

AirCare[®]

REPAIR

The Emissions Repair Advisor

Published by the British Columbia AirCare Program

2011 #2

Technician Seminars Coming in Oct. and Nov.

The AirCare program will be hosting its annual Certified Repair Industry Information Seminars in October and November.

The information sessions will cover topics that are important to all repair shops and technicians including the future of the AirCare program, technician certification and emissions diagnosis and repair issues. We will also be reviewing sample questions from a past certification exam.

...cont'd on page 10

AirCare REPAIR Goes Green

By: Dave Gourley, General Manager, PVTT

This issue, the 64th in the history of the AirCare REPAIR Newsletter will be the last hard copy version the AirCare program will print and distribute to certified shops and technicians. Beginning with the Spring 2012 issue, you will be able to view the AirCare REPAIR newsletter only through AirCare RepairNet or via email.

The decision to go strictly digital is an environmental one. With the technological ability to quickly produce and distribute AirCare REPAIR at our finger tips, to continue to print thousands of pages every year seemed wasteful and contrary to AirCare's mandate as an environmental program.

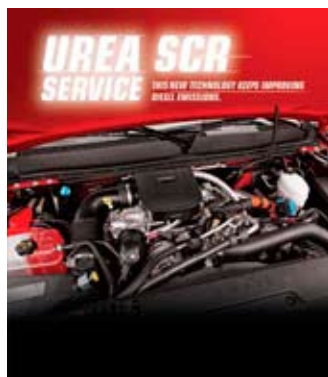
To ensure you continue to receive your copy of the AirCare REPAIR newsletter, please ensure that we have your correct email address by emailing Connie Hajdik with your current email address. She can be reached at Connie_Hajdik@translink.bc.ca.

Urea SCR Service

By Tony Martin. Reprinted with Permission.

This new technology keeps improving diesel emissions.

A new day has dawned for the diesel engine. Once known as a dirty technology, diesels are breaking free from their old reputation. Diesel emission regulations have continued to tighten over the past 20 years, and diesels now are held to the same standard as gasoline engines. Cleaner fuels have played a role in the cleanup effort, but the diesel engine itself has been transformed and has come a long way from where it was even just five years ago. These refinements in design have changed the customer's driving experience but also impacted the way we go about things in our service bays.



The 2011 Chevrolet Silverado pickup equipped with the 6.6 liter Duramax diesel uses selective catalytic reduction (SCR) as part of its emission control strategy. Note the blue DEF fill cap near the firewall. (Photo: General Motors)

...cont'd on page 2

WHAT'S INSIDE

AirCare REPAIR Goes Green.....1

Technician Seminars Coming in Oct. and Nov.1

Urea SCR Service.....1

Three Certified Shops Voted Best in Vancouver.....5

2009/2010 Operational Report Now Released.....6

Most Common OBD Trouble Codes.....7

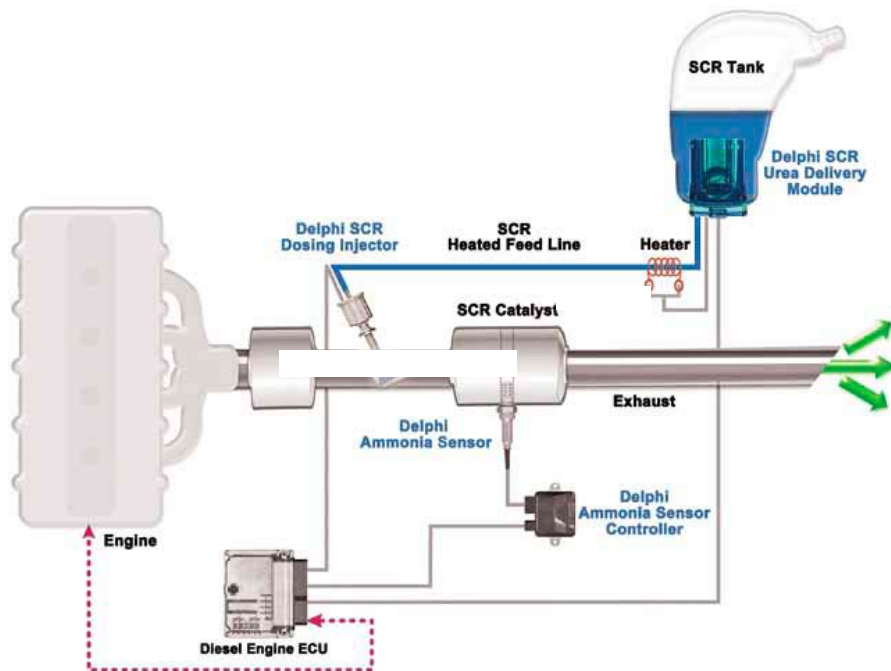
Quality Repair Awards.....8

The Analyzer: Exhaust Emissions Diagnosis: Air/Fuel Ratio vs. Converter Efficiency.....11

Urea SCR Services cont'd

Diesel engines traditionally have been “bad actors” in regard to two regulated emissions: particulate matter (PM) and oxides of nitrogen (NOx). Diesel PM is made up mostly of the black smoke that once was considered to be a status symbol, an indication that the engine was making power. NOx wasn't visible, but made your eyes and nostrils sting as it formed nitric acid in the presence of moisture. Diesels produced large amounts of both NOx and PM, which only reinforced their image as dirty workhorses. Looking back, it makes you wonder how we put up with it all those years, especially in light of where the technology is now.

Government agencies have been cracking down on PM and NOx emissions for many years, raising the bar incrementally and nudging diesel engine manufacturers toward cleaner technologies. Many changes have taken place, including limiting sulfur in diesel fuel to 500 ppm in 1993 and then 15 ppm in 2006. A major milestone was reached with the introduction of the 2007 Environmental Protection Agency (EPA) regulations that limited PM to the point where the industry had no choice but to install diesel particulate filters (DPFs) on pickups and commercial vehicles.



The Delphi SCR system uses an ammonia sensor for closed loop control of the Diesel Exhaust Fluid (DEF) injection process. The feed line to the dosing injector is heated to prevent DEF freezing in cold weather. (Photo: Delphi)

The development of the DPF made PM relatively easy to deal with, leaving NOx as the major technical challenge. At that time, most domestic diesel engine manufacturers chose to reduce NOx using in-cylinder techniques such as cooled exhaust gas recirculation (EGR). EGR acted as a heat sink in the engine cylinders, soaking up heat that otherwise caused nitrogen to combine with oxygen to form NOx. EGR also was inexpensive, certainly cheaper than aftertreatment techniques.

The 2010 EPA regulations forced everyone's hands, as now NOx was reduced to the point where in-cylinder techniques were being pushed to the limit. All on-road diesel engine manufacturers continued to use EGR, but now most adopted an aftertreatment technology called selective catalytic reduction (SCR) to meet the new NOx regulations. SCR was already being used in stationary power plants and in on-road vehicles in Japan and Europe. SCR worked very well in reducing NOx emissions.

The rub with mobile applications was that it required the customer to periodically purchase and install a somewhat exotic additive to keep the emission control system working. This was not lost on the EPA, whose main concern was if the truck ran out of the additive, it would run the same but would be out of compliance regarding NOx emissions. It took years before the EPA granted a waiver so SCR could be used in mobile applications in the U.S.

Urea SCR Service cont'd



Always look for the API Certified symbol when purchasing diesel exhaust fluid. This ensures that the DEF meets ISO 22241 standards and will maximize performance of the SCR system. (Photo: Tony Martin)



The DEF fill cap from a 2011 Duramax diesel specifies that the fluid must meet ISO 22241 standards.

SCR Technology

The basic idea behind SCR is to install a special catalyst in the diesel exhaust system, and then inject ammonia (NH_3) into the exhaust stream ahead of the catalyst. The term *selective* in SCR means that the ammonia prefers to react with the oxygen in the NO_x and not with the oxygen in the exhaust gases. NO_x molecules (NO and NO_2) that leave the engine cylinders enter the SCR catalyst along with the ammonia, where NO_x is broken up into nitrogen (N_2) and water (H_2O). Ammonia is the critical ingredient, and in the SCR reaction, it is known as a reductant because it reduces NO_x into less complex (and less harmful) components.

While ammonia works best as a reducing agent in the SCR process, it has some serious downsides in mobile applications. Ammonia is an aggressive and highly toxic fluid that requires special handling during shipment and storage.

A friendlier alternative to ammonia that works very well for mobile SCR is AUS32, or aqueous urea solution. AUS32 is non-toxic and is made up of 32.5 percent (by weight) high purity urea and 67.5 percent deionized water. In Europe, it is known as AdBlue®, while in the U.S., it is known generically as diesel exhaust fluid (DEF). So what is urea, and how is it able to take the place of ammonia in the SCR process?

Urea essentially is a nitrogen fertilizer that can be made from a number of different materials, the most common being natural gas. An aqueous urea solution will naturally decompose into ammonia and carbon dioxide, and this process takes place more rapidly with increases in temperature. Thus, urea acts as a carrier for the ammonia that is required for the SCR reaction.

When DEF is injected into the hot gases ($>400^\circ\text{F}$) in the diesel exhaust stream, ammonia is released in two different processes: thermolysis and hydrolysis. The released ammonia then flows along with NO_x molecules into the SCR catalyst where the reduction reaction takes place, preferably at temperatures between 570°F and 750°F . SCR catalysts are constructed similar to many other automotive catalysts, but they do not use precious metals. Instead, copper or iron zeolites are used as the catalyst material. Presently, copper zeolites appear to be the preferred technology for mobile applications.

DEF Challenges

A major downside of using DEF as a reductant is that it freezes at 12°F and will expand by 7 percent when frozen. While freezing does not degrade the DEF itself, the SCR system would be disabled temporarily and even could be damaged. The most vulnerable components are the DEF feed lines to the injector, which would be the first to freeze in cold weather.

Most SCR systems are designed so that either the injector or a purge valve opens and the dosing pump runs backwards during a key-off cycle in order to clear the lines. The feed lines often are insulated and use electric heat to prevent freezing during vehicle operation. The DEF tank also will have heat available to it, using either electric heaters or engine coolant lines that loop through the tank.



The 2011 Duramax diesel uses an SCR catalyst with a diesel particulate filter (DPF). In this application, the DPF is located downstream from the SCR catalyst.

Urea SCR Service *cont'd*

Some SCR systems are designed with two tanks: a larger storage tank and then a smaller active tank that supplies DEF to the injector. The large tank pumps DEF to the small tank as needed during vehicle operation, but only the small tank is heated. The idea here is that the small tank could be thawed relatively easily, bringing the SCR system online quickly after the DEF freezes. Once the vehicle is in operation, the large tank would thaw due to heat from nearby exhaust components, etc. and then would be able to continue supplying DEF to the small tank.

SCR System Service

The greater part of SCR system service will involve keeping your customer's trucks filled with high-quality DEF solution. SCR systems are calibrated to use anywhere from 1 to 5 percent of the vehicle's diesel consumption in DEF, depending on the system design and the drive cycle. Most DEF tanks are designed with enough capacity to take the vehicle to the next oil change before requiring a refill. If the vehicle is operated under moderate load conditions, it's possible that the driver could leave all DEF service to whomever is doing their scheduled service.

However, the vehicle gives the driver warnings when the DEF tank is getting low, starting around 800 miles to empty. The system will not let the driver forget about it, as the warnings get more pronounced as time goes on. If left long enough, the typical SCR vehicle will tell the driver that it is going to derate the engine if the DEF level is not increased, and then start by limiting road speed.

If the driver still doesn't get it, the vehicle either will not come off idle after a restart, or might not start at all. Regardless, the system will tell the driver that all they have to do is refill the DEF tank to make the truck run properly again. Let's say even the most stubborn operator will be trained quickly if they don't take the system seriously the first time.

So what happens if the driver puts something other than DEF (such as water) in the tank? While that might serve to get the rig started, the system is going to know in short order that you didn't put the right stuff in. The driver will be issued another warning that the DEF quality is poor and the warning cycle will be reinitiated. At this point, the driver will have to take the vehicle in for service and have the DEF tank flushed and filled with the correct solution.

If chemicals such as diesel fuel or washer fluid have been put into the DEF tank, this might require all DEF system components to be replaced. Again, it won't take more than one or two of these episodes to make the driver realize that it is easier to just leave the system alone and to keep the DEF topped up.

Your shop might see enough of these trucks that you will want to keep DEF in inventory. If so, keep a few important points in mind. First, only buy DEF that is clearly marked as API Certified, as this will ensure that you are getting a product that meets ISO 22241 standards. The DEF should be stored in and dispensed from its original container to prevent contamination. You also should keep in mind that DEF has a finite shelf life, and this gets shorter as ambient temperatures rise. DEF needs to be kept cool (under 86° F) and must be stored away from direct sunlight. It is good practice to rotate your DEF inventory as new product is brought in.

Technicians should receive some basic training on refilling DEF tanks. Emphasize the importance of putting the DEF in the correct tank, and to prevent spillage on the vehicle and themselves. Use of proper personal protective equipment (PPE) should be expressed. While DEF is non-toxic, it is a mild irritant and should be rinsed immediately with clean water if the technician gets it on their skin. It also is corrosive to aluminum and copper, so be sure to not spill it on electrical connections or other parts of the vehicle.



The DEF injector is located upstream from the SCR



The 2011 Duramax SCR system is monitored using two NOx sensors. This photo shows the second sensor that is located between the SCR catalyst and the DPF.

Urea SCR Service *cont'd*

Parting Thoughts

SCR systems are new in the U.S., but like any new technology they represent an opportunity to expand your customer base and increase revenue. If you keep an open mind, simple filling of DEF tanks could mark the beginning of a move into the profitable world of diesel engine repair.

Tony Martin is an associate professor of automotive technology at the University of Alaska Southeast in Juneau, Alaska. He holds Canadian Interprovincial status as a Journeyman Heavy Duty Equipment Mechanic. He also has 19 ASE certifications, including CMAT, CTT, L1 and L2.

COPYRIGHT NOTICE: "Reprinted with permission from Motor Age, Vol. # 130, Issue # 5, May 2011, Motor Age is a copyrighted publication of Advanstar Communications Inc. All rights reserved."

A DIFFERENT FREEZE FRAME

DEF Freeze Frame

DIESEL EXHAUST fluid is made up of 32.5 percent urea and 67.5 percent deionized water (by weight). When mixed at this ratio, urea and water will freeze and thaw at the same rate. This ensures that the DEF will not become dilute or over concentrated as it thaws. SCR systems are calibrated for DEF that is mixed at this concentration, and their onboard diagnostics can detect changes that affect NOx conversion efficiency in the SCR catalyst. It also is important to note that DEF is made from high purity urea in order to meet ISO 22241 standards. Ordinary fertilizer-grade urea contains many trace minerals, etc. that could damage the SCR catalyst.

A Different Freeze Frame

Three Certified Shops Voted Best of Vancouver

Three AirCare Certified Shops were voted the Best of Vancouver by customers and Vancouver residents in the Georgia Straight's 16th annual survey of the best that the city has to offer.

In the annual survey, readers voted for the best businesses and services in over 200 categories including best local TV anchor, shoe store, neighbourhood and weekend getaway. In the category of 'Best Auto Service (Independent)', the top three spots were all filled by AirCare Certified Repair Centres. The top three shops are:

- Pawlik Automotive - 30-966 Southwest Marine Drive
- Tremblay Motors - 1505 West 3rd Avenue
- Auto Repairs R Wee - 1115 Kingsway Vancouver

Please join us in congratulating these shops for this outstanding recognition. For more information about the Georgia Straight's Best of Vancouver annual survey, go to www.straight.com/bov/category/2011/54

2009/2010 Operational Report Now Released

Since 2001, when biennial testing was introduced for 1992-and-newer model year vehicles, it has been customary to publish a report documenting the results pertaining to each two-year inspection cycle. The analysis of the fifth biennial cycle, covering calendar years 2009 and 2010, has just been completed and a full report has been posted on the AirCare website.

The tables below show the key operating stats for the two calendar years.

Summary of Inspection Data in 2009 and 2010

	2009	2010
Inspections Performed	498,316	533,599
Vehicles Inspected	423,111	459,388
Failed Test for all Reasons Combined (Vehicles)	65,948 (49,018)	61,517 (46,663)
Failed Test for Emissions Only (Vehicles)	52,519 (36,435)	45,733 (31,726)
Tested According to OBD II (Vehicles)	181,755 (166,447)	252,050 (233,064)
Failed OBDII (Vehicles)	9,472 (8,812)	12,134 (11,433)
Tested According to IM240 Test (Vehicles)	158,730 (131,404)	147,892 (122,407)
Failed IM240 Test (Vehicles)	27,639 (18,921)	25,777 (17,893)
Tested According to ASM/Idle Test (Vehicles)	138,842 (113,524)	110,829 (90,946)
Failed ASM/Idle Test (Vehicles)	27,435 (20,273)	22,219 (16,336)
Tested Idle-Only Test (Vehicles)	4,210 (3,143)	4,467 (3,245)
Failed Idle-Only Test (Vehicles)	1,148 (782)	1,147 (753)
Diesel Vehicles Inspected (Vehicles)	8,072 (7,734)	9,245 (8,877)
Failed Diesel Opacity Inspection (Vehicles)	249 (207)	233 (207)
Unloaded Diesel Opacity Inspection (Vehicles)	889 (859)	874 (849)
Failed Unloaded Diesel Opacity Inspection (Vehicles)	5 (4)	7 (7)

Summary of Ancillary Tests for 2009 and 2010

	2009	2010
Gas Cap Tests Conducted	216,340	183,125
Failed Gas Cap Pressure Test	8,266	7,697
Failed Gas Cap Pressure Test (% Fail)	3.82%	4.20%
Failed Catalytic Converter Pressure Test (% Fail)	0.05%	0.03%
Catalytic Converter Advisories (1987-and-Older Only in %)	3.68%	3.47%

For a full explanation of the results and a calculation of the effectiveness of the program, go to aircare.ca and click the "News and Publications" banner, followed by "Reports".

By the way, did you know that since the program started back in 1992, more than 2.4 million different vehicles have been tested at least once and more than 900,000 of them have failed at some point? That's more than 38%! It may take a few years, but that one-millionth failing vehicle will happen.

Happy reading.

Most Common OBD Trouble Codes

(Excerpt from the 2009-2010 AirCare Program Operational Report)

There are thousands of different diagnostic trouble codes (DTCs) that can be set by the OBD system and any one of them can result in the MIL being illuminated. However, some codes are much less common than others. In fact, in the two-year period covered by this report, a total of only 269 different generic codes have been observed. Table 8 shows the 20 most common DTCs that have been observed in this period for gasoline vehicles arriving for their initial inspection.

Overall, 89% of OBD failures had one of the Top 20 codes set, and 68% had one of the Top 10 codes set. But we can go even further by looking at what the DTCs are for. The two most common codes are P0171 and P0174, which are for System Too Lean Bank 1 and Bank 2 respectively. Between them, we see that 22% of all the gasoline vehicles that had the MIL commanded ON were indicating lean operation. This is consistent with the previous reporting period (2007-2008). The other codes in the Top 10 and Top 20 are equally consistent. They are typically for Catalyst Efficiency, EGR operation, O₂ sensor problems, Misfires and Evaporative system problems.

It has also been observed that more than half of the vehicles that have the MIL commanded ON, have only one DTC, and there are very few that have more than two. Therefore, although in principle, the OBD system is capable of indicating thousands of different problem conditions and combinations of problems, in reality, the number of problems actually encountered is relatively limited.

Table 8. Most Common Trouble Codes where MIL Commanded ON in 2009 and 2010 Combined

DTC	Number	Description	% of Total
P0171	3052	System Too Lean (Bank 1)	13%
P0174	2203	System Too Lean (Bank 2)	9%
P0401	2101	Exhaust Gas Recirculation Flow Insufficient Detected	9%
P0420	1795	Catalyst System Efficiency Below Threshold	8%
P0442	1214	Evaporative Emission System Leak Detected (small leak)	5%
P0135	1202	O2 Sensor Heater Circuit	5%
P0440	1172	Evaporative Emission System	5%
P0455	1139	Evaporative Emission System Leak Detected (large leak)	5%
P0300	1008	Random/Multiple Cylinder Misfire Detected	4%
P0141	925	O2 Sensor Heater Circuit	4%
15,811		Total top 10 codes	68%
P0301	617	Cylinder 1 Misfire Detected	3%
P0446	554	Evaporative Emission System Vent Control Circuit	2%
P0302	541	Cylinder 2 Misfire Detected	2%
P0304	538	Cylinder 4 Misfire Detected	2%
P0303	468	Cylinder 3 Misfire Detected	2%
P0325	428	Knock Sensor 1 Circuit	2%
P0441	428	Evaporative Emission System Incorrect Purge Flow	2%
P0172	398	System Too Rich	2%
P0138	397	O2 Sensor Circuit High Voltage	2%
P0133	377	O2 Sensor Circuit Slow Response	2%
20,557		Total top 20 codes	89%
23,197		Total number initial Gasoline with MIL commanded ON	100%

QUALITY REPAIR AWARDS

Quality Repair Award winners for the 12 month period from April 1, 2010 to March 31, 2011



Carl J. Bier
Broadway Motors
Chilliwack
(1st time winner)



Byron Chong
Velocity Auto Works
Burnaby
(1st time winner)



David D. China
Mastercare Automotive
Surrey
(1st time winner)



Haigo Mardikian
Hi-Tech Automotive
North Vancouver
(5-time winner)



Bernhard Otto Pawlik
Pawlik Automotive
Vancouver
(1st time winner)



Aaron Siemens
Gerry's Auto
Abbotsford
(1st time winner)



Miro Vavruska
Cloverdale Service
Cloverdale
(8-time winner)

QRA CRITERIA

- Minimum number of repairs = annual industry median number of repairs for the same period
- Initial re-inspection success rate = 95% or higher
- REI of 8.2 or higher

...cont'd on page 9

Quality Repair Awards *cont'd*

Quality Repair Award winners for the 12 month period from September 1, 2010 to August 31, 2011



Carl J. Bier
Broadway Motors
Chilliwack
(2-time winner)



Byron Chong
Velocity Auto Works
Burnaby
(2-time winner)



Eugene Eng
Morrey Nissan
Burnaby
(3-time winner)



Bert John Gansekoele
Visscher Auto Repair
Surrey
(2-time winner)



Andrew R. Hudson
Hudson Automotive
Langley
(2-time winner)



Haigo Mardikian
Hi-Tech Automotive
North Vancouver
(6-time winner)



Steven Scott Montgomery
Bruno Automotive Inc.
North Vancouver
(1st time winner)



Bernhard Otto Pawlik
Pawlik Automotive
Vancouver
(2-time winner)



Richard John Payne
Fountain Tire
Surrey
(1st time winner)

Miro Vavruska
Cloverdale Service
Cloverdale
(9-time winner)

Tech Seminars Coming in Oct. and Nov. *cont'd*

The presentations will be followed by a Question & Answer period. Sandwiches and refreshments will be provided.

If you attend one of these sessions, your name will be entered into a draw for a chance to win some great prizes, including tickets to a future Vancouver Canucks game. You must be registered and in attendance to qualify for the draw. The sessions will be held on:

Date	Location	Room
Monday, October 24	UFV (Abbotsford Campus)	Rm. B121
Thursday, October 27	BCIT (Burnaby Campus)	Telus Theatre (SE6)
Tuesday, November 8	Sheraton Vancouver Guildford Hotel (Surrey)	Green Timbers Room

The sessions will run from 7 pm to 9 pm. Please arrive at 6:30 pm to register. This is a great opportunity for technicians and owners/managers to share any concerns or issues with AirCare staff. These information sessions are open to all AirCare Certified Repair Centre owners and technicians.

To reserve your seat, contact Connie Hajdik at 604-453-5152. Seating is limited. For more information or to get a map for each location, visit repairnet.aircare.ca.

The AirCare Repair is a bi-annual publication of the British Columbia AirCare Program:
208 - 6741 Cariboo Road
Burnaby, BC V3N 4A3

Technical Editor:

Ron Leavitt
Emissions Technical Advisor,
Pacific Vehicle Testing Technologies

Edit & Layout:

Rashpal Rai
Manager, Public Relations
Envirotest Canada

AirCare Phone Numbers:

Main Phone:
604-435-SMOG (7664)

Main Fax:
604-453-5150

Tech Line:
604-453-5163

Certification:
604-453-5152

RepairNet Help:
604-453-5165

Policy:
604-453-5165

The ANALYZER

Published by the British Columbia AirCare Program

2011 #2

Exhaust Emissions Diagnosis - Air/Fuel Ratio vs. Converter Efficiency

By Brad Coupland, Emissions Testing Specialist, PVTT

Virtually all AirCare technicians have seen an air-fuel ratio chart in one form or another (see Figure 1). Most technicians can easily identify which line represents each of the five gases at a glance, but understanding how to use this information when diagnosing an emissions failure still seems to be a challenge for some technicians.

To address this, let's review the characteristics of each gas and, more importantly, let's see how the air/fuel ratio chart can be used when diagnosing emissions failures by analyzing some actual case studies that put the use of an air/fuel ratio chart into practice.

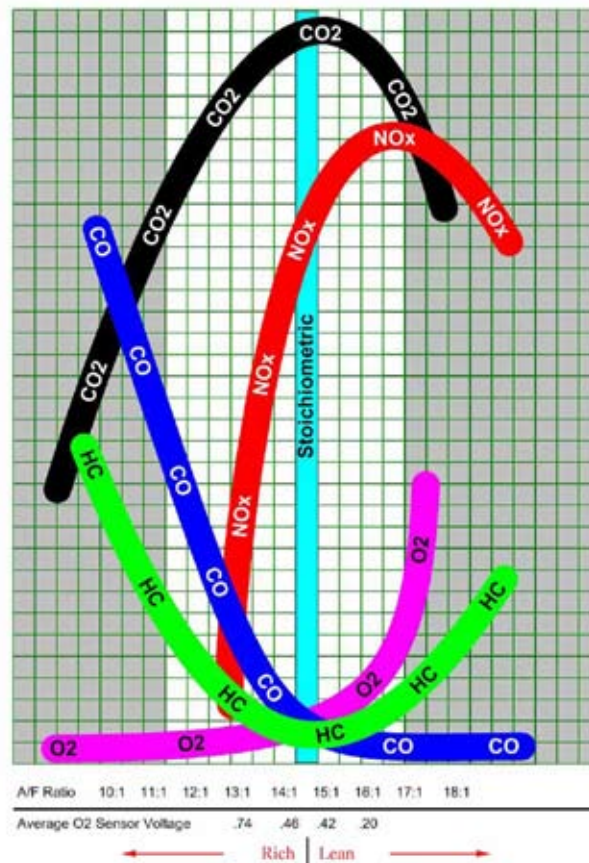


Figure 1: This air/fuel ratio chart shows the relationship of the five exhaust gases emitted from gasoline-fuelled engines for all air/fuel ratios. It also includes the O₂ sensor voltages corresponding to various air/fuel ratios. At stoichiometric (14.7:1 A/F ratio), a Zirconia O₂ sensor's voltage output is .45 volts!

...cont'd on page 12

Exhaust Emissions Diagnosis *cont'd*

Now let's examine the composition of exhaust gases for rich and lean mixtures, as well as at the chemically correct, stoichiometric air/fuel ratio.

Carbon Monoxide – The Rich Indicator

One can easily observe that as the air/fuel ratio becomes richer than stoichiometric, Carbon Monoxide (CO) increases significantly (see Figure 2). This is the only one of the five gases that behaves in this manner, and therefore, is an excellent indicator of a rich air/fuel mixture. At the stoichiometric air/fuel ratio, the engine-out level of CO will be about .45%! However, you will also notice that as the air/fuel ratio becomes leaner than stoichiometric, the CO chart more or less flattens out. CO is a great indicator of a rich air/fuel ratio, but it is not a good indicator of lean air/fuel mixtures.

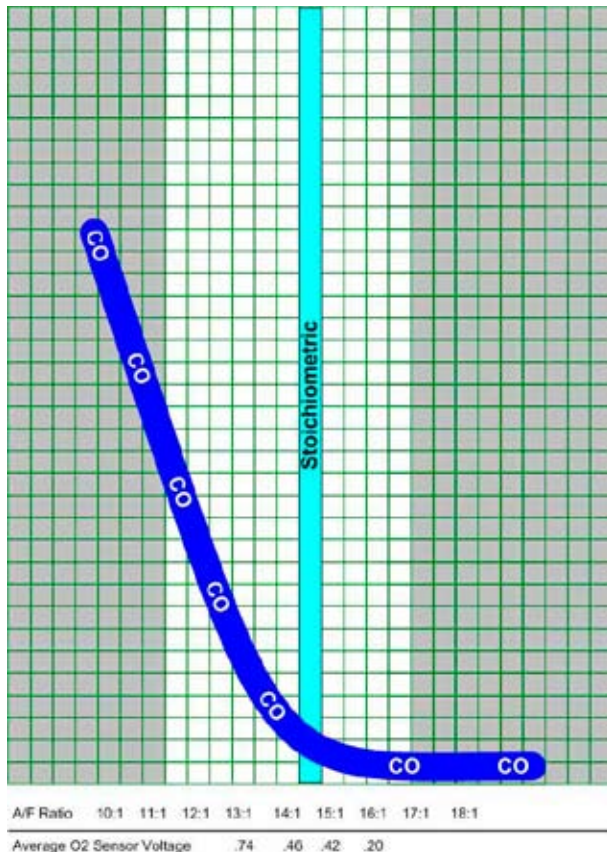


Figure 2: CO vs. air/fuel ratio

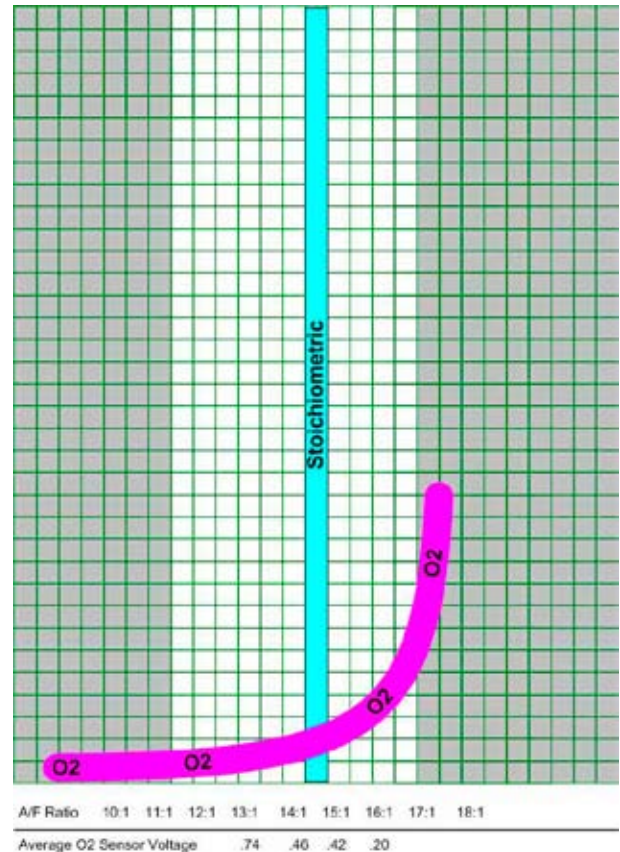


Figure 3: O₂ vs. air/fuel ratio

Oxygen – The Lean Indicator

Now let's look at the oxygen (O₂) level in combustion gases (see Figure 3). At air/fuel ratios richer than stoichiometric, there is very little oxygen left over from combustion. This is because the engine consumed all of the oxygen it ingested to burn the excess fuel present when the air/fuel mixture is richer than stoichiometric. When the air/fuel ratio is leaner than stoichiometric, note how the O₂ increases significantly! This makes oxygen an excellent indicator of lean air/fuel ratios. At the stoichiometric point, the oxygen concentration will also be very similar to the CO concentration at approximately .5 %.

It is extremely important when evaluating oxygen levels (or any gas for that matter) to ensure your sample is not diluted due to exhaust leaks, that your sample point is leak proof and that your analyzer has been calibrated and leak checked. Don't waste valuable time tracking down a lean air/fuel ratio only to discover you had a leak in your sample system! Your analyzer's oxygen sensor should be replaced as per its maintenance schedule to ensure accurate oxygen and air/fuel ratio measurements!

Exhaust Emissions Diagnosis *cont'd*

Carbon Monoxide and Oxygen – A Balancing Act

At the stoichiometric air/fuel ratio, CO and O₂ will be approximately .5%, but this is for perfect combustion and, in practice, technicians will encounter vehicles that may be less than perfect.

As a vehicle ages, some deterioration occurs in the engine mechanical condition (cylinder and valve sealing), gaskets and hoses (vacuum leaks) and perhaps fuel injector condition (spray pattern, deposits etc.). This may result in engine-out levels of oxygen increasing above the ideal of .5%. As the exhaust gases pass by the oxygen sensor(s), the excess oxygen will be reported to the vehicle's Powertrain Control Module (PCM) and additional fuel will be injected. When a vehicle is in closed loop, the PCM will try to maintain CO and O₂ levels at near equal levels.

If the engine-out concentrations of oxygen have increased slightly due to any of the previously mentioned issues, the CO level will also increase when the vehicle is in closed loop. As previously mentioned, the engine-out CO level with a stoichiometric air/fuel ratio will be .45%, but if the engine has slightly elevated engine-out O₂ levels, we will see the engine-out CO level increase as well. Typically .45 - .7% CO is a normal range for higher mileage vehicles. Engine-out oxygen levels are typically within .2 - .3% of engine-out CO levels when a vehicle is in fuel control. Oxygen levels in excess of 1% pre-catalytic converter, will drastically affect the reduction efficiency of a Three-way Catalyst (TWC).

Carbon Dioxide – The Efficiency Indicator

If combustion was perfect, all of the air and fuel ingested by the engine would be converted to Carbon Dioxide (CO₂) and water vapour (H₂O). Even though combustion is never perfect, when an engine is running as designed, CO₂ is always the most abundant constituent of the exhaust gases by mass or concentrations. As you can easily see from the CO₂ gas chart (see Figure 4), CO₂ peaks near the stoichiometric air/fuel ratio. Typical engine-out levels of CO₂ are 13.5 - 14.5%. Tailpipe levels of CO₂ on catalytic converter equipped vehicles should generally be over 15%. You should also notice that on the rich side of stoichiometric, CO and CO₂ emissions trend inversely. As CO emissions increase, CO₂ emissions will decrease. It is also noteworthy that the sum of CO and CO₂ is approximately 15.5% in an undiluted exhaust sample.

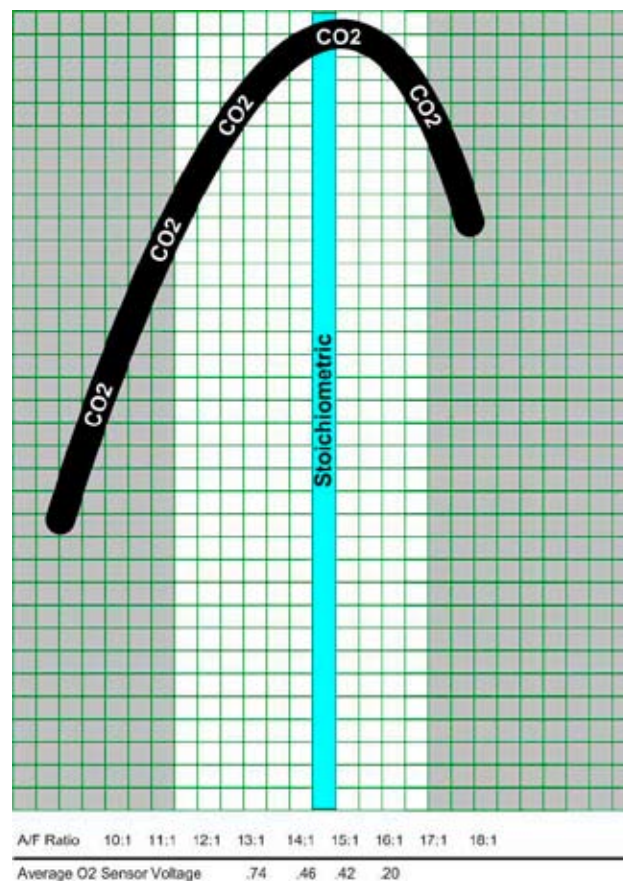


Figure 4: CO₂ vs. air/fuel ratio

...cont'd on page 14

Exhaust Emissions Diagnosis *cont'd*

Hydrocarbons – The Unburnt Fuel Indicator

All motor fuels consist of various hydrocarbon chains. If combustion was perfect, they would all be consumed during the combustion process. But as it is never perfect, there will always be some hydrocarbons (HC) present in the exhaust gases, albeit very small concentrations on late model vehicles. There can be several sources of excess hydrocarbons in the exhaust gases. Cylinder sealing, especially exhaust valve leakage, ignition system defects and EGR dilution are just a few areas that can contribute to elevated HC levels. With regard to an air/fuel ratio chart, you will notice that HC levels are at their lowest when the mixture is at stoichiometric (see Figure 5), but increase significantly as the mixture goes rich or lean from ideal.

It's very easy to see that a mixture that is too rich or too lean will cause a vehicle's HC emissions to be higher than normal. In fact, one of the most common complaints we hear is from the owners of carburettor-equipped vehicles with HC emission failures. Often we receive calls where the customer states "my mechanic leaned the crap out of it and now it's failing worse than ever". And that's exactly what will happen when the vehicle is leaned to the point of misfire. Hydrocarbon emissions alone are not an indicator of any specific problem area, only an indication of excess unburnt fuel present in the exhaust gas stream. Incorrect air-fuel mixture (rich or lean), engine mechanical condition, ignition defects, induction leaks, incorrect EGR flow are all potential sources of high HC emissions. Normal engine-out levels of HC are typically 200 ppm or less.

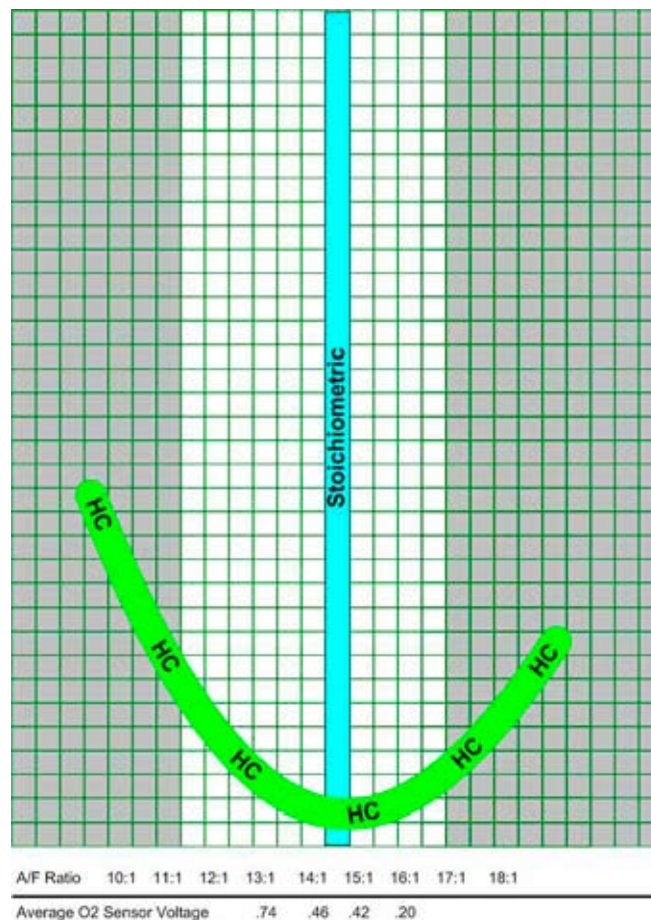


Figure 5: HC vs. air/fuel ratio

Exhaust Emissions Diagnosis *cont'd*

Nitrogen Oxides Chart

The NOx line of an air/fuel ratio chart, like the HC chart, is not an indicator of a specific problem. You will notice that NOx gases are at their highest level, slightly lean of stoichiometric, typically around an air/fuel ratio of 16.5:1 (see Figure 6 on page 8). Ensuring a stoichiometric mixture is critical to controlling NOx gases. This is because the catalytic converter provides the vast majority of NOx reduction on vehicles with electronic fuel control and as you will see in the catalyst efficiency chart (see Figure 7 on page 9), the converter's ability to reduce NOx is greatly affected by lean air/fuel ratios.

NOx production is also influenced by high combustion pressures and temperatures. Ensuring the ignition timing is at specification and the advance functions of the distributor, if equipped, are working correctly is also key to keeping NOx emissions controlled.

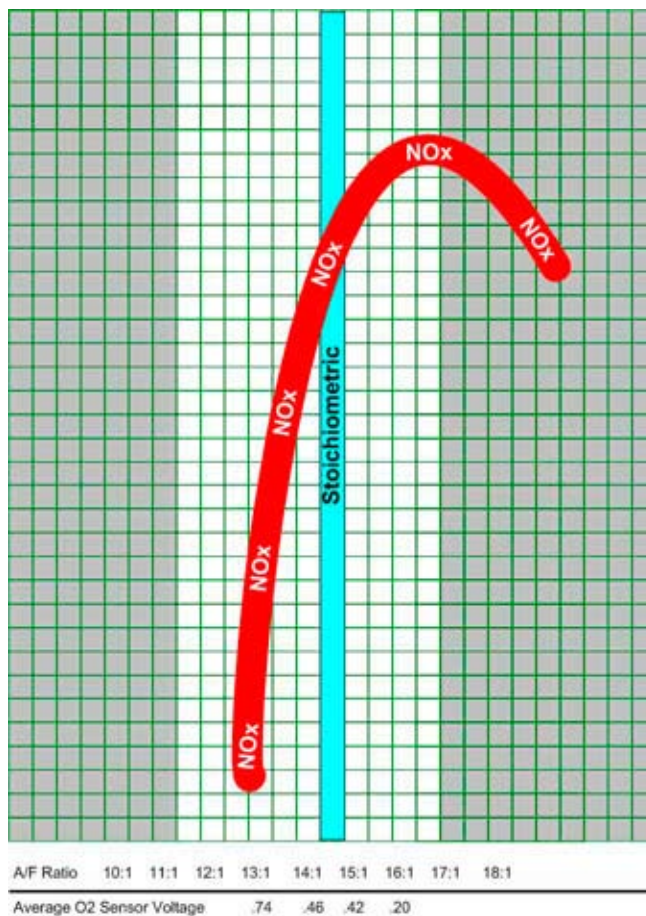


Figure 6: NOx vs. air/fuel ratio

Anything that can affect cylinder temperature and pressure can affect NOx levels. Combustion chamber deposits can raise cylinder pressures and contribute to high NOx levels. A vehicle that audibly pings or detonates will typically have sky high NOx emissions.

At times, technicians may attribute excessive NOx levels to higher than normal coolant or intake air temperatures. While these may have some small effect, in practice, we seldom observe any appreciable NOx reductions from cooling system or intake air ducting repairs. Remember, NOx is generated under high internal cylinder temperatures and pressures (>2500 ° F). Reducing the cooling system's operating temperature by a few degrees will have very little impact on the in-cylinder combustion temperature. NOx emissions higher than 1000 ppm for TWC-equipped vehicles or 1800 ppm for pre-TWC or non-catalyst vehicles are abnormal.

Exhaust Emissions Diagnosis *cont'd*

Catalytic Converter Efficiency vs. Air/Fuel Ratio

The catalytic converter has been the most important emission control system on vehicles for some time. Virtually all gasoline fuelled vehicles since 1988 have closed loop fuel control and TWC(s). For a catalytic converter to work optimally, the air/fuel ratio must be at the stoichiometric ratio for gasoline of 14.7:1 by mass ($\text{Lambda}=1$). An OE catalytic converter will be over 95% efficient for all three regulated emissions when the air/fuel mixture is at stoichiometric (see Figure 7 on page 9). For an IM240 inspection, the vehicle's catalytic converter(s) should be 90% efficient, and approximately 80% efficient for vehicles that will receive an ASM inspection. The transient nature of an IM240 inspection increases the demands on the catalyst, therefore the catalytic converter's efficiency requirement is higher.

A three-way catalytic converter cannot arbitrarily decide which gases it will treat. If a vehicle fails for NO_x emissions with HC and CO readings that are excellent, this cannot be a defective catalytic converter. A vehicle that has high CO and HC emissions and low NO_x emissions cannot be attributed to a faulty catalytic converter. These scenarios are caused by a vehicle not operating at stoichiometric air/fuel mixtures and thereby, adversely affecting the efficiency of the catalytic converter. Let's have a look at catalytic converter efficiency versus air/fuel ratio chart.

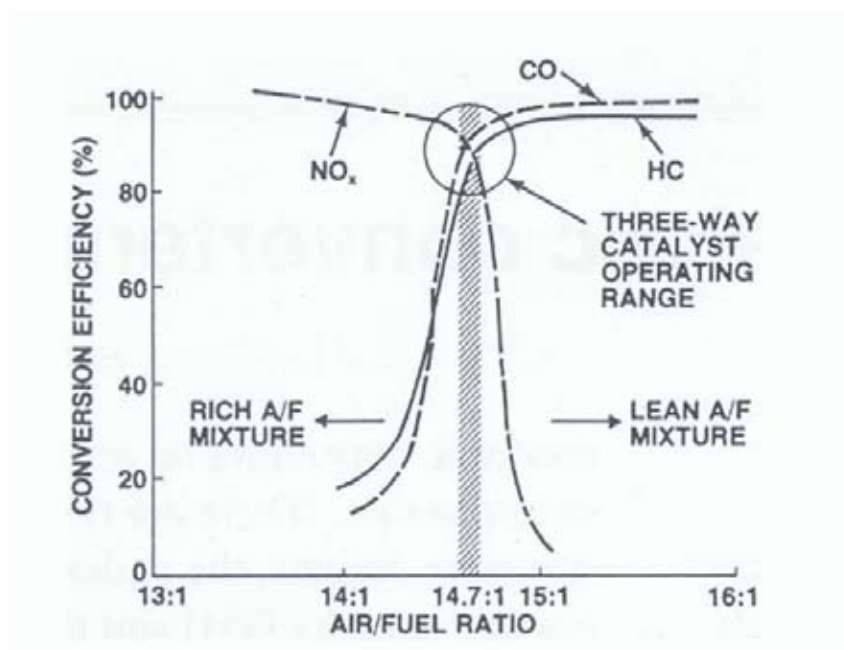


Figure 7: Catalytic Converter efficiency vs. air/fuel ratio

Figure 7 clearly indicates that when the air/fuel ratio is at stoichiometric, a catalytic converter's efficiency is well over 90%. If the air/fuel ratio shifts slightly lean to 15:1 ($\text{lambda}=1.027$), the catalytic converter's NO_x efficiency drops to below 20%! At the same time HC and CO efficiency increases. This is because the oxygen content of the catalytic converter's feed gas has increased. The excess oxygen from the slightly leaner than stoichiometric mixture promotes the oxidation of HC and CO and conversely, diminishes the catalyst's ability to reduce NO_x emissions. When the air/fuel ratio is slightly rich of stoichiometric, the HC and CO efficiency drops quickly as there is now too little oxygen to oxidize the HC and CO. At an air/fuel mixture of 14.4:1 ($\text{Lambda}=.979$), HC and CO conversion efficiency has dropped to less than 40%!

These rules are true of high quality catalytic converters. Low quality catalytic converters may never achieve these levels of efficiency even with a stoichiometric mixture. Luckily, there are some excellent quality aftermarket catalytic converters that are over 90% efficient, and at the same time, are competitively priced!

Exhaust Emissions Diagnosis *cont'd*

Case Studies – Putting the Air/Fuel Ratio Chart into Practice

Let's look at three 1991 and older vehicles which received Acceleration Simulation Mode (ASM) inspections as their AirCare inspection. We'll use the vehicle's second-by-second data and our knowledge of the air/fuel ratio chart to quickly determine if there is an imbalance with the fuel mixture and how this may affect the performance of the vehicle's catalytic converter.

ASM and Idle HC & CO Failure – A Rich Condition

Description: 1990 PONT 6000		Current AirCare Standards for this Vehicle										
Engine:	3.1 L	ASM HC Standard:	90 ppm									
Fuel Type:	G	ASM CO Standard:	0.76 percent									
Vehicle Type:	P	ASM NOx Standard:	1117 ppm									
		Idle HC Standard:	101 ppm									
		Idle CO Standard:	0.74 percent									

Date/Time	Odometer (000's)	ASM HC	ASM CO	ASM NOx	Idle HC	Idle CO	Idle CO2	Idle O2	Gas Cap	Overall Result	Detailed Data
2011-02-08 11:55:35	198	235	6.39	2	510	9.99	6.32	4.50	P	F	

Second Of Test	Speed (km/hr)	Hydrocarbons (ppm)	Carbon Monoxide (%)	Oxides of Nitrogen (ppm)	Carbon Dioxide (%)	Oxygen (%)
80	39.8	235	6.39	0	9.85	0.13
81	39.8	234	6.41	0	9.90	0.11
82	39.9	233	6.36	3	9.90	0.09
83	39.9	233	6.37	2	9.81	0.09
84	39.9	235	6.41	2	9.81	0.10
85	39.9	236	6.40	2	9.84	0.06
86	39.9	236	6.40	3	9.84	0.04
87	39.9	235	6.40	0	9.82	0.04
88	39.9	235	6.39	3	9.83	0.06
89	39.9	237	6.35	0	9.83	0.07
90	40.0	374	6.30	0	9.60	0.02

Figure 8: AirCare inspection result and final 10 seconds of test from RepairNet's Second-by-Second data for this ASM test

As you can easily see from figure 8, this vehicle has very high CO and HC emissions and at the same time the oxygen levels are very near zero. NOx emission and CO2 levels are also lower than what they should be for a vehicle operating in closed loop. Using our air/fuel ratio chart there can only be one scenario that can cause this: an air/fuel ratio richer than stoichiometric! If you were to attempt to determine the catalytic converter's efficiency under these conditions, the results would be misleading. You would find that the converter was not reducing the HC or CO emissions at all. But this is not because the converter is defective! It is because there is no oxygen left over from combustion to allow the converter to promote oxidation. The low oxygen content is good for NOx reduction and contributes to the extremely low NOx readings seen here. In fact, in many instances, repairing the over-fueling condition will bring a catalytic converter back to life! You will need to correct the over-fueling condition and then re-evaluate the efficiency of the catalytic converter once the vehicle is operating in closed loop again.

Exhaust Emissions Diagnosis *cont'd*

ASM NOx Failure – A Lean Condition



Figure 9: AirCare inspection history and last 20 seconds from RepairNet's Second-by-Second data for this ASM test

The second-by-second data in figure 9 indicate that the HC levels are low and CO is zero. The NOx levels are obviously excessive as it is failing for NOx. The oxygen level is a dead giveaway for this diagnosis. With tailpipe oxygen levels averaging near 2.5%, this vehicle appears to be lean. Remember, if the vehicle is in proper fuel control, CO and O2 should be approximately .5% and O2 pre-cat must be below 1%! The main reason this vehicle has failed is not because the lean air/fuel ratio has increased the levels of NOx emitted from the engine, but the excessive oxygen left over from combustion has adversely affected the three-way catalytic converter's ability to reduce NOx (see figure 7). The extra oxygen also increases the catalyst's oxidation efficiency as well as diluting the tailpipe CO2 concentrations. This could also be caused by a significant exhaust leak upstream of the catalytic converter or from a defect in the Pulse AIR system keeping the AIR upstream of the cat during driving conditions.

Exhaust Emissions Diagnosis *cont'd*

ASM NOx Failure - Defective Catalytic Converter

Description: 1990 VOLK Jetta		Current AirCare Standards for this Vehicle									
Engine:	1.8 L	ASM HC Standard:	94 ppm	ASM CO Standard:	0.93 percent	ASM NOx Standard:	1339 ppm	Idle HC Standard:	114 ppm	Idle CO Standard:	0.89 percent
Fuel Type:	G										
Vehicle Type:	P										

Date/Time	Odometer (000's)	ASM HC	ASM CO	ASM NOx	Idle HC	Idle CO	Idle CO2	Idle O2	Gas Cap	Overall Result	Detailed Data
2011-02-22 16:04:20	373	47	0.37	1515	26	0.00	13.48	1.87	P	F	

Second Of Test	Speed (km/hr)	Hydrocarbons (ppm)	Carbon Monoxide (%)	Oxides of Nitrogen (ppm)	Carbon Dioxide (%)	Oxygen (%)
5	40.1	79	0.54	1758	14.47	3.38
6	39.8	75	0.51	1754	14.42	2.08
7	39.5	73	0.48	1750	14.39	1.00
8	39.4	71	0.48	1728	14.41	0.79
9	39.2	64	0.46	1684	14.39	0.64
10	39.1	62	0.43	1676	14.47	0.55
11	39.1	58	0.39	1647	14.51	0.53
12	39.1	57	0.38	1676	14.52	0.48
13	39.1	57	0.39	1684	14.66	0.44
14	39.2	55	0.40	1687	14.60	0.45
15	39.4	56	0.42	1673	14.72	0.39
16	39.6	54	0.41	1653	14.63	0.40
17	39.8	52	0.39	1689	14.67	0.39
18	40.0	52	0.39	1702	14.66	0.35
19	40.1	50	0.37	1682	14.69	0.38
20	40.2	50	0.36	1661	14.70	0.36
21	40.3	50	0.36	1644	14.64	0.32
22	40.4	48	0.36	1648	14.72	0.36
23	40.5	48	0.35	1642	14.67	0.29
24	40.6	51	0.36	1654	15.12	0.32
25	40.7	47	0.36	1618	14.71	0.31
26	40.7	48	0.39	1669	14.71	0.28

Figure 10: AirCare inspection result and 22-second extract from RepairNet's Second-by-Second data for this ASM test

Looking at the second by second data in figure 10 provides several clues as to the root cause of this vehicle's high NOx emissions. As the test progresses, HC, CO and NOx are all trending downward, a typical observation for a defective catalytic converter. The key here is the vehicle's carbon monoxide level. As we saw in our CO chart, engine-out CO is approximately .5 % when operating in closed loop. The CO at second 5 is .54%, a typical engine out value. The average CO for the last five seconds of test time used for this example is .36 %. This suggests a catalytic converter efficiency of only 33% (Gas in – Gas out / Gas in X 100).

A quick road test to confirm closed loop fuel control and you have very quickly determined the root cause of this vehicle's NOx failure. Replacement of the catalytic converter with a high quality replacement unit allowed this vehicle to pass easily without exceeding the \$500 Repair Cost Limit for this model year vehicle.

Exhaust Emissions Diagnosis *cont'd*

Using an Air/Fuel Ratio Chart and SBS Data as an Aid for IM240 Failure Diagnosis

Below is the speed vs. time plot for the IM240 test (see figure 11). You can see that there are 2 low-speed cruise sections where the same principle for an ASM inspection can be used to determine the air-fuel ratio, and condition of the catalytic converter(s).

The first cruise is at approximately 50 kph and occurs between seconds 56 and 80. The second cruise is at 40 kph and occurs between seconds 140 and 159. The vehicle should be in closed loop during both of these operating conditions. Engine-out CO should be around .5% and tailpipe CO should be very close to zero.

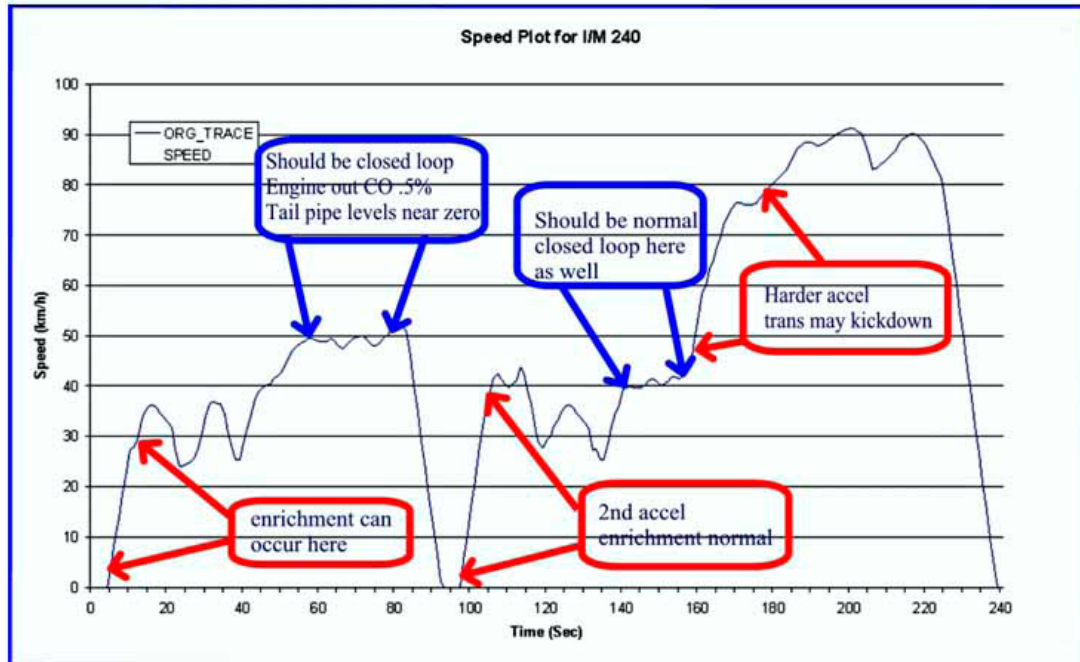


Figure 11: IM240 speed plot illustrating closed loop cruising conditions and enrichment periods

The second-by-second data available on RepairNet, converts the mass emissions measurements to concentrations, in units of percent and parts per million. This allows you to apply the same methods discussed earlier for ASM diagnosis to the transient IM240 cycle. Due to the nature of the sampling system used for IM240 inspections, the Constant Volume Sampling (CVS) does not directly measure oxygen content of the exhaust gases. The oxygen content of the exhaust provided on RepairNet is derived from a mathematical formula to approximate tailpipe levels.

Let's look at three IM240 inspection case studies and see how easily an air/fuel ratio chart and RepairNet's second-by-second data can provide valuable insight as to the likely cause of an IM240 emissions failure.

Exhaust Emissions Diagnosis *cont'd*

IM240 HC & CO Failure – A Rich Condition

Here is an example of an IM240 HC and CO failure. Let's use RepairNet's second by second data and the air/fuel ratio chart to determine which direction we need to go to diagnose this vehicle's emissions failure.

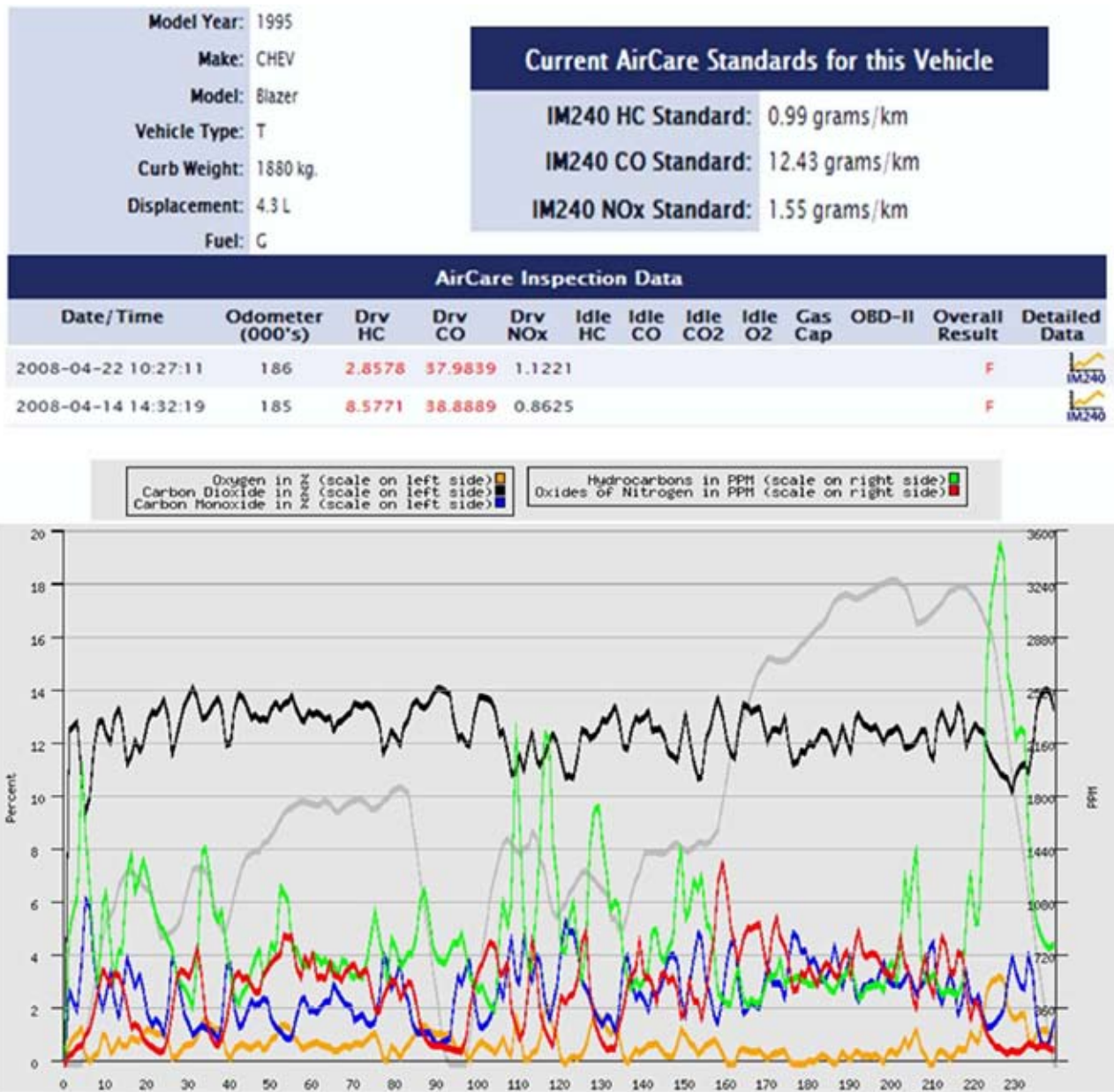


Figure 12A: IM240 AirCare inspection report and diagnostic trace from RepairNet's detailed data

Exhaust Emissions Diagnosis *cont'd*

Second	Speed (km/hr)	Hydrocarbons (ppm)	Carbon Monoxide (%)	Oxides of Nitrogen (ppm)	Carbon Dioxide (%)	Oxygen (%)
56	48.6	783	1.79	646	13.32	0.88
57	49.1	683	2.38	578	13.00	0.63
58	49.1	663	2.47	725	12.95	0.58
59	49.6	663	2.00	661	13.28	0.72
60	49.4	739	2.04	749	13.18	0.77
61	49.4	726	1.95	573	13.26	0.79
62	49.0	675	2.13	595	13.18	0.69
63	49.0	706	2.34	580	13.00	0.66
64	48.8	636	2.32	691	13.08	0.60
65	49.0	678	2.96	602	12.59	0.46
66	49.0	596	2.64	591	12.89	0.48
67	49.1	703	2.45	564	12.93	0.62
68	49.0	694	2.22	627	13.10	0.68
69	48.9	595	2.14	660	13.24	0.62
70	49.0	585	1.62	678	13.62	0.76
71	49.2	606	1.74	592	13.52	0.74
72	49.4	573	1.83	614	13.48	0.69
73	49.6	703	1.54	637	13.57	0.89
74	49.6	842	1.44	523	13.53	1.04
75	49.0	1042	1.57	361	13.26	1.17
76	48.4	837	2.51	359	12.76	0.72
77	47.8	729	4.12	443	11.72	0.17
78	48.6	544	3.77	509	12.13	0.10
79	49.7	859	2.79	566	12.55	0.66
80	50.5	780	3.20	555	12.32	0.47
81	51.2	652	3.79	441	12.02	0.19
82	51.7	692	2.74	491	12.73	0.53
83	51.2	749	2.35	551	12.96	0.69
84	49.4	743	1.59	532	13.51	0.91

Figure 12B: Second-by-Second data for first low speed cruise for this vehicle's IM240 inspection

Figures 12A and B clearly indicate an over-fueling condition as the CO concentrations through the low speed cruise should be approximately .5% and it is actually between 1.5 and 4%! The HC levels are also significantly higher than expected, indicating some combustion issues as well.

The vehicle owner had his "regular mechanic" replace the spark plugs and O2 sensor after the first failure. This resulted in significant improvement in HC levels although they are still extreme on the second failure. The replacement of the O2 sensor provided absolutely no benefit.

The vehicle was then taken to an AirCare certified shop. Their AirCare tech reviewed the SBS data and immediately knew the vehicle was over-fueling drastically. The O2 sensor was pegged at over 900 millivolts and the fuel trim data indicated the PCM was attempting to reduce the injector pulse width but had reached its limits. The Block Learn (long term fuel trim) and Integrator (short term fuel trim) values had shifted from the ideal 128 value to less than 100. As the fuel trim data indicated the PCM recognized the rich condition but was unable to compensate for this, clearly we have a problem in the vehicle's fuel delivery system! Fuel pressure was at spec so the root cause of the over-fueling had to be the injection system. The defective CPI assembly was replaced and the vehicle now had excellent fuel control and normalized Block Learn and Integrator data. The high HC measurements for this level of over-fueling was caused by several of the new spark plugs randomly misfiring as they had already become fuel fouled.

Exhaust Emissions Diagnosis *cont'd*

IM240 NOx Failure – A Lean Condition

Model Year: 2000	Current AirCare Standards for this Vehicle IM240 HC Standard: 0.37 grams/km IM240 CO Standard: 6.21 grams/km IM240 NOx Standard: 0.93 grams/km
Make: HYUN	
Model: Sonata	
Vehicle Type: P	
Curb Weight: 1409 kg.	
Displacement: 2.5 L	
Fuel: G	

AirCare Inspection Data												
Date/Time	Odometer (000's)	Drv HC	Drv CO	Drv NOx	Idle HC	Idle CO	Idle CO2	Idle O2	Gas Cap	OBD-II	Overall Result	Detailed Data
2008-03-27 09:32:29	109	0.0181	0.0093	2.1162							Q	
2008-03-26 11:11:24	109	0.0039	0.0172	2.8920							F	

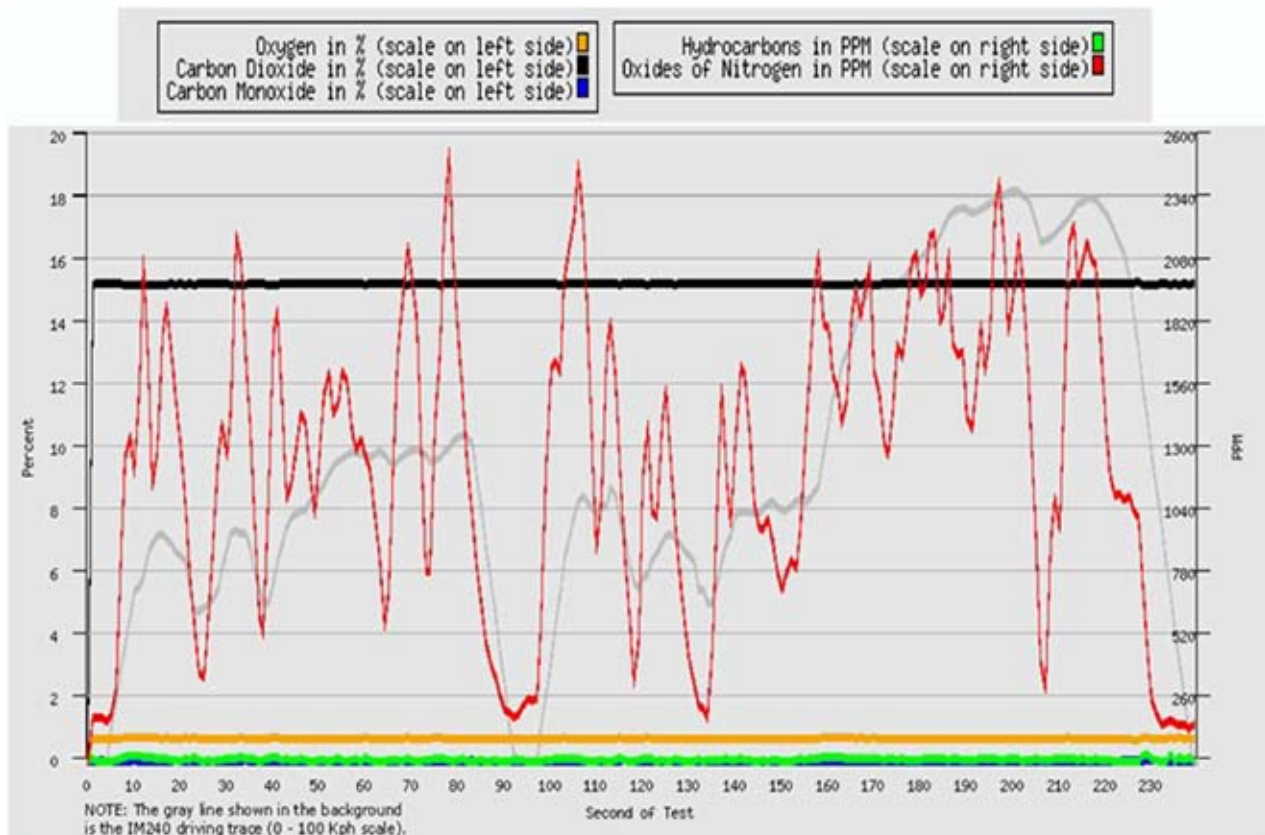


Figure 13A: IM240 AirCare inspection report and diagnostic trace from RepairNet's detailed data

Exhaust Emissions Diagnosis *cont'd*

Second	Speed (km/hr)	Hydrocarbons (ppm)	Carbon Monoxide (%)	Oxides of Nitrogen (ppm)	Carbon Dioxide (%)	Oxygen (%)
56	48.9	0	0.00	1573	15.28	0.72
57	49.4	1	0.00	1363	15.28	0.72
58	49.7	6	0.00	1294	15.28	0.72
59	50.0	0	0.00	1340	15.29	0.71
60	49.8	12	0.00	1271	15.27	0.73
61	49.5	5	0.00	1203	15.28	0.72
62	48.8	0	0.00	1045	15.29	0.71
63	48.2	0	0.00	859	15.29	0.71
64	47.2	0	0.00	559	15.28	0.72
65	46.3	3	0.00	701	15.28	0.72
66	46.7	1	0.00	1270	15.28	0.72
67	48.1	2	0.00	1680	15.28	0.72
68	49.1	0	0.00	1925	15.28	0.72
69	49.8	10	0.00	2140	15.27	0.73
70	50.2	4	0.00	2016	15.28	0.72
71	49.9	0	0.00	1837	15.28	0.72
72	48.6	0	0.00	1351	15.29	0.71
73	45.7	4	0.00	791	15.28	0.72
74	44.5	2	0.00	788	15.28	0.72
75	44.7	10	0.00	1401	15.28	0.73
76	46.9	11	0.00	1710	15.27	0.73
77	49.8	8	0.00	2217	15.28	0.72
78	51.3	5	0.00	2539	15.28	0.72
79	52.1	0	0.00	2098	15.28	0.72
80	51.9	5	0.00	1770	15.28	0.72
81	51.7	6	0.00	1482	15.28	0.72
82	50.5	0	0.00	1235	15.28	0.71
83	48.6	0	0.01	1019	15.29	0.71
84	45.6	0	0.00	824	15.29	0.71

Figure 13B: Second-by-Second data for first low speed cruise for this vehicle's IM240 inspection

The owner of this vehicle took it to an AirCare Certified Repair Centre where the catalytic converter was diagnosed as defective and replaced. This resulted in no significant change in the vehicle's NOx emissions. The tech believed that the "NOx part" of the converter was defective.

As we have seen from the catalyst efficiency chart (see figure 7), if the air/fuel ratio is lean of stoichiometric the reduction efficiency of the converter is drastically reduced. Note how low the HC and CO levels are. A vehicle with a defective converter cannot arbitrarily oxidize HC and CO this well and not treat the NOx gases. Also note the CO2 levels of over 15% on both the graph as well as the raw data for the first cruise of this IM240 inspection. This is indicative of a good catalytic converter.

Remember that the CVS analyzers used for an IM240 inspections do not measure oxygen so the values posted on RepairNet are mathematical approximates of tailpipe O2 levels. Confirm the O2 levels and air/fuel ratio or Lambda readings as part of your baselining procedures. The fuel trim data provided valuable diagnostic information on this vehicle as they were over 20% long term positive correction. In fact, this vehicle likely had the MIL illuminated and fuel trim codes stored prior to the first inspection but the owner had cleared the DTCs and extinguished the MIL thinking they could then pass their AirCare inspection. The vehicle owner did not bring this to the technician's attention (naturally), and while the tech did connect a scan tool and check for any DTCs, he only checked the vehicle's engine data in the service bay and overlooked the positive long term trim data as this really showed up during a road test. The tech also overlooked checking for pending DTCs and looking at the readiness monitor status. A pending P0171 DTC had been set, and 2 monitors not ready suggests that someone has recently cleared DTCs. The root cause of this failure was a defective MAF sensor causing a lean shift in the air/fuel ratio!

...cont'd on page 25

Exhaust Emissions Diagnosis *cont'd*

IM240 NOx Failure - Defective Catalytic Converter

Model Year: 1999	Current AirCare Standards for this Vehicle
Make: CHEV	
Model: Tahoe	
Vehicle Type: T	
Curb Weight: 2033 kg.	
Displacement: 5.7 L	
Fuel: G	
IM240 HC Standard: 0.5 grams/km	
IM240 CO Standard: 8.08 grams/km	
IM240 NOx Standard: 1.12 grams/km	

AirCare Inspection Data												
Date/Time	Odometer (000's)	Drv HC	Drv CO	Drv NOx	Idle HC	Idle CO	Idle CO2	Idle O2	Gas Cap	OBD-II	Overall Result	Detailed Data
2011-02-24 15:52:47	338	0.3602	3.4565	2.2089							F	

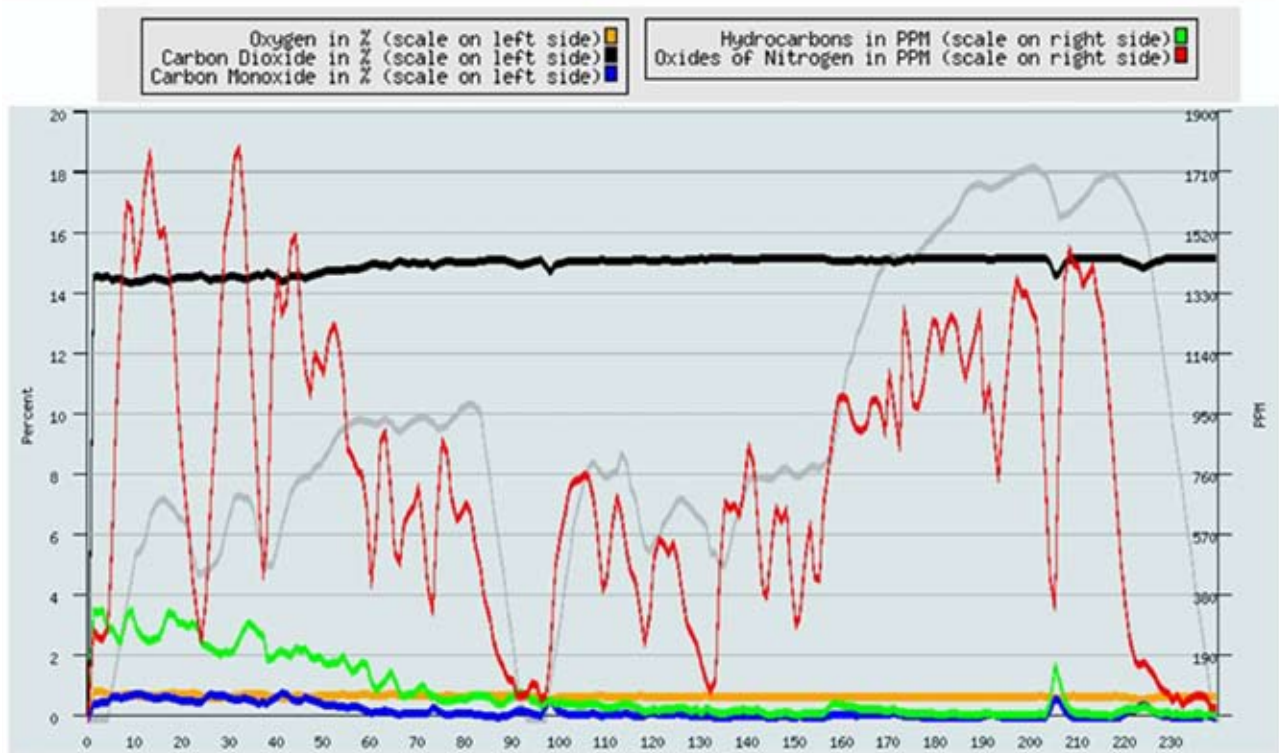


Figure 14A: IM240 AirCare inspection report and diagnostic trace from RepairNet's detailed data

Exhaust Emissions Diagnosis *cont'd*

Second	Speed (km/hr)	Hydrocarbons (ppm)	Carbon Monoxide (%)	Oxides of Nitrogen (ppm)	Carbon Dioxide (%)	Oxygen (%)
56	48.0	146	0.37	821	14.89	0.74
57	48.7	158	0.37	776	14.88	0.75
58	49.3	176	0.31	770	14.91	0.78
59	49.0	172	0.23	657	14.97	0.80
60	48.4	116	0.18	422	15.05	0.77
61	47.5	89	0.19	588	15.07	0.74
62	47.9	101	0.22	864	15.04	0.74
63	49.3	120	0.23	899	15.01	0.76
64	49.5	144	0.22	717	15.00	0.78
65	49.1	121	0.16	521	15.07	0.78
66	48.1	77	0.10	484	15.15	0.76
67	47.6	69	0.14	617	15.12	0.74
68	48.1	77	0.17	647	15.09	0.73
69	49.1	74	0.16	673	15.11	0.74
70	50.0	95	0.15	729	15.09	0.75
71	50.0	102	0.15	584	15.09	0.76
72	49.2	80	0.15	416	15.11	0.74
73	48.2	71	0.32	335	14.99	0.69
74	47.9	64	0.29	634	15.02	0.69
75	48.1	56	0.16	873	15.12	0.72
76	48.6	55	0.11	833	15.16	0.73
77	49.1	53	0.12	695	15.15	0.73
78	49.7	59	0.17	626	15.11	0.72
79	50.9	61	0.17	638	15.11	0.72
80	51.7	58	0.15	676	15.13	0.72

Figure 14B: Second-by-Second data for first low speed cruise for this vehicle's IM240 inspection

Virtually all of the diagnostic information needed to determine the cause for this final case study is contained in the vehicle's Diagnostic Trace and Second-By-Second data. Note how all three pollutants are trending downward in figure 14A. At the same time you can easily see that the CO₂ levels are increasing, this is indicative of a catalytic converter that is slow to achieve light-off.

Now let's look at the second-by-second data (see figure 14B) for the first cruise section of this IM240. The HC and CO levels at second 56, suggest that the vehicle does not have any combustion issues (HC 146 ppm) and has good fuel control (CO .37%). The HC, CO and NO_x levels are all diminishing while the CO₂ is increasing, a dead giveaway that the cat is defective. The cat appears to be only 26% efficient at the beginning of this cruise and its efficiency is barely 70% by the end of this 50 kph cruise. Remember, a vehicle's catalytic converter needs to be approximately 90% efficient to pass an IM240 comfortably.

The vehicle was road tested to verify fuel control and normal fuel trims. The catalytic converter was replaced with a high quality replacement, and this vehicle passed very easily.

In conclusion, understanding the relationship of the gases of our air/fuel ratio chart and the effect that air/fuel mixture has on catalyst performance will speed up your diagnoses and provide invaluable, logical direction to any emissions diagnosis you may be performing. The second-by-second data and graphs take only seconds to download from RepairNet and once you have become comfortable using this information, will allow you to get to the root cause of an emissions failure much more quickly. Give us a call on the tech line, Ron or I would be happy to assist you in utilizing this valuable tool!