and in to the engine after passing through a screen, baffle, or other simple system to arrest a flame front, to prevent a potentially explosive atmosphere within the engine crank case from being ignited from a backfire in to the intake manifold. The baffle, filter, or screen also traps oil mist, and keeps it inside the engine.

Once inside the engine, the air circulates around the interior of the engine, picking up and clearing away combustion byproduct gases, including a large amount of water vapor, then exits through a simple baffle, screen or mesh to trap oil droplets before being drawn out

through the PCV valve.” Mmmmm – obviously in many engines, this “trap” is not enough to catch ALL the oil droplets.

PCV valve



“The *PCV valve* connects the crankcase to the intake manifold from a location more-or-less opposite the breather connection. Typical locations include the opposite valve cover that the breather tube connects to on a V-8 or V-6 engine. Some engines place the valve in locations far from the valve cover. The valve is simple, but actually performs a complicated control function. At idle, the intake manifold vacuum is near maximum. It is at this time the least amount of blow by is actually occurring, so the PCV valve provides the largest amount of restriction. As engine load increases, vacuum on the valve decreases proportionally, and blow by increases proportionally. Sensing a lower level of vacuum, the PCV valve opens further to allow more air flow. At full throttle, there is nearly zero vacuum. At this point the PCV valve is nearly useless, and most combustion gases escape via the "breather tube" where they are then drawn in to the engine's intake manifold anyway.

Operation

Should the intake manifold's pressure be **higher** that of the crankcase (which can happen under certain conditions, such as an intake backfire), the PCV valve closes to prevent reversal of the exhausted air back into the crankcase again. This is where the *positive* comes from in the name. *Positive* is basically a synonym for *one-way*. Many PCV valves will contain a small spring. As in a checkvalve assembly, the spring keeps a ball away from its seating surface unless a flow that is opposite to normal flow, (with enough pressure behind it) pushes the ball against its seat, completely stopping flow of air in that direction.

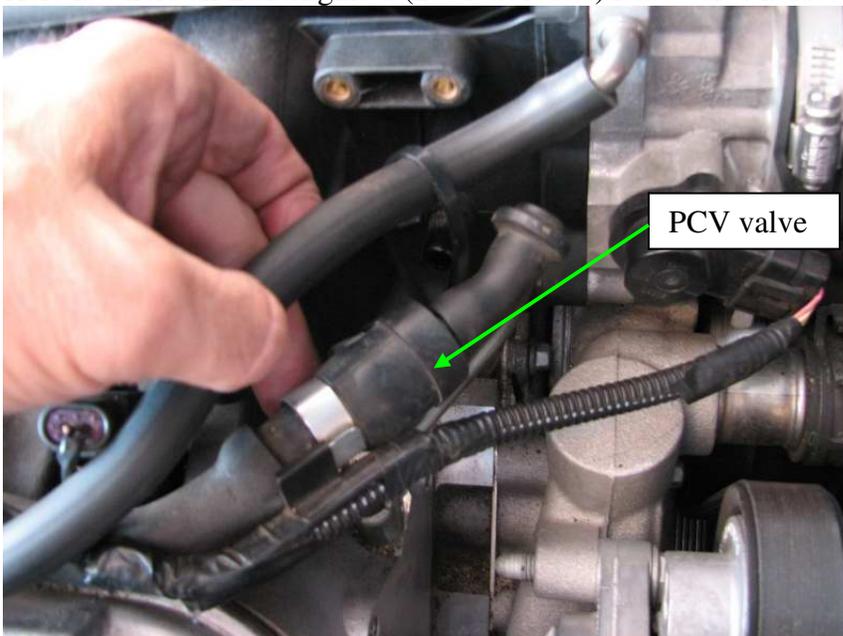
PCV Line Oil Removal 102 (continued)

It is critical that the parts of the PCV system be kept clean and open, otherwise air flow will not be correct. **A plugged or malfunctioning PCV system will eventually damage an engine. PCV problems are primarily due to neglect or poor maintenance, typically engine oil change intervals that are inadequate for the engine's driving conditions. A poorly-maintained engine's PCV system will eventually become contaminated with sludge, causing serious problems. If the engine's lubricating oil is changed with adequate frequency, the PCV system will remain clear practically for the life of the engine.** However, since the valve is constantly changing its resistance to flow by opening and closing proportionally as one drives a car, it is subject to eventual wear out over time. Typical maintenance schedules for gasoline engines are to replace the PVC valve whenever spark plugs are replaced. The long life of the valve despite the harsh operating environment is due to the trace amount of oil droplets suspended in the air that flows through the valve. *These droplets keep the valve lubricated. This means that you probably shouldn't remove all oil before the PCV valve and fortunately, most oil catch cans are placed in-line after the PCV valve.*

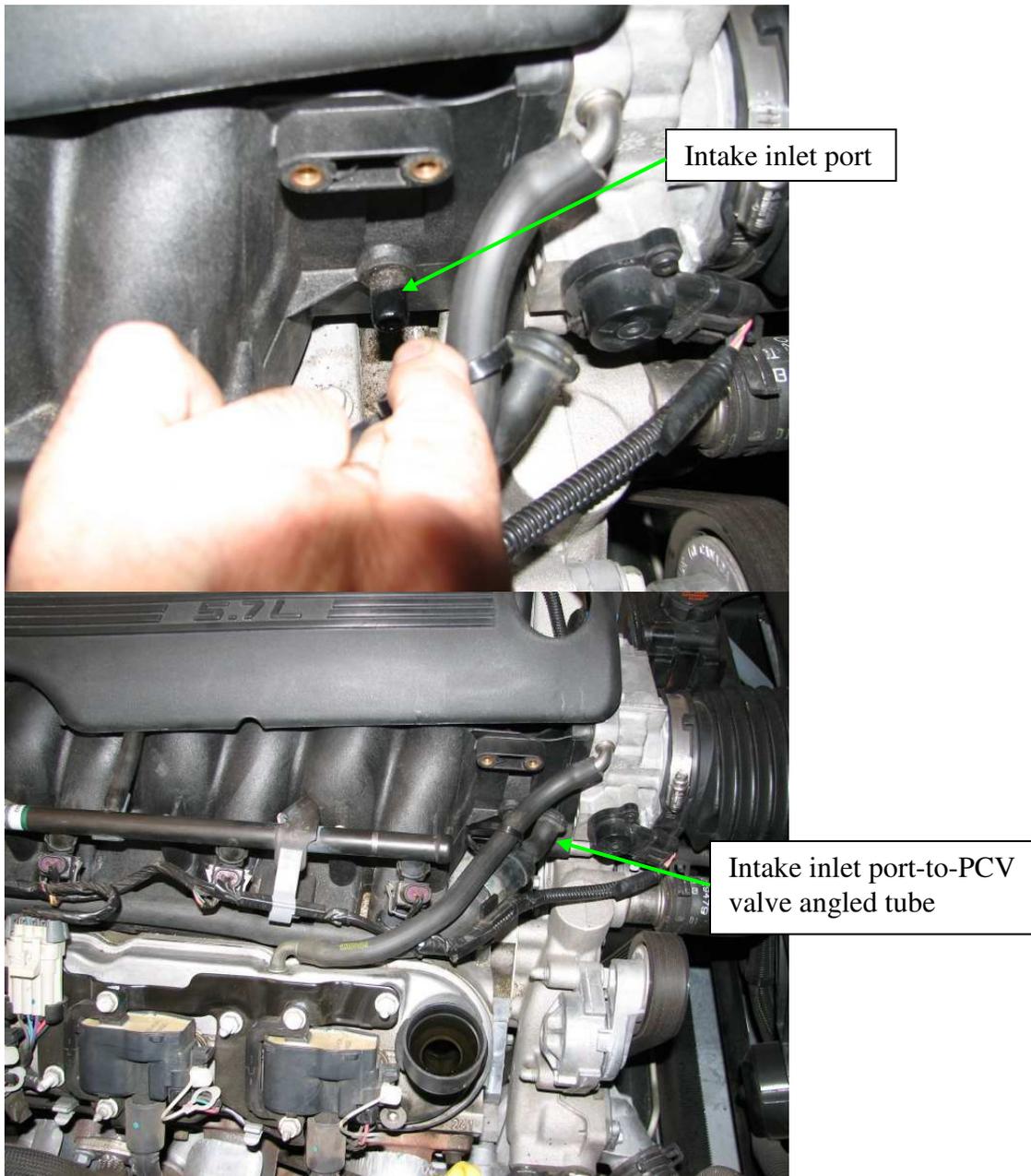
Not all gasoline engines have PCV valves. Engines not subject to emission controls, such as certain off-road engines, retain road draft tubes. Dragsters use a scavenger system and venturi tube in the exhaust to draw out combustion gases and maintain a small amount of vacuum in the crankcase to prevent oil leaks on to the race track. Small gasoline 2-cycle engines use the crank case to compress incoming air. All blow by in these engines is burned in the regular flow of air and fuel through the engine. Many small 4-cycle engines such as lawn mower engines and small gasoline generators, simply use a draft tube connected to the intake, between the air filter and carburetor, to route all blow by back in to the intake combustion air. The higher operating temperature of these small engines has a side effect of preventing large amounts of water vapor and light hydrocarbons from condensing in the lube oil.”

For some good images of PCV systems, see <http://www.autoshop101.com/forms/h63.pdf>

Here is where an LS1 engine's (2001 Corvette) PCV valve is located:



PCV Line Oil Removal 102 (continued)



Got that info? Good – let's move on to **existing catch can designs**.

Most catch cans consist of either a simple, welded aluminum body, or a machined rod of aluminum (as the body) with a matching top piece. This inexpensive type of catch can is good only for trapping liquid oil among the blowby gases. At best, it can be mounted in a cool area of the engine bay, which would encourage some coalescence of air-borne oil onto the inside wall of the unit. Unless you are severely lacking of funds, avoid this type of catch can. You can pretty much count on a \$19.99 Ebay catch can to have no filtering media inside it.

PCV Line Oil Removal 102 (continued)



Inside view of
inexpensive
Ebay can

Some of the more expensive versions have steel wool mesh inside. Here's a common version of this type of filter:

Important note: After researching and receiving samples of many types of filter media, I have come to the conclusion that most woven and non-woven stainless steel and even non-metallic filter media formed as a mesh pad contains loose strands of this media. Unless a very fine strainer-type filter is used downstream of the filter media container, some of that media may be pulled into the intake of the engine. Damage to its cylinder walls may occur!



Stainless steel mesh
is contained in this
top piece.

Advantages of a typical Stainless steel or copper mesh-type catch can:

- Well-made components of thermally conductive material and seals
- Resistance to ice formation if mounted as recommended by manufacturer
- Will trap some of the oil and water (before unit heats up with engine bay temp. rise)
- Filter material is relatively inexpensive to replace.
- Very low pressure drop

Disadvantages of Stainless steel mesh-type catch can:

- The bore o-ring seal used is generally not recommended for vacuum-sealing applications as the compression of the o-ring is often insufficient for higher vacuum

PCV Line Oil Removal 102 (continued)

pressure conditions. Leaks could allow unfiltered air to be pulled into the intake manifold.

- Strands of media may be pulled away from mesh pad and enter the engine's intake manifold, potentially causing damage to cylinder walls and/or valves.
- Location recommended by manufacturer not best to coalesce water and oil (mounting unit to engine with thermally-conductive bracket will transmit heat to unit. As a rule of thumb, the higher the temperature of the filter media, the greater the percentage of oil aerosols that will get past the media and end up in your intake.
- High cost of unit
- Velocity of gasses may be insufficient for adequate impaction of oil droplets against mesh material. The large diameter of filter media contributes to this reduced velocity.
- Direction of air flow exposes air exiting filter to liquid oil.
- Entrapped oil/water is not visible to user.
- Particulates and smaller-sized oil aerosols in blowby gases may easily get past the very medium-course filter media
- Large quantity of trapped oil can slosh around when subjected to rapid oscillations due to rough roads and high vehicle speeds. Some of this oil may become airborne and be pulled out (retrained from the oil) of the can and sent to the intake manifold.

Non-metallic filter media catch cans:



This type of filter media has an upper temperature limit that is almost certainly lower than that of the stainless steel media, so if you have this type of catch can, ask the vendor what the media temperature limit is. Keep this in mind when mounting the unit.

Advantages of a typical non-metallic mesh-type catch can:

- Well-made components of thermally-conductive material (except filter media)
- Resistance to ice formation if mounted as recommended by manufacturer
- Will trap some of the oil and water (before unit heats up with engine bay temp. rise)
- Filter material is relatively inexpensive to replace.
- Very low pressure drop

Disadvantages of non-metallic mesh-type catch can:

- The bore o-ring seal used is generally not recommended for vacuum-sealing applications as the compression of the o-ring is often insufficient for higher vacuum pressure conditions. Leaks could allow unfiltered air to be pulled into the intake

PCV Line Oil Removal 102 (continued)

manifold. Compared to the metallic-filter catch's o-ring can shown previously, this o-ring's cross-section is larger – an advantage but still not ideal.

- Location recommended by manufacturer not best to coalesce water and oil (mounting unit to engine with thermally-conductive bracket will transmit heat to unit. As a rule of thumb, the higher the temperature of the filter media, the greater the percentage of oil aerosols that will get past the media and end up in your intake.
- Direction of air flow exposes air exiting filter to liquid oil.
- Entrapped oil/water is not visible to user.
- Particulates and smaller-sized airborne oil in blowby gases may easily get past the medium-course filter media
- Large quantity of trapped oil can slosh around when subjected to rapid oscillations due to rough roads and high vehicle speeds. Some of this oil may become airborne and be pulled out (retrained from the oil) of the can and sent to the intake manifold.

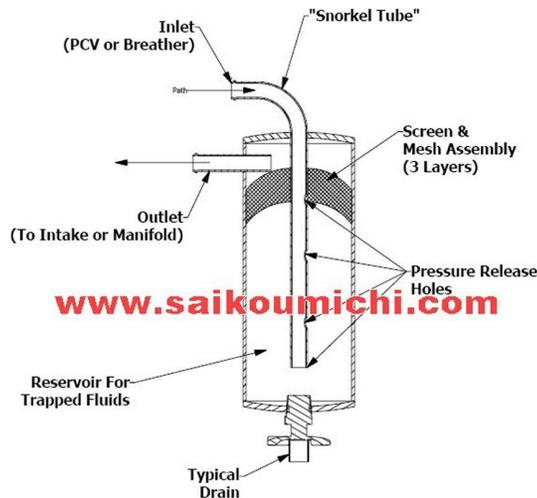
Another variation of the above.....



Unlike the previous two catch can designs, this one features a face o-ring seal, which is preferred for vacuum pressure sealing. However, the filter media diameter is large enough so that blowby gas velocity may be insufficient to allow adequate impaction of oil droplets against the media. The outer body is a full 2.5 inches in diameter, which can make it a bit tricky to mount in tight places.

Another interesting feature is the inner wall surface. Grooves are cut into the wall to discourage oil climbing. My guess is that the direction of the gas flow path is such that the air travels downward through the media, exposing itself to the liquid oil that is traveling in the same direction. The air then travels in between the inner and outer pieces. This is another setup that will trap bulk liquids and some of the mid-to-larger droplets, but much of the smaller droplets common to crankcase blowby gasses will escape.

Large diameter filter media-type catch cans



Dual Chamber Function Explained

The purpose of this OCC design is to allow gases and blow-by to enter the snorkel tube. The oily gases are allowed to enter and condense within the main chamber. Heavy Fluids will just settle to the bottom. Vaporized oils collide and swirl within the chamber and also cool which creates droplets which will settle to the bottom as well. The 2nd line of defense is the mesh assembly which creates a "baffle" with many surfaces to collide with. This will help turn the vaporized oil into more droplets which will have a smaller probability of exiting the OCC.

In some ways, the design of this catch can is a step up from the previous three types because its airflow direction ensures blowby gases exit the can immediately after being filtered. The air is not exposed to entrapped oil on its way out. However, the size (diameter) of the filter media is not ideal; air velocity through the media may be insufficient for adequate impaction of oil droplets against the media.

Another type of catch can includes a long, perforated internal tube. Blowby gases are directed out of the tube through the many small holes in it and against the inner wall of the "can". Critical to extracting the most amount of oil from the blowby gases is the mounting location of this unit. (cooler area is better). Unfortunately, this unit is very large and thus, mounting options can be limited.

Advantages of this large filter media-type catch can:

- Correct flow direction of gases – exits media after being filtered

Disadvantages of this large filter media-type catch can:

- Welded body doesn't appear to be user-servicable
- Velocity of blowby gases may slow down excessively through filter media
- Entrapped oil/water is not visible to user.

The next catch can is essentially a very large (32-oz capacity) aluminum housing with a perforated tube positioned in its center. Air flows into the tube and out the holes that are drilled into the tube's side. The idea here is that the blowby gasses will impact the inner wall of the housing, causing oil and water to coalesce and drop to the bottom.

Advantages of perforated tube catch can:

- Large body can store as much as a quart of oil
- Somewhat effective if mounted in cool area of engine bay
- Very low pressure drop
- large capacity may be a good choice for racing conditions.

Disadvantages of perforated catch can:

- Large quantity of trapped oil can slosh around when subjected to rapid oscillations due to rough roads and high vehicle speeds. Some of this oil may become airborne and pulled out of the can to the intake manifold.
- Entrapped oil/water is not visible to user
- Particulates in blowby gases are not trapped and will pass through to intake
- Entrapped oil/water is not visible to user.

Okay, what else is there? A thorough search of oil/water separators brought up an interesting invention – the multi-twister separator by Dana Corporation. From their website.....

Dr. Dieter Grafl, manager of a physical and chemical laboratory for Dana Corp., says, "Blow-by contains approximately 60% water, along with other components including air, oil, soot, wear debris and dust. Any process involved with cleaning this stream must take into account the high concentration of water."

Blow-by gas emissions can represent up to 25% of total vehicular emissions. New technology that can reduce this source of vehicular emissions will help OEMs meet more stringent regulations.

MultiTwister(TM) Air/Oil Separator

*Dana has introduced a new approach to separating oil from the air in the blow-by gas stream to reduce vehicular emissions. The technology is known as the Multi-Twister(TM) air/oil separator (AOS). Dr. Pedro Bastias, senior FEA engineer for Dana, says, "**The purpose of the MultiTwister AOS is to separate oil from the air in the blow-by gas using the physical principle of centrifugal forces. Facilitating this separation is the inclusion of multiple swirling tubes in a typical MultiTwister design.**"*

*A key feature of the MultiTwister AOS is the presence of "double helixes" in each channel, which create a spiral flow and the attending centrifugal forces needed to separate oil from the air. Bastias adds, "**In the presence of centrifugal forces, the larger mass oil particles are propelled against the wall of the channels where they coalesce and are, thus, removed from the air stream.**" The oil can then be recycled back into the crankcase. Figure 3 shows the action of the MultiTwister AOS carrying out this process.*

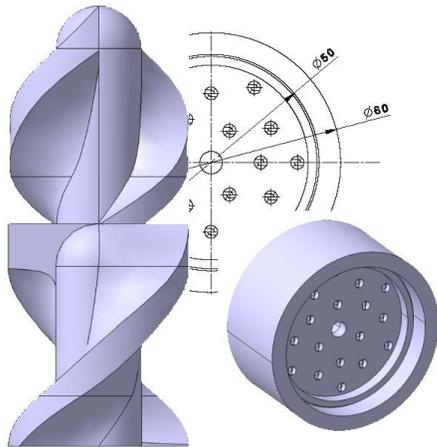
Dana can tailor the MultiTwister AOS design to meet the needs of specific engines by utilizing different flow geometries. This enables certain oil particle sizes to be targeted and removed.

Dana has designed the MultiTwister AOS to be installed in the cylinder-head cam cover. The temperature of the oil/water separation process is critical due to the high level of moisture in blow-by gas.

Grafl says, "Integration of the MultiTwister AOS into the cylinder-head ensures that any condensed moisture will not freeze, even under the most extreme weather conditions, which can present a serious problem with external separator and oil drain back tubing. It is more desirable to have a minimum temperature of the blow-by gas between 60 C and

PCV Line Oil Removal 102 (continued)

70 C. This avoids condensation of the moisture, which accumulates in the sump and can present a problem for the engine oil pump."



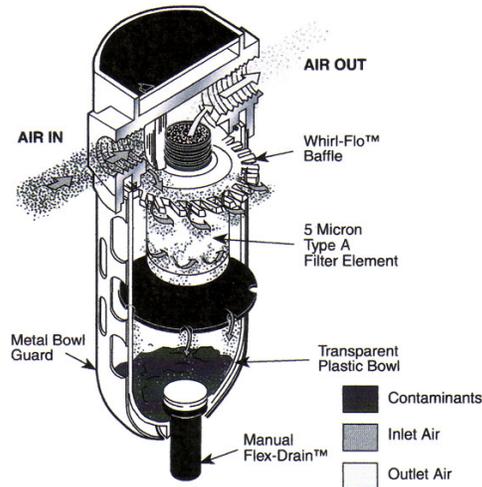
Dana's MultiTwister design

Ah, finally, some specifics about how oil can be removed from blowby gasses without requiring a filter. Unfortunately, very small oil droplets in the blowby gasses are free to exit the cam cover and be pulled into the intake. Still, one can only wonder how particulates and water, both of which are contained in blowby gasses, are disposed of. Most likely, they are directed to the crankcase in the hope that the oil filter will eventually catch them. Now, we can't go out and buy a Dana catch can, so what can we buy to "spin off" blowby gasses against a surface to coalesce oil onto it? Read on...

Particulate filters: In a compressed air system, these filters are typically installed before aerosol-trapping (coalescing) filters. Particulate filters are designed to trap solid particle contaminants down to 5 microns and to some extent, coalesce oil and water before separating particulates in the air. Bulk liquids, of course, will also be trapped. One other thing I can't mention enough is the fact that any filter that has a clear, polycarbonate bowl **is a bad choice** as an oil catch can for 2 reasons:

1. The typical clear bowl – equipped filter has maximum operating temperature of 120 or 125° F. An LS1 engine bay can reach temperatures beyond 140° F, quite easily, potentially causing the seal between the bowl and the inlet/outlet component to leak.
2. Many of these filters contain warning labels that state that the bowl material is not compatible with synthetic oil.

PCV Line Oil Removal 102 (continued)



Particulate filter (shown)

The image shown above is that of a standard particulate filter. What is very interesting is the direction of air flow. Notice any similarity between it and Dana's patented air/oil separator design? Air enters the bowl directly above a swirling device. As the air hits this device, it is directed centrifugally at the inner bowl surface. Any liquid oil or water then drops down, but coalescence is also happening, especially if the bowl surface is cooler than the air. The air then exits through the filter element, which traps particulates and any moisture that made it past the "slamming against the wall" path. Under vacuum conditions, this flow path is most desirable.

Unfortunately, most particulate filters that are not very large in size and subsequently, have a very small reservoir to hold entrapped oil and water.more on this later.....

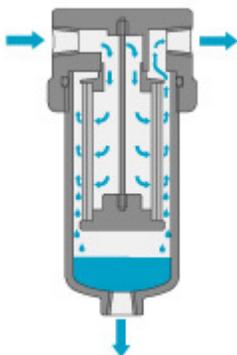
Coalescing Filters:

Coalescing filters rely on mechanical filtration, which means that the flowing particles collide and eventually adhere to filter fibers.

This type of filter is specifically designed to remove solid particulates, water and oil aerosols down to .01 micron. Most of the well-known coalescing filter manufacturers, like Wilkerson use borosilicate glass micro fibers. Compared to simple stainless steel mesh, they provide "superior filtration".

Anyway, according to the folks at Wilkerson, "The compressed air/gas passes through the inner layer of the filter element which acts as an integral prefilter to remove large contaminants. This gives protection to the layer of high-efficiency filter material which substantially removes submicronic aerosols and solids from the air flow stream.

The fine liquid particles, including aerosols begin to collect or coalesce, forming larger droplets. The separated liquid drops from the bottom of the filter element and falls to the bottom of the filter housing....." See image, below.



“Why then” , you might ask, “won’t catch can makers use either of these tried and true methods of trapping oil and water?” That’s a great question, the answer to which I can only guess. My assumption is that a coarse, relatively inexpensive mesh, such as stainless steel, is more likely to last longer than a particulate or borosilicate filter, primarily because the stainless steel mesh will not trap as many contaminants/oil and hence, clog as easily.

Normally, a compressed air system filter is sized according to the flow rate and pressure at the filter. Particulate and coalescing filters, like compressors, are rated for flow at a particular pressure. The pressure at the filter helps push the air past the filter at a desired flow. As pressure drops, so does flow, so sizing the filter for the system dynamics is critical for obtaining optimum filtering efficiency. To compensate for low-pressure conditions in a typical automotive PCV line, a true particulate or coalescing filter should be rated for a much higher flow rate than what is possible in the PCV line. If you are using this type of filter, check vacuum pressure drop between the filter and the PCV valve. If the vacuum pressure is 2 inches of mercury less than a PCV line with no filter, the filter media is too dense.

What PCV line pressure and flow rate are we talking about? I was able to borrow a digital flow meter and measured flow after the PCV in my LS1 engine. I also measured vacuum pressure by using a mechanical vacuum gauge that was calibrated in inches of mercury. In order that I choose a filter than can stand the heat, I measured engine bay temps in a couple of different places by taping a HOBO data logger underhood and then later extracting temperature data. Here’s what I found:

Vacuum pressure: -20 in-Hg (approx. -10 psi vacuum)

Flow at 800 rpm: 36 LPM = 1.27 CFM

Flow at 4000 rpm: 37 LPM = 1.31 CFM

Maximum temp. between right side head and fender during 20 minute ride home on a 75 degree day: 140°F

Maximum temp. in battery compartment during 20 minute ride home on a 75 degree day: 132°F



PCV Line Oil Removal 102 (continued)

While a coalescing filter is excellent way to trap oil, I have come to find that even in an automotive application that of course, includes an oil filter, a matched-flow coalescing filter element will need to be changed often if a particulate filter is not installed upstream. Also, assuming that most people do not have differential pressure measurement equipment or even a very accurate vacuum gauge, I now recommend that a good, high-flow particulate filter be installed after the PCV valve and preferably, away from the main heat source in your engine bay – your engine. The advantages of this type of filter are as follows:

1. Like Dana Corp's MultiTwister oil separation design, the particulate filter's air-swirling disc throws the air and liquids against the inside wall of the "can", allowing airborne oil and water to coalesce and drop down into the reservoir, or "quiet zone".
2. Unlike stainless steel wool – like media, a particulate filter traps a majority of blowby byproducts that can pass through coarse, steel wool media.
3. And unlike the typical mesh-type filter, the air exiting the filter is not exposed to the trapped liquids, which can slosh enough to allow retrainment of oil into the airstream that is heading into the intake manifold.
4. Compact design fits in areas that are too small for larger catch cans.
5. The filter elements are easily replaced, inexpensive, and are readily available from distributors throughout the US.
6. Available in both aluminum and glass-body designs. Both can withstand up to 200 degrees F. temperatures.



Zinc body with drain valve

The as-purchased filter assembly. Yes, it is small, but see the following website for optional extra-capacity glass and aluminum options:

http://www.conceptualpolymer.com/new_page_1.htm

Now there's one more thing I should mention – hose type. Do **NOT** use any old type of hose for extending the PCV line; use **fuel line hose** only. I found that there are at least two types available in automotive supply stores. Since pressure in the hose will be low, the least expensive type will do just fine.

Hey, what about our "fresh air line"; does it need a "catch can" too? The fresh air line will see reverse flow of dirty air out of the valve cover and to the air filter housing under

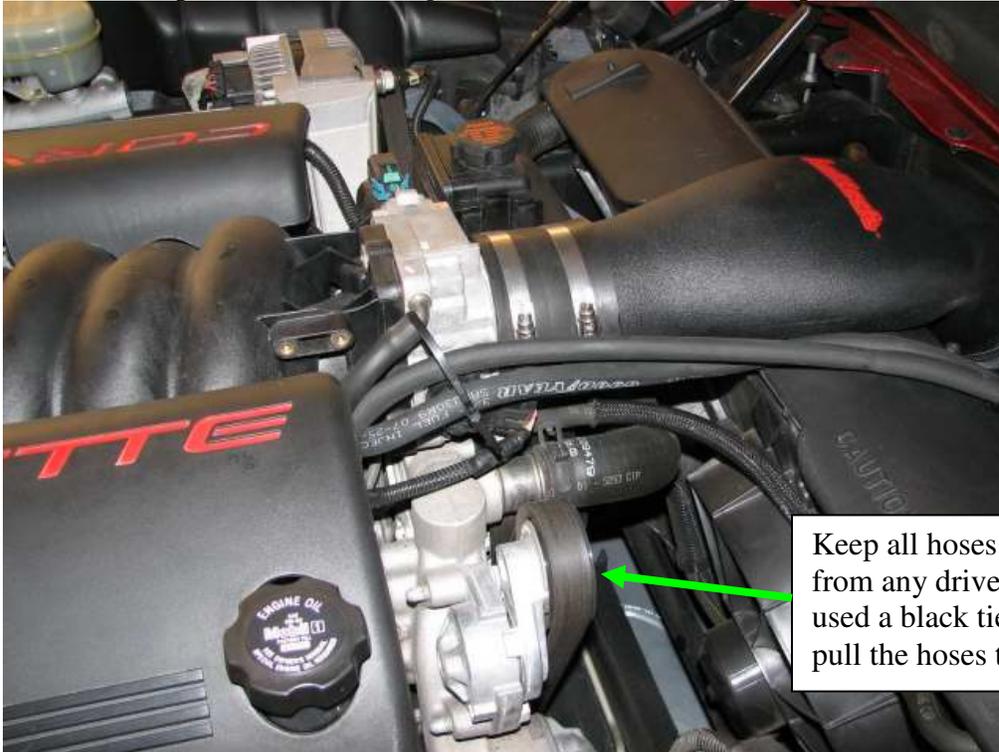
PCV Line Oil Removal 102 (continued)

Wide Open Throttle (WOT) conditions. The problem with plumbing a catch can in this line is that most are designed for a single flow direction only. Allowing a reverse flow of “dirty” air may make matters worse by adding oil aerosols to the air. This extra oil may then get pulled into the engine’s intake – just what we are trying to avoid.

So what should we do? Well, you could plumb in two fresh air lines from the valve cover to the air filter housing, one containing a catch can and check valve that would allow only reverse-flow air to flow through the catch can (under WOT conditions). The other hose would include a check valve that allowed air to flow from the air filter housing to the valve cover, but would block any reverse-flowing, dirty air from flowing through the catch can-free line.

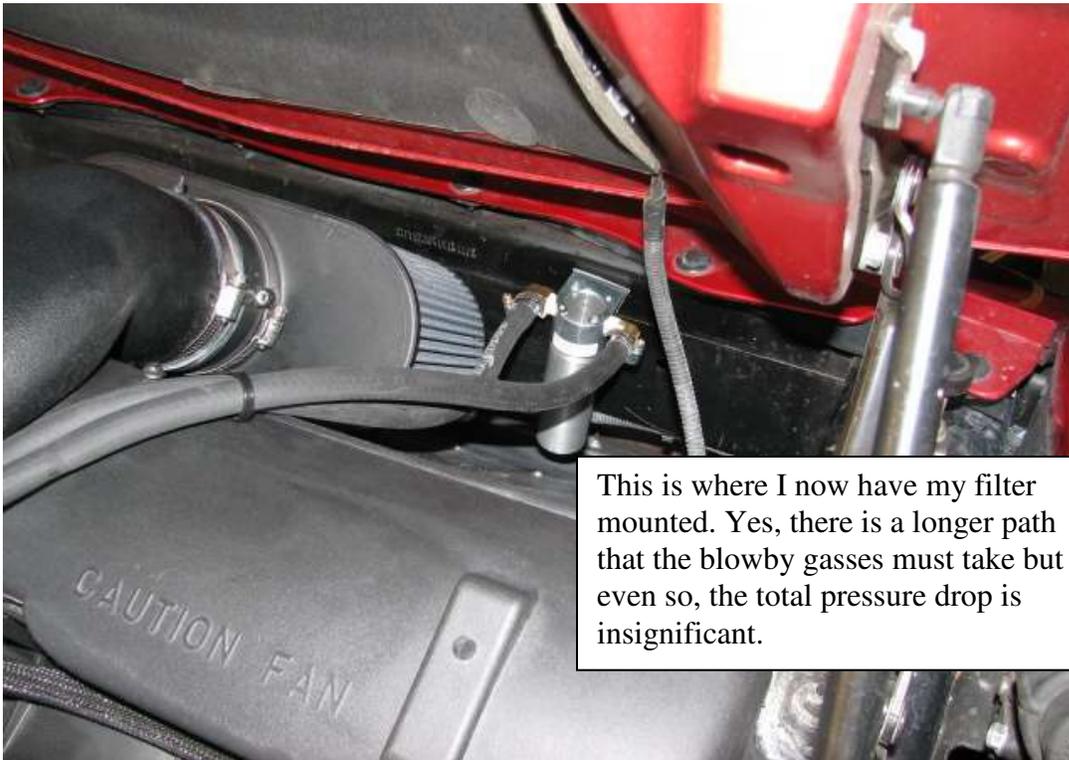
...OR, if you don’t normally drive WOT to work every day, just leave this line alone. The bulk of your oily air will be flowing through the PCV valve and your cleverly-mounted catch can/particulate filter.

Here’re a couple of shots showing the front end mounting setup:



Keep all hoses away from any drive belts! I used a black tie-wrap to pull the hoses together.

PCV Line Oil Removal 102 (continued)



This is where I now have my filter mounted. Yes, there is a longer path that the blowby gasses must take but even so, the total pressure drop is insignificant.



...and here's my glass catch can. It sure is nice to see how much oil is being trapped!

Currently, I am further-researching filter media and its effect on oil entrapment and vacuum pressure drop. Filtering synthetic oil in particular is a not a simple task, as airborne oil of this type has a very small molecular size, which allows it to bypass conventional mesh-type filters very easily. In the meantime, I believe the safest media is a conventional particulate filter. This type is more or less a single piece and will not allow hard pieces to be pulled downstream. Stay tuned for more info.

Dave