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ON THE MOVE
OEM ORIGINAL ENGINE MANAGEMENT
VOL. 3

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ON THE MOVE

INCHES OF MERCURY

The internal combustion engine is sometimes referred to as being a big air pump. When we consider the 720 degrees of the four stroke cycle- intake, compression, combustion, and exhaust- it's clear that 75% of the cycle is simply moving around air and spent exhaust gasses. The timing, measurement and management of air within the engine is so critical to performance it has spawned technologies such as variable camshaft timing, variable camshaft lift, variable intake control whether thru butterfly valves opening additional intake ports to intake manifolds that change their geometry and length on some high performance exotics.
In the age of carburetors engine vacuum was the source of the venturi effect that determined the mixture of fuel and air being sent to the cylinder. Today proper intake vacuum (or pressure) and the management of it is just as critical in the operation of the modern electronically fuel injected vehicle. Some of the terms used to express the amount of pressure within the various parts of the engine are Pounds-per-Square Inch (psi), Bar (1 Bar is about equal to normal air pressure at sea level or 14.5 psi) and kilopascals (kPa which is simply the smaller metric unit upon which we derive Bar so 100 kPa is equal to 1 Bar) You may have heard the term "Inches of Mercury" (in. Hg) before in terms of intake vacuum, and this older method of describing manifold vacuum refers to the use of a mercury manometer. The measurement of air pressure at sea level using a manometer is 29.9 in.Hg when compared to an absolute vacuum. As turbo charging, supercharging, and electronic fuel injection became more prevalent the Inches of Mercury became less relevant due to the positive pressure of the intake manifold in the case of forced induction. The world has moved to using the absolute scale (thus manifold ABSOLUTE pressure) for the modern MAP sensor. This allows for tighter control of air metering, and provisions for the above mentioned forced induction systems. On the absolute scale, zero is a complete and total vacuum like outer space. This can be expressed in terms of zero kPa or 0 Bar. Remember, the air you are breathing right now on the absolute scale is actually at about 14.5 psi, 100 kPa, or 1 Bar, what is referred to as one atmosphere. Even though most pressure gauges use 1 atmosphere as their ZERO reference point, your MAP sensor for the purpose of EFI is actually reading 14.5 psi or 1 bar in key on, engine off condition.

Now that we have a basis for measurement, we can look at the different conditions that exist while a vehicle is actually driving down the road. At idle, the intake manifold develops a good amount of vacuum, around .4 Bar or 18 Inches of Mercury. As the throttle is opened and an increasing load is applied to the engine the pressure in the intake manifold most vehicles will see an increase in the MAP reading to around .9 Bar or just 4 Inches of Mercury at wide open throttle under a heavy load. As the throttle opens or a load is applied manifold vacuum drops, in. Hg drops, and absolute pressure increases. In the case of forced induction engines, the pressure may actually rise to above 1 Bar according to a gage calibrated to zero for pressure of air at sea level.

Continued on Page 2...


Variable intake manifold

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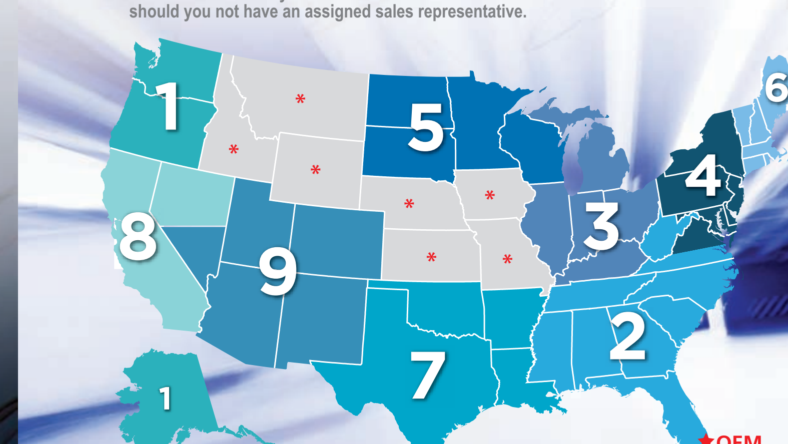
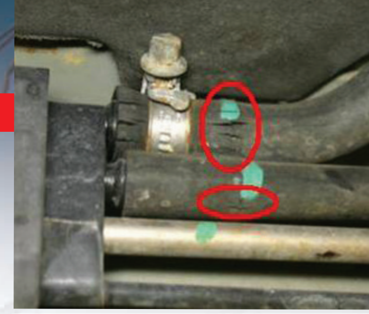


INCHES OF MERCURY *CONTINUED...*

The subtle changes in pressure can tell us a lot about what the needs of the engine are at any particular moment, and numerous components such as fuel pressure regulators, exhaust gas return valves and pollution control devices such as the EVAP system rely on manifold vacuum for proper operation. Sensors such as the Manifold Absolute Pressure (MAP) sensor turn the amount of pressure in the manifold into an electrical signal by sending a precisely controlled reference signal of 5 volts from the engine control unit (ECU) to the MAP sensor. The sensor varies its internal resistance in response to manifold vacuum; the return signal reflects the level of pressure within the manifold, which also tells us how much of a load the engine is under. Under low load conditions (high vacuum) the return signal will be low. As load increases the throttle must be opened more to maintain power, the manifold pressure will raise and the MAP signal voltage will increase. It is important to note this is the typical manner a MAP operates; some manufacturers such as Ford utilize a MAP sensor which alters the frequency of a square wave signal to communicate with the ECU. This signal is used in conjunction with other sensors such as the coolant temperature sensor for example to determine the fuel delivery and ignition requirements of the vehicle under a variety of conditions.

The fuel pressure regulator (FPR) is another example of an engine management component whose operation is linked directly to manifold pressure. Even though the FPR may not contain any electrical components it still does a good job of regulating fuel pressure in response to manifold pressure by mechanical means. Fairly simple in theory- a diaphragm or set of bellows is attached to a valve that restricts the flow of fuel when a high vacuum is applied from the intake manifold (such as at idle). As the throttle is opened and load increases, the pressure applied by the vacuum drops and a spring moves the valve open to allow higher fuel pressure under high load conditions.



Always check for cracks in vacuum hoses!

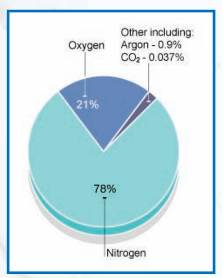
Finally- the exhaust gas return (EGR) valve may have control lines connected to the intake manifold that could become clogged with buildup which would affect operation and in extreme cases set DTC codes even though the vehicle still seems to operate normally. The EGR system, its operation and purpose will be discussed in a separate article below.

Remember- many drivability concerns can be traced back to intake manifold leakage, cracked, disconnected or otherwise faulty vacuum lines, and clogged vacuum ports on the manifold. Be sure to carefully inspect for manifold leaks and issues like these before condemning any engine management sensor as faulty.

EXHAUST GAS RECIRCULATION

EGR is the acronym for Exhaust Gas Recirculation. What does it do? If you answered "It recirculates exhaust so unburned fuel can be burned to reduce emissions." you would be half right.

The EGR mixes inert gas (exhaust) with the incoming charge to reduce combustion temperature thereby reducing oxides of nitrogen or NOX emissions as well as increase fuel economy.

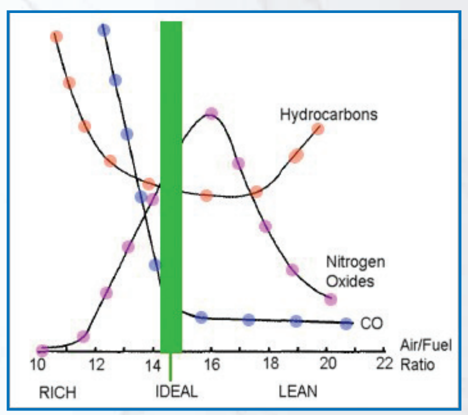


To understand the EGR we must first know that the air we breathe is only about 21% oxygen and the remaining 79% comprised of inert gas, mainly nitrogen. The popular power adder Nitrous Oxide or NO2 is approximately 66% oxygen and can make tremendous amounts of power provided additional fuel is added to maintain safe air-fuel ratios. When oxygen is burned during a combustion event, the inert gas (nitrogen) does not combust. If the combustion is too hot, the nitrogen remaining will be oxidized, or extremely scorched in simple terms. Increasing the heat of combustion will facilitate the formation of NOX (either NO or NO2) compounds. NOX emissions were previously incapable of being treated by the older 2 way catalytic convertors and fuel ratios were calibrated overly rich so the convertor could easily treat the slightly elevated CO emissions. Newer vehicles with 3 way convertors can treat reasonable levels of NOX, and as a result, air fuel ratios can be lean yielding improved fuel economy.

So let's examine EGR function. During cruise, coasting downhill, or during other light load events the vehicle requires very little or no power to maintain forward movement. The engine cannot lean out the air-fuel ratio or combustion temperatures will cause NOX emissions. If the heat of combustion is hot enough to cause the sparkplug, valves, or sharp piston edges to glow red, the incoming charge can combust and cause pre-detonation and considerable engine damage. If we inject an inert gas (exhaust) during light or no load conditions, we can displace the amount of air and fuel consumed by the vehicle, thereby increasing fuel mileage and reducing the amount of heat produced during combustion. The newest vehicles have variable displacement engines where fuel injectors are shut off to conserve fuel with no pollution penalty and valve timing configured to pose little to no pumping losses within the engine. If we mix too much exhaust with the incoming charge, the diluted mixture will never be ignited by the sparkplug and raw unburned fuel will enter the catalytic converter. An EGR that is stuck open or leaking can cause a multitude of drivability issues.

The EGR was never meant to function during heavy load, idle, or warm up and can cause drivability issues under said conditions.

Vehicles produced after 1995 that are ODB2 compliant will often have an EGR flow monitoring device that ensures optimum EGR flow and can alert of EGR leaking, clogging, or other malfunction. The diagnostic codes often lead to the exact source of the trouble. On older vehicles, the mechanic will have to rely on their troubleshooting skills and experience to diagnose EGR malfunction. Unplugging vacuum supply hoses and tapping on EGR valves to loosen a stuck pintle are simple ways to check for EGR operation. Mechanical cleanings of the ports and scheduled replacement can maintain the integrity of the EGR system, the performance of your vehicle, and the cleanliness of the air we all breathe.



AIR FILTERS - WHAT I KNOW NOW AND WHAT I DIDN'T KNOW WAY BACK WHEN

One of the things my Dad let me do as a kid was help maintain the family car. One of the not too technical jobs that he assigned to me was cleaning the air filter. For a kid, any job that involved dirt was a way cool thing to do!

Spin the wing nut off the air filter housing, remove the round filter from the housing, tap it on the fender or tire, or if you had access to compressed air (like at your local service station, back when there was service at the stations) then you blew the dirt off. Once the filter has given up as much of its collected dirt into the surrounding air, clothes, and exterior/interior of the car as possible, then you placed the filter back into the filter housing and cranked that wing nut as tight as possible. Job Done! (Except my Dad always rechecked my tightening of the wing nut after I was done).

When I first started to work with filters, I pretty much believed that my system for cleaning an air filter was the right one, and up to that time no one had ever said otherwise. Other "common knowledge" I had picked up along the way included:

1. **A clean air filter improves gas mileage,**
2. **A clean air filter does a better job of filtering,**
3. **If you could afford to, change that inexpensive air filter every time you change your oil and your engine will last longer.**

Well, I was able to let go of the old habits and bad "knowledge" I had picked up prior to joining a company that did nothing but filters.

WHY TAPPING & BLOWING OUT AIR FILTERS IS A BAD, REALLY BAD, IDEA.

First, take a look at an automotive air filter. I don't care which one, any filter you have handy will do.

IT IS NOT BUILT TO WITHSTAND A BEATING AND A HIGH PRESSURE AIR BLOW OUT!

Actually, it is built to do only a couple of things:

1. **Hold a certain amount of filtering media between the outside, incoming air, and the inside of the engine.**
2. **While holding this filtering media it is expected to seal the filtering media and the housing so that ALL of the air goes through the filtering media, and not around the seals.**
3. **It has to be strong enough to withstand the force of the air going through it up to the time it needs to be changed (really it need to go a bit further for us forgetful types, but not much).**
4. **It has to be strong enough to withstand whatever clamping forces are built into the housing, and the general automotive environment it finds itself in (vibration, heat, moisture, etc.)**

COMMON KNOWLEDGE, UNCOMMONLY WRONG!

1. A CLEAN AIR FILTER IMPROVES GAS MILEAGE

If an air filter goes WAY past its life and dirt holding capacity, this could be true, but by the time a filter gets this loaded up with dirt, bugs, leaves and other stuff, and gets really restrictive enough to affect gas mileage, the filter is just as likely to collapse, lose its seal, split the media and dump dirt down into the engine. Vehicle/engine designers usually place a maximum, upstream clean filter restriction limit that allows about 10 inches of water column restriction rise to occur before they recommend changing the filter. For most of us, city or suburban drivers on paved roads, this is 12-25,000 miles of driving. Driving in high dust or sooty environments can shorten this change time dramatically.

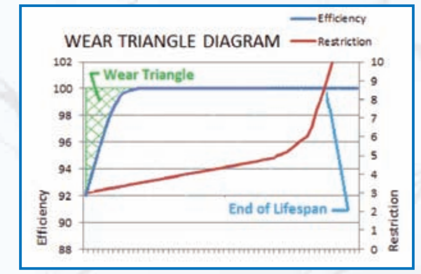
2. A CLEAN AIR FILTER DOES A BETTER JOB OF FILTERING

This is a tough myth to dispel. It took a great boss of mine (the one with the saintly patience) to go over and over it with me. He was a good teacher and knew that sometimes he had to draw me a picture before I would understand. He was smart enough to draw that picture, literally, so that even the densest newbie (me) could get it. The results, ladies and gentlemen, are simply:

AN AIR FILTER IS AT ITS WORST, STOPS THE LEAST DIRT, AND HAS THE LEAST EFFICIENCY, WHEN IT IS NEW!

Lies! You say! But, no, it's true.

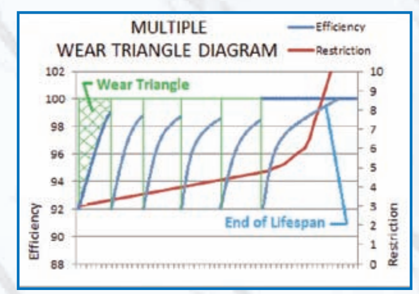
An air filter is designed to hold back the abrasive contaminants that cause harm to an engine. In doing this the filtering media is laid down in a way that the fibers form a dense overlapping pattern that allows air to pass, without too much restriction, while stopping most of the contamination particles. In order to do so without being too restrictive, passageways must exist through the media for the air to get through. These passages are small, but so is the contamination it tries to hold back. As a matter of fact the "dirt" is made up of particles of all sizes, from sub-micron to large sand particles of 50-200 microns (a micron is 1/1,000,000 (one millionth) of a meter). A single strand of hair usually has a diameter of 20 to 180 microns. Red blood cells are approximately 8 microns in diameter. Any reputable air filter will stop nearly all particles 15+ microns in size. These dirt particles are captured on the surface of the filter. But since any dirt entering the engine between 0.5 to 15 microns (the size of the moving part clearances) causes the most damage, and the passages of an air filter are in the same range, a filter that is new does less to stop dirt during this time than after it has collected a good "cake" of dust on its surface. It takes about 5-10% of a filter's dust holding capacity to build this "cake", but once there, the filter's efficiency reaches almost 100%, and since the "cake" is quite porous to air, the filter allows the needed air to get through without undue restriction. Take a look at the diagram below. The early life of a filter's efficiency curve, called the "Wear Triangle", is when most of the damaging particles of dirt that is going to get through the media does so, and as you can see the filter becomes almost a perfect filter for the rest of its useful life. The second curve on the graph shows the filter's restriction, low when it is new, and after quite a while into its lifespan, it increases to where the filter should be replaced.



And this is why a new air filter, one without a dust "cake", is much less efficient in filtration than one that has been in service for a while. It also shows that the silly kid who "whacked" the dust "cake" off, just to see the dirt fly, was not only doing potential hidden damage to the filter itself, but he was removing the one thing that made the filter most efficient. Filters do have to be replaced, yes, but using them to their full life potential lets less dust into the engine than replacing it too often. This takes us to the last "common knowledge" myth:

3. IF YOU COULD AFFORD TO, CHANGE THAT INEXPENSIVE AIR FILTER EVERY TIME YOU CHANGE YOUR OIL AND YOUR ENGINE WILL LAST LONGER.

Here is where I can show you my modification of the above illustration, one where a filter is changed every oil change rather than when its life is over. It is one I have used to pass what I know of filter change intervals to many, many others, which is what a good mentor/teacher does. If at every oil change, say at 3,000 mile intervals, a filter is changed rather that at the 15,000 miles commonly recommended today for air filter changes, the chart would look like this:



As can be seen, this poor "change the air filter every oil change" fellow never lets his car's engine get out of the Wear Triangle, continuously exposing his engine to the least efficient period of each filter's life.