Attention

Before the first class meeting, you must complete the following items:

1. Read the two Motors articles covering CAN and ETC
2. Complete the take home exam and give to instructor in the first day of class
3. Complete the Internet Assignment
2009 Technician Update Training Course

Smog Check Failure Diagnostics

Butte College Automotive Technology
The purpose of the Bureau of Automotive Repair’s (BAR) update training course is to update technicians on new automotive technology and emission testing procedures that affect California’s Smog Check vehicle inspection program. Both initial applicants seeking a license and currently licensed Smog Check technicians must successfully complete this course prior to obtaining or renewing their license after December 31, 2008.

Course Description:
The 2009 Update Training Course will include course lectures, homework assignments, laboratory assignments, and a final examination. BAR approved course materials shall be distributed by the instructor to the student prior to (or at the start of the first class). The course will be a minimum of 16 hours in length, and will include the following subject areas:

- Advanced Electrical/Electronic systems diagnostic and repair procedures as they pertain to vehicle emission failures.
- Practical application of the internet to obtain automotive diagnostic and repair information.
- BAR Updates

Instructor Presentation:
The instructor will cover step-by-step methods that may be used to diagnose HC, CO, and NOx emission failures. The instructor will discuss two case studies for each emission failure problem noted above, and provide an instructor led demonstration (e.g. testing techniques, equipment set up, test results documentation, application of critical thinking skills, etc.) related to each emission failure. In addition, the instructor will discuss final invoice documentation procedures required by law for emission failure diagnosis and repairs.

The instructor will cover basic use of the internet and accessing websites relevant to emission failure diagnosis and repairs.

To pass the 2009 Update course the student must:
- Attend all course hours.
- Pass all laboratory examinations.
- Score 70% or better on all examinations.
- Score 70% or better on all homework assignments

Hand-On Laboratory Examinations:
Students will be provided a series of laboratory examinations to perform in the shop environment. Students must complete all the laboratory assignments successfully to pass the course.

Homework assignments (supplied by the instructor):
- Read the following two articles:
  - “Meddle With the Pedal: Electronic Throttle Control” (Mike Dale – Motor Magazine, July 2007).
  - “Diagnostics Using OBD II Data Bus Communication Networks” (Bosch)
- Complete the (take home) examination related to the two articles noted above.
- Complete the internet laboratory assignment.
It may well be that software integration of automotive electronic systems will turn out to be the most significant automotive technological development of this decade. Originally electronic systems such as ABS, HVAC and emissions were developed separately by those groups within each carmaker that were most responsible. The brakes and suspension group worked on ABS while emissions and engine control issues were handled by powertrain people. Software integration has brought these systems together. The result is new, interrelated technologies that produce better mileage, safer cars and reduced emissions.

At the head of this trend, as an enabling technology, is electronic throttle control (ETC), which is part of an industrywide response to calls for better fuel economy, reduced emissions and a reduction in vehicular fatalities. This story is not so much about hardware as it is about software that uses ETC as an input and an actuator to make the new technologies possible.

Without ETC, the planned advances in hybrid and diesel technology that are now right around the corner would not be possible. Current advances such as electronic stability control (ESC), expected to save thousands of lives per year, would simply not be possible without ETC. Best yet, ETC reduces cost and complexity for carmakers by integrating formerly stand-alone features such as idle control, cruise control and throttle control into a single, mostly software-based system.

This latest version of electronic throttle control should not be confused with the earlier stand-alone systems that replaced the mechanical link between the driver and the engine. In these new systems, the output of the pedal sensor is an input not only to the engine control system but to the software system as a whole. As such, pedal angle becomes a valuable input to other electronic control systems. The algorithms that control the ABS, ESC, cruise control, HVAC and other system functions all use pedal angle data in the decision-making process. The throttle angle that results is not only what the driver wants but what the systems needs for correct and safe operation.

In these new-generation ETC systems, the accelerator pedal module becomes a two-way device: It accepts information about desired engine output from the driver, plus it can feed back tactile information to the driver as a warning that the selected engine output is either wrong or dangerous.
The Technological Need for ETC

The clear goals of the automotive industry are to improve fuel economy, reduce emissions and improve function and safety for the driver. To understand the design options available to accomplish these goals, you need to know what produces the best results and what causes subpar performance. These complicated goals are further complicated by trade-offs that have to be made.

Fuel economy and emissions output per mile traveled are directly related to the size of the vehicle and the size of the engine. In keeping with the laws of physics, cutting fuel consumption is about either reducing the mass of the vehicle or reducing acceleration. Since the systems are not perfect, there’s another path that can be traveled—by improving efficiency to reduce losses.

The first thing to know is that most automobile engines are much larger than they need to be for most real-world operating conditions. The big V8 often selected for full-size pickups is really chosen to pull a boat or trailer the owner may have in mind. Yet trailer towing may amount to less than 10% of the actual vehicle miles; 90% of the time a smaller engine would do just fine.

The fact that engines generally spend most of the time running at a small fraction of their peak power output is referred to as the partial power problem. Toyota says the Otto cycle engine is most efficient at 40% to 45% of its redline rpm. This is the point at which torque is at about 70% to 80% of its peak value for a given engine. In this most efficient operating range, the engine produces about 40% of its peak power rating.

Let’s use Toyota’s 108-hp ECHO engine as an example. Given the numbers just mentioned, it would be best if most of the time the engine output were in the range of 40 to 50 hp. Unfortunately, this is not enough for adequate acceleration or hill climbing. Calculations show that if the ECHO had only a 30-hp engine, it would need 30 seconds to accelerate to 60 mph. If such a vehicle were to encounter a 10% grade, it would slow down to 30 mph before it reached the top of the hill.

On the other hand, only 15 hp or so is needed to maintain 60 mph on level roads, and even less power is needed for idling and low-speed travel. The net result is that the engine power output that was chosen for adequate passing and hill-climbing is larger than necessary for most of the operating circumstances of the vehicle.

In addition, engines are seldom operated under the circumstances that would produce the best results for fuel economy and emissions output. For a typical engine with a redline of 5000 rpm, the sweet spot should be at about 2000 rpm. In practical terms, most engines actually operate in a much broader range between idle and 3200 rpm. There are the occasional zooms to redline, but they represent a small part of the true operational circumstances.

Given normal gearing, the peak efficiency point for a vehicle turns out to be around 55 mph. The double-nickel speed limit was not chosen randomly, but rather with an eye to best fuel economy for the average vehicle. For a given distance traveled, fuel economy tapers off at both higher and lower speeds. Holding a constant speed is an advantage, as it avoids both the extra fuel needed for acceleration and the increased emissions that often result from deceleration.

Not surprisingly, the sweet spot of engine efficiency is also the sweet spot of emissions output. It’s the cold-start events and sudden speed changes that challenge emissions control systems. Electronic throttle control can actually help emissions through strategies that lean out the mixture in concert with retarded ignition timing to assure an earlier light-off for the converter.

Efficiency losses occur on both sides of the sweet spot for a given engine. At high engine speeds, friction among the piston, the rings and the cylinders accounts for more of an engine’s lost output. These friction losses become more significant as engine size is reduced. Parasitic losses to engine accessories such as the oil and water pumps also increase as a function of rpm. Another issue is the need to richen the fuel mixture to get maximum torque output from the engine. It may help acceleration but it doesn’t help emissions output or fuel consumption.

The major cause of efficiency losses at low speed is called pumping loss. Reducing the output of an engine is accomplished by limiting the airflow into the engine. The throttle plate restricts the intake of air by forcing the engine to drag air through a narrow or restricted inlet. The restriction of the air intake...
creates a differential pressure across the throttle plate we know as intake manifold vacuum. Since the air entering the cylinder is below atmospheric pressure, less air enters the cylinder. The engine control system measures the pressure differential and reduces fuel input accordingly. The reduced quantities of air and fuel result in the desired reduction of power output.

The downside to this is that having partial pressure in the intake manifold wastes energy. As the piston moves downward on the intake stroke, normal pressure below it and partial vacuum above it cause drag on the rotation of the crankshaft. These pumping losses occur during most engine operating conditions, as the throttle is seldom truly wide open.

Diesel engines are known to be approximately 25% more efficient than gasoline engines. According to Toyota, one reason is that the diesel engine uses no throttle, and thus suffers reduced pumping losses. In gasoline engines, the throttle-related losses are believed to be in the range of 7% to 10%. Diesel engines are also more efficient due to their higher compression ratio.

GM says that it’s difficult to achieve all of the design goals of better fuel economy, reduced emissions and driver safety at the same time. Typically, in a fixed-valve-timing engine, best power has been traded off against other desirable elements such as torque, idle stability and fuel economy.

There are other approaches that try to deal with the issue of the throttle-related partial power problem. Gasoline direct injection is an approach to improving efficiency by calibrating each combustion event to the needed power requirements. The direct injection system controls engine power by injecting only that amount of fuel needed to produce the desired engine power output.

Another approach is through variable valve timing. VVT systems offer varying degrees of control based on system complexity limits. Early intake valve closing (EIVC), late intake valve opening (LIVO), late intake valve closing (LIVC) and fully variable valve lift strategies have demonstrated reduced pumping losses and improved fuel economy.

GM has tried the EIVC strategy, which uses the variable intake valve closing and intake valve lift control to unthrottle the engine at part-load and light-load operating conditions. Here the intake valve duration and lift are significantly reduced to control airflow into the engine, allowing it to operate at higher intake manifold pressures with the potential to fully unthrottle the engine under all operating conditions.

Electronic or hydraulic valve actuators under the direction of software-controlled cam profiles may someday offer even greater flexibility. These systems have been talked about and demonstrated. Renault had one in a Formula One racer a while back with a 17,000-rpm redline. So far the software cam has not appeared in a production vehicle due to the dynamic complexity of landing the valve back on its seat without noise. The actuators shown so far are also bulky and expensive in comparison to mechanical actuation.

According to GM, the downside to these various VVT strategies for production engines is that they require moderate to significant changes to the engine’s architecture to successfully package the VVT components. Cam phasers not only take up space, but also add to the vehicle in terms of complexity, weight and cost.

**Using ETC to Achieve System Goals**

Automakers have taken this research into engine efficiency and done their best to make sure the engine spends more of its time in and around the sweet spot. They know that the vehicle has to feel “normal” to the driver and have gone to great lengths to make that happen. From the driver’s standpoint, what the computing platforms are adjusting and controlling is strictly in the background. Getting greater efficiency is accomplished in several ways:

**Transmission Control.** Keeping the engine at its rpm sweet spot is accomplished by having more of the need for rpm compensation between the engine and the drive wheels handled by the transmission. Six-, seven- and eight-speed transmissions, as well as CVTs,
are becoming commonplace. As CVTs are still limited in their peak torque handling capability, vehicles with high-output engines have stayed with conventional multispeed transmissions.

Ford and GM are in production now on their joint venture six-speed transmission. About 85% of the components are meant to be shared by both manufacturers. Expectations are for a 4% increase in fuel economy while at the same time providing a 7% improvement in 0-to-60 times. Unlike conventional transmissions, with their ratio spread of approximately 4.0 to 1.0, the new Hydraumatic/Ford transmission has a wider overall ratio of 6.0 to 1.0. Electronic throttle control is an integral part of the improvements in both fuel economy and acceleration.

Having so many gears requires some adaptations. Toyota's eight-speed transmission, for example, has a software provision to skip gears during deceleration to make the downshifting smoother and less apparent to the driver. The ETC system smoothes the shift performance between gears by adjusting the throttle opening at the shift point. Programmed steps in the ETC system can be used to give the driver the "feel" of a conventional transmission, so the CVT doesn't feel odd.

Driveline management software is used to select the combination of engine output and gear ratios that will deliver the needed torque in the most efficient way. The software is capable of reducing the torque input to the transmission during the shift sequence to reduce mechanical shock to the drivetrain. This driveline management software is especially important for on-demand AWD. The shift from two-wheel to four-wheel drive must be controlled to avoid torque bumps and other interactions between the drive wheels.

Displacement Reduction for Light-Load Conditions. GM, Chrysler and others have implemented variable displacement strategies. GM's Displacement Reduction for Light-Load Conditions during steady-state, low-speed on Demand system reduces efficiency and allows for the loss of torque and power that results from these engine settings. For a given engine setting, the driver will feel reduced power when the strategy is implemented. Software compensations to the throttle angle can be made that maintain the original pedal-to-throttle relationship the driver is used to. ETC can also be used to control actual throttle angle during acceleration and deceleration to minimize pumping losses. Often the throttle angle implemented by the ETC system could be more favorable than the driver is able to select.

The greatest impact on emissions performance of ETC systems is the above-mentioned variable displacement strategies. Cadillac's first attempt at variable displacement (V-8-6-4) in the early '80s foundered at the time for a variety of reasons, including driver dissatisfaction with how the engine "felt" as it dropped or picked up displacement. ETC, with its computer control, is able to automatically make the throttle angle changes needed so the change is seamless to the driver.

Another benefit of ETC, according to GM, is the ability to modify vehicle response to a change in pedal angle position. Consumer research shows that vehicle response to accelerator inputs greatly affects a driver's overall satisfaction with the vehicle. The response of the vehicle to the first 20mm (.8 in.) of throttle movement may be more important than the actual 0-60 acceleration time.

Vehicle Safety. Electronic stability control is probably the most significant safety development since the invention of the seat belt. By federal requirement and automaker cooperation, this system will be standard on all vehicles by 2010. The hope is that as many as 10,000 lives per year will be saved. To function as it does, ESC depends on ETC.

Electronic stability control systems are an integration of existing vehicle systems (ABS, TC, ECM), coupled with added sensors to determine steering angle and yaw. A key input to the system is the pedal angle position sensor output. The ESC system runs an algorithm that determines if the requested engine output is safe. When it's advisable, the output from the system can be a throttle angle command that's not what the driver requested. When there's a possible loss of traction and/or steering control, the ESC system can overrule driver input to reduce throttle angle and engine power.

Electronic throttle control can also be used to protect the engine, driveline and tires from operation that may cause excess wear or damage. Rev limiting can be accomplished in software by governing the throttle angle rather than shutting off fuel or ignition. This results in a much smoother limiting that does not cause the driver to sense that the engine has "cut out," as can be the case with ignition- and fuel-based limiter systems. Rental car companies have
pushed for rev limiters as a way of protecting their assets from drivers who don't care how hard they push a vehicle simply because they don't own it.

**Using ETC to Enable Other Technologies**

GM's Vortec 5.3L V8 uses Active Fuel Management (AFM), with ETC as a key input. The 3.9L V6 also uses AFM, but in combination with VVT. GM says the 3.9 is the first to use both cylinder deactivation and VVT on the same engine. Under light-load conditions, either engine can deactivate half the cylinders. Real-world fuel savings of 7% is what GM is advertising, although the benefit reportedly is greater for those who do a lot of steady-state highway cruising.

The E38 ECM measures load conditions based on inputs from vehicle sensors such as ETC and interprets that information to manage more than a hundred engine operations. Fuel injection, spark control and electronic throttle control are all included. When loads are light, the engine computer automatically closes both the intake and exhaust valves, while at the same time cutting fuel delivery. When the driver demands acceleration or increased torque to move a load, the cylinders are reactivated.

In these systems, ETC is used to balance torque to prevent the driver from “feeling” the cylinders as they come or go off-stream. During deactivation, both valves are closed. The energy used to compress the air in the cylinder is returned to crankshaft on the downstroke as the trapped air acts as a spring. The transition takes less than 20mS, and the driver never notices it.

The actual hardware used to control the deactivation is called a lifter oil manifold assembly (LOMA), and is located in the valley of the V8 engine. Four electric solenoids are controlled by the result of the E38's processing of the load algorithm. These solenoids determine the number of active cylinders by controlling oil flow to the lifters of the affected cylinders.

In an AFM-equipped engine, pumping losses are reduced during deactivation primarily by the increase in intake manifold pressure. During deactivation, the remaining cylinders need reduced throttling in order to provide an equivalent amount of work. Without electronic throttle control, the driver would notice the deactivation as a sag in performance. Without the driver needing to change the pedal angle, the software changes the throttle angle to reflect the fewer number of functioning cylinders.

AFM operation is load-based. The load is measured and combined in an algorithm with the driver's demand for power as measured by throttle application. Active fuel management does not affect emissions output from the active cylinders. For the inactive cylinders, no fuel is wasted or burned, and the result is lower emissions for the distance traveled.

The key point here is that the only mechanical components needed are the three or four special valve lifters and the solenoids to control them for the cylinders that are to be deactivated. The software-based control system uses inputs about engine load, vehicle speed, driver intention, safety and emissions inputs in making the decision to shut down individual cylinders. The ETC system already in place is used to make sure the vehicle operates “normally” during the deactivation.

The Gen IV Vortec 5.3L takes ETC to the next level by taking advantage of the processing capability available in the E38 computer. The increased integration allows for the elimination of the throttle actuator control (TAC) module. In previous systems, the TAC module took commands from the ECM and operated the electric stepper motor that controls throttle position. In the new system, the ECM operates the throttle directly. This direct link between the throttle and the computer speeds up response time. Eliminating the TAC also reduces wiring, reliability issues and the need to monitor the TAC module for correct operation.

The flex-fuel 5.3 requires no special fuel sensor. Earlier flex-fuel engines used a light-reactive sensor to determine what blend of fuel was in the system. The Gen IV engine uses a virtual sensor programmed into its software. Based on readings from the oxygen sensors, fuel level sensor and vehicle speed sensors, the ECM determines the fuel blend and adjusts the fuel injector pulse width and the throttle angle as required. The ETC system makes the needed throttle angle changes. Because ethanol has a lower BTU rating for the same volume as gasoline, more fuel is required to provide the same power at wide-open throttle.
Toyota is using what it calls Power Train Management on the Lexus LS 460. With this system, the most suitable vehicle drive power is accurately accomplished with optimized engine torque and gear ratio. Toyota’s emphasis is on what the driver experiences, which is torque at the drive wheels. Toyota says that with conventional powertrain controls, a target throttle opening and gear ratio are determined according to the driver’s pedal angle input. Consideration in terms of throttle angle is given to other vehicle systems such as cruise control and vehicle stability control (VSC). The result is that the target throttle opening and target gear ratio are set separately. In previous systems, this situation worked well because each of the vehicle systems was not large, and the desired accuracy requirements were not particularly high.

This situation has changed. Newer vehicle systems with precrash safety systems and intelligent parking assistance (IPA) systems have caused the relationships among vehicle systems to become more complicated. It has become more difficult to align all the different systems to achieve the desired drive power.

Toyota says it has developed something called Vehicle Dynamics Integrated Management (VDIM) to integrate the vehicle stability control, traction control, ABS and electric power steering. ETC is used for VDIM sensor inputs and control actuators. The VDIM system controls the “drive power” by selecting the combination of engine power and transmission gear to give the needed drive wheel torque at the highest possible efficiency. By having an integrated system, the best choices for ignition timing, engine rpm and gearing can be chosen to deliver torque and acceleration the driver senses.

The torque and power of the drive-train for hybrid vehicles can come from the internal combustion engine, the generator and/or the electric motor. Combining and distributing the torque is handled by a planetary gearset that both Toyota and Ford call a power split device (PSD). In the PSD, the carrier gear is connected to the engine, the sun gear is connected to the generator and the ring gear is connected to the electric motor. The planetary gear configuration provides decoupling of engine speed from vehicle speed.

While a hybrid drivetrain offers the possibility of improved fuel economy, there are some added constraints. Ford says one issue is that power split vehicles are sensitive to such noise factors as engine torque mismatches that conventional vehicles are not. These systems are also sensitive to overuse of the battery that may affect its durability. To overcome these issues, Ford Escape/Mercury Mariner engineers had to determine powertrain operating points compatible with the battery and high-voltage
bus architecture to ensure that power, voltage and durability issues were met.

Ford says that the determination of a desired powertrain operating point for a conventional vehicle is relatively straightforward, since there's only one path to the wheels from the power-generating device (the engine). There are three variables that need to be determined—the transmission gear, the torque converter clutch state and the desired engine torque. The driver's intent is reported by the pedal angle sensor. The gear and torque are determined by computer algorithm, with the result that the throttle angle is controlled.

In a hybrid vehicle, there are three power-producing devices—the generator, the motor and the engine. The control system determines what the driver-demanded wheel torque is by way of the pedal angle sensor. From this, the computer software can choose the optimum combination of desired engine speed and desired wheel torque. Engine speed is the result of the throttle position algorithm's control of the throttle angle. Wheel torque is the result of the choice of power sources and the gearing between them and the wheels.

In the power-split hybrid electric vehicle, generator torque and generator speed—and, therefore, generator power—are largely determined by the desired engine speed and actual engine torque. So the battery power limit is essentially a constraint on motor power. Since motor speed is determined by vehicle speed, this effectively limits motor torque. Motor torque is also limited by what the driver wants in terms of driveability. The hybrid control system has to manage the interactions of the three possible power sources. Electronic throttle control integrated into the system is used to accept driver input and to then control the engine's output in accordance with the other two sources of power.

At the heart of the hybrid control system described by Ford is the electronic throttle control system and its ability to accept driver input and then output a throttle angle position in keeping with the best interests of the whole system. It's the integrated software of the transmission and engine control systems that gives the system response.

To sum up, what started out as a means of eliminating the mechanical connection between the throttle pedal and the engine has evolved and taken on a larger and far more important role. By integrating the safety, emissions and powertrain electronic subsystems, it has become possible to implement new technologies that could not have been implemented independently. Electronic throttle control is a mandatory element of these advanced systems.

Visit www.motor.com to download a free copy of this article.
Overview:

Vehicle On-Board Control Modules are changing the automotive industry in two related areas. The first area concerns the expansion and use of multiple on-board control units. Today’s modern vehicle will have on-board control modules controlling vehicle components such as the engine, antilock braking system, transmission, instrument panel, chassis and body control functions, to name just a few. An on-board control module does more than just make sure its own input and output devices work correctly. The on-board controller also participates and communicates in one or more communication networks in the vehicle. These vehicle networks exist to allow the sharing of information among components and to reduce the numbers of wires and sensors required in the vehicle.

The second area in which microcontrollers are changing the automotive industry concerns the way we interact with our vehicles. Computers are now common in the passenger area and consumers can now interact with their vehicles in a variety of ways. This allows consumers to run already familiar programs in the vehicle — email, GPS navigation, calendar management, etc.
The second phase of this migration also allows the automotive technician to interact with the vehicle’s on-board controllers, gathering information, controlling the vehicle directly and aiding in the diagnosis of problems. This interaction can occur with the use of a scan tool or in some case accessing the on-board controller directly through an operation sequence or a control panel on the vehicle.

2005 Dodge Neon with Idle Air Control Motor DTC (P0508). This code was obtained by cycling the ignition key on/off three times. Notice how the code is displayed directly on the dash panel.

Network and Scan Tool Communication:

An automotive controlled network consists of multiple series of control modules electronically communicating complex information and requests in a digital language format. This digital language is known to technicians as “vehicle protocols”. Modules can be connected on the network in serial or parallel interface. The term used for this type of communication interface is called “Multiplexing” and can be carried through single or dual circuits. When a scan tool is connected and interfaced into the network it should be considered as one other control module on the network.
Primary Purposes of Networking:

One of the major driveability concerns in automotive diagnostics is circuit related problems due to bad connections creating opens, shorts, resistance and voltage drop problems. Networks help resolve these problems by eliminating miles of wires, connections and splices. With networking, a fuel pump circuit that would normally be wired to the PCM to be commanded on could now be wired to a Rear Control Module (REM) reducing wire length and potential circuit problems. With networking, the command from the PCM to turn on the fuel pump could be sent to the REM module over the network that would then activate the fuel pump circuit.

Note: As networks evolve look for control modules to be located in various quadrants within the vehicle and components located near that quadrant reporting to a specific control module.

2004 Volvo S 80 Control Module Network Configuration.

Circuit Diagram from CAS/SIS Diagnostics ESI[tronic] Robert Bosch LLC
Network Topology:

Linear: Interconnection of multiple ECU’s on common linear bus. A multi-master principle is generally used, allowing high stability with enhanced fault localization. This system is used in drivetrain and body network systems.

Ring: Short path interconnection of multiple ECU’s in a fiber-optic series ring. The information passes through each ECU. This system is used in multimedia networks. Multimedia systems require large volumes of data to be transferred in short amounts of time. To transmit a digital TV signal with stereo sound requires a data transfer rate of around 6 Mbit/s. MOST (Media Oriented Systems Transport) can transfer data at a rate of 21.2 Mbit/s.

Star: Interconnection of multiple ECU’s in a star structure network control by central master ECU. This system uses a master-slave, time triggered protocol. The network is designed as a low cost, local sub-system single wire interconnect network for use in on-off devices such as car seats, door locks, sunroofs, rain sensors and door mirrors.

Terminating Resistors:

Terminating resistors are used in CAN systems to create proper electrical load between the CAN_H and CAN_L circuits. This load helps to reduce electrical noise on the data circuits, which allows for a cleaner voltage signal on the data bus.

Terminating resistors in the high speed CAN systems are required to be 120 ohms with a maximum range of 118-132 ohms. Lower speed CAN systems may use different values. CAN systems can use split termination, which means there may be more than two terminating resistors in the system. Terminating resistors may be physically located inside any of the control modules connected to the CAN harness, with a junction connector. The resistors may also be part of the wiring harness. Terminating resistors may or may not be identified in circuit wiring diagrams. Do not attempt to conduct wiring diagnostic fault procedures such as voltage or resistance tests without proper service information.

The figure on the next page shows an example of a CAN system with terminating resistors.
Signal protocols:

There are five basic signal protocols currently in use with the OBD-II interface.

- SAE J1850 PWM
- SAE J1850 VPM
- ISO 9141-2
- ISO 14230 KW
- ISO 15765 CAN (C&B)

Pin Assignment Table:

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<td>Fused Battery Power</td>
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<tr>
<td>2</td>
<td>SAE J1850 (SCP Bus -)</td>
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<td>ISO 15765-4 CAN Low (Bus -)</td>
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<td>K Line of ISO 9141</td>
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J1850 from the Society of Automotive Engineers Protocols:

Ford “Standard Corporate Protocol”:

Protocol operates at 41.6 kB/sec with two wires on the bus.

- SAE J1850 PWM (41.6 kbaud, standard of the Ford Motor Company)
- Pin 2: Bus-
- Pin 10: Bus+
- High voltage is +5 V

SAE J1850 PWM

MTS 5100 Robert Bosch LLC
General Motors Class 2 Bus:

Protocol operates at 10.4 kBa/sec with one communication wire. Chrysler also has an adaptation of the GM Class 2 protocol.

- Pin 2: Bus+
- Bus idles low
- High voltage is +7 V
- Decision point is +3.5 V
- Message length is restricted to 11 bytes, including CRC

ISO 9141-2 from the European-influenced International Standards Organization:

This is a single-wire where the ISO modules talk only when asked and only to the scan tool, not to each other. This protocol is slower than GM and Chrysler versions of SAE J1850. The ISO 9141-2 protocol has a long wake-up call which allows for each control module to report PID data.

ISO 9141-2 protocol has a data rate of 10.4 kbaud and is primarily used in Chrysler, European and Asian vehicles.
NOTES:

- Pin 7: K-line
- Pin 15: L-line (optional)
- UART signaling (though not RS-232 voltage levels)
- K-line idles high
- High voltage is Vbatt

Just because a vehicle has an ISO protocol does not mean that the control modules are unable to talk to each other. An example would be a 2001 Volkswagen Passat where the modules talk to each other on a CAN protocol network. The CAN protocol is then transmitted to the IP instrument cluster module where the signal protocol is converted to ISO format for communication with the scan tool.

ISO 14230:

In use by 1997, ISO 14230 was an upgrade to ISO 9141-2. One of the major enhancements of ISO 14230 was a faster wake-up call.

- Pin 7: K-line
- Pin 15: L-line (optional)
- Physical layer identical to ISO 9141-2
- Data rate 1.2 to 10.4 kbaud
CAN Systems:
Controller Area Network (or CAN) is the latest communication system within the automotive world. CAN is a means of linking all of the electronic systems within a car together to allow them to communicate with each other. As on-board computers increase, so does the number of different electronic systems. Today’s modern vehicles may have as many as 50 or more on-board computer systems on them. The information recorded and processed by each control module is often used by one or more control modules on the system. A requirement for a standardized means of quickly passing information between the control modules was needed leading to the development of CAN.

CAN History:
CAN protocol was created in 1984 by Robert Bosch Corporation with anticipation of future advances in on-board electronics. The first production application was in 1992 on several Mercedes-Benz models. CAN is now being used on more and more new vehicles. By 2008, all new vehicles sold in the U.S. will be required to have a CAN-compliant diagnostic system.

CAN Protocols:
ISO 15765 (CAN-B&C)
CAN-B, the medium-speed network (nominally about 125 kB/sec), will be used for body electrical systems and normally will operate at 83.3 kB/sec. On some Mercedes cars, there may be as many as 30 modules on the CAN-B bus.

- Pin 3: CAN High
- Pin 11: CAN Low

CAN-C is a 500 kbit/s high speed two-wire system for powertrain, transmission and ABS modules. CAN-C is intended to operate at a 500 kB/sec baud rate, about 50 times faster than GM's Class 2 data bus version of J1850 and over 60 times faster than ISO 9141-2.

- Pin 6: CAN High
- Pin 14: CAN Low

Note that Pins 4 (chassis ground), 5 (signal ground) and 16 (battery positive) are present in all configurations.

The next page shows a CAN_High and CAN_Low waveform.
Internal CAN Communication:

CAN networks can communicate internally, but not with the scan tool. Many CAN modules will talk with each other and a gateway; or translator module, will convert the protocol so a scan tool can understand it.

CAN Translators VW Example:

Instrument clusters from 08.99 > are integrated into the vehicle CAN Data Bus network. The CAN-Bus on-board diagnostic Interface “J533” (which is integrated into the instrument cluster) enables data to be exchanged between the vehicles CAN Data-Bus network and the Data Link Connector (DLC) “K-wire”.

The CAN-Bus On-Board Diagnostic Interface “J533” has specific on-board diagnostic (OBD) capabilities that are accessed by using scan tool address word 19 – “Gateway”.

The next page shows a network diagram of a VW Passat with three different networks.
Volkswagen Passat showing four different networks

**CAN A: Comfort & Convenience Systems:**
- Low/med speed data of 1k bit/s to 20k bit/s
- No real-time requirements
- Single wire
- Cost effective
- Uses various protocols

**CAN D: Multimedia:**
- Real time data 1M – 400M bit/sec
- Fiber-optic network protocol with capacity for high-volume streaming, include automotive multimedia and personal computer networking.

The graphic on the next page shows a fiber-optic CAN_D network.
A Growing List of CAN Applications:

Below is a list of some vehicles that are currently in CAN compliance. CAN compliant means that the CAN network broadcasts diagnostic information to the scan tool (Pins 6 & 14 or 3 & 11) in CAN protocol language. Many scan tools have to be updated with CAN module adapters to communicate at the higher baud rates that CAN systems produce.

2003 Ford Excursion      2003 Ford F-250 and F-350
2003 Ford Focus and Thunderbird 2003 General Motors Saturn ION
2003 Lincoln LS          2003 Mazda 6
2003 Saab 9-3           2004 Buick Rendezvous
2004 Cadillac CTS, XLR and SRX 2004 Dodge Durango
2004 Ford Taurus        2004 Lexus LS430
2004 Mercury Mountaineer 2004 Mercury Sable
2004 Mazda 3 and RX-8    2004 Toyota Prius
2004 Volvo S40

2005 Audi A4 and A6      2005 Cadillac STS
2005 Chevrolet Equinox    2005 Chevrolet SSR
2005 Chevrolet Trailblazer EXT 2005 Chrysler 300C
2005 Dodge Dakota and Magnum 2005 Ford E-150
2005 Ford Escape and Expedition 2005 Ford Freestyle
2005 GMC Envoy ESV and XL 2005 Isuzu Ascender
2005 Jeep Grand Cherokee 2005 Lexus LS400 and GX470
2005 Lincoln Town Car    2005 Mercury Mariner
2005 Pontiac G6, Grand Prix and GTO 2005 Land Rover LR3
2005 Mazda MPV and Tribute 2005 Mercedes-Benz SLK350
2005 Saab 9-7X           2005 Toyota Avalon
2005 Buick LaCrosse, Rendezvous and Rainier
2005 Chevrolet Cobalt, Corvette and Malibu
2005 Mercury Grand Marquis, Montigo and Sable
2005 Ford Crown Victoria, Five Hundred, Focus and Mustang
2005 Toyota 4Runner, Sequoia, Tacoma and Tundra
2005 Volvo S60, S80, V50, V70, XC90
Strategy Based Diagnostics

General Motors developed strategy-based diagnostics for their technicians and the diagnostic procedure can be used on all vehicle applications.

- **Verify the customer concern:** A technician needs to know how the system is supposed to function normally before deciding that the system is malfunctioning. A thorough customer interview, or a diagnostic worksheet filled out by the customer, is necessary before troubleshooting can begin.

- **Preliminary checks:** Operate the suspect system and evaluate its performance. Perform a thorough visual inspection of all components, including fuses, connectors, grounds and harness routing. This is also an ideal time to pull up the service history on the vehicle.

- **Perform published diagnostic system checks.** If there is a published diagnostic procedure that will help you narrow down the cause of the problem, use it first.

  \textit{Note: This is the time to connect the scan tool and request diagnostic information from the control modules on the network.}

- **Check for bulletins:** If you have access to published service bulletins for the vehicle, search those for a possible fix. This can save time in the long run. You can also print safety bulletins for your customers at this point, as an added value.

- **Stored diagnostic trouble codes (DTC’s) and symptoms with no DTC’s:** If there is a hard trouble code, then follow the diagnostic procedure for the particular DTC. If you have a repeatable symptom, then use the Symptom Charts. Both these procedures will quickly help you narrow your diagnostic focus.

- **No published diagnostics:** When there is no DTC stored and no matching symptom for the condition in the service manual, you will have to develop your own diagnostic process based on your understanding of how the circuit operates. This is the time when there is no substitute for advanced systems training.

The graphic on the next page shows the diagnostic flow chart for Strategy Based Diagnostics.
Verify the Customer Concern Expanded:

Know how the vehicle systems operate, the driving habits of the customer and the environmental driving conditions.

The figure on the next page shows a 2001 VW Passat Central Locking Module located in a pan below the driver’s seat. Mud and snow can leak into this box and short out the computer, thus killing the communication with the Scan Tool. At this time there is no TSB on this problem, but you can find information on the problem by browsing the Internet.

Even though the Internet is a great resource for information, you should take the time to make sure the information is accurate by checking other websites.

**Note:** Bosch does not support, promote, or endorse any websites other than its own company website (www.Bosch.com).
Perform published diagnostic system checks expanded:

Connecting the Scan Tool:

Is there power on Pin 16 to power-up the Scan Tool? Many OEM scan tools may not have internal batteries and will require Pin 16 to have power in order for the scan tool to communicate. Be aware that no power on Pin 16 may affect some aftermarket scan tools (consult your operator’s guide). Many times Pin 16 will not have power due to something as simple as a blown cigarette lighter fuse. Remember Pin 16 is Battery Power Un-switched. Many technicians panic when their scan tool doesn’t power up off the 16 Pin connector. In some cases the technician will think the computer or computer(s) are dead and not communicating with the scan tool. A quick work around is to power up the scan tool through an alternate battery source or AC power source. Remember Pin 16 has nothing to do with communication, it is only there to power up your scan tool for diagnosis.

Pins 4&5 are also important as one of these grounds will be needed for your Scan Tool to power up the OBD II link and establish a reference link for scan tool communication. If you are having communication problems it is imperative that you check the integrity of these grounds. In some instances one of these grounds may be open or have high resistance. There is also a possibility that the scan tool might complete a ground that is faulty when the scan tool is not connected. If the OBD connector has power or ground problems you should validate the connections when the scan tool is removed.
NOTES:

OBD II Network Diagnostics

Using the scan tool in conjunction with a 16 Pin Breakout Box:

Different types of 16 Pin breakout boxes are available in the aftermarket. Some breakout boxes hook up in parallel, allowing you only the ability to probe the circuit with a scope or DVOM. Other breakout boxes like the AES LineSpi, hook in a series circuit, allowing the scan tool to command data bus protocols from the on-board computer while diagnosing with a lab scope or DVOM.

AES LineSpi, MTS 5200, MTS 3100 connected to Ford ISO 9141-2 in Module Status Check. (www.aeswave.com)
What Computers Are Talking on the Network?

When diagnosing vehicle driveability problems with networked computer modules, know what computers are on the network for the particular vehicle application you are working on. Many vehicle applications may add or delete computer modules based on the amount of accessories and options. Most electronic information systems will have a computer network schematic at the beginning of the wiring diagrams section.

The Invention of the “U Code”:

“U” codes were classified by the SAE as the 4th item for trouble code descriptions. In the early years of OBD II the “U” designation was classified as undefined. “U” codes are becoming more prevalent on today’s modern vehicles adding more advanced on-board diagnostics. Control modules are now programmed to know what other modules they should be in communication with on the network. Based on network communication problems, a “U” code could be set if a particular module was not communicating on the network. Flash reprogramming new control modules is necessary because new control modules need to know how that particular vehicle is configured in order to perform their function on the network properly.

• The first character identifies the system related to the trouble code.
  - P = Powertrain
  - B = Body
  - C = Chassis
  - U = Network (for years “U” was undefined)
Example of Generic U-Codes:
U0100 Lost Communication With ECM/PCM “A”
U0101 Lost Communication With TCM
U0102 Lost Communication With Transfer Case Control Module
U0103 Lost Communication With Gear Shift Module
U0104 Lost Communication With Cruise Control Module
U0105 Lost Communication With Fuel Injector Control Module
U0106 Lost Communication With Glow Plug Control Module
U0107 Lost Communication With Throttle Actuator Control Module
U0108 Lost Communication With Alternative Fuel Control Module
U0109 Lost Communication With Fuel Pump Control Module
U0110 Lost Communication With Drive Motor Control Module
U0111 Lost Communication With Battery Energy Control Module “A”
U0112 Lost Communication With Battery Energy Control Module “B”
U0113 Lost Communication With Emissions Critical Control Information
U0114 Lost Communication With Four-Wheel Drive Clutch Control Module
U0115 Lost Communication With ECM/PCM “B”
U0116 Reserved by Document
U0117 Reserved by Document
U0118 Reserved by Document
U0119 Reserved by Document
U0120 Reserved by Document
U0121 Lost Communication With Anti-Lock Brake System (ABS) Control Module

Example of GM Manufactured Specific “U” Codes:
U1000 Class 2 Communication Malfunction
U1001 U1254 - Loss of XXX Communications
U1002 U1015 - Loss of serial communications for Class 2 devices
U1016 Loss of Class 2 Communication with VCM
U1016 Loss of Communications with PCM
U1017 U1025 - Loss of serial communications for Class 2 devices
U1026 Loss of ATC Class 2 Communication
U1027 U1039 - Loss of Serial Communications for Class 2 Devices
U1040 Loss of Class 2 Communications with ABS
U1041 Loss of EBCM Communication
U1042 Lost Communications with Brake/Traction Control System
U1043 U1055 - Loss of Serial Communications for Class 2 Devices
U1056 Loss of Communications with RSS
U1057 U1060 - Loss of Serial Communications for Class 2 Devices
U1161 Loss of PDM Serial Data

*Bosch Diagnostics conducts courses on this subject as well as many other topics in the field of automotive and diesel technology. For more information on courses in your area, go to www.boschtechinfo.com or call (800) 321-4889.*
2009 Update Course (take home) Examination

Student Examination Instructions:
1. Read the two articles (noted below) that were provided to you by your instructor:
   • “Meddle with the Pedal: Electronic Throttle Control” (Mike Dale, Motors Magazine)
   • “Diagnostics Using OBD II Data Bus Communication Networks” (Bosch)

   NOTE
   Your instructor should allow you at least 2 days to complete this assignment. To pass this examination, you must answer 10 questions or

2. Using the articles noted above, answer the following questions:

Questions #: 1 – 7 can be answered using the article titled “Meddle with the Pedal: Electronic Throttle Control”

(Circle the best answer)
1) What two factors are fuel economy and emissions output per mile traveled directly related to?
   a) Vehicle size and tire size
   b) Vehicle size and transmission type
   c) Vehicle size and engine size
   d) Engine type and vehicle accessories

2) Which of the following reflects the article’s statement regarding engine efficiency/emissions on today’s vehicles?
   a) Most vehicle engines are not large enough to provide adequate torque for most real-world operating conditions.
   b) The “sweet spot” of engine efficiency (peak efficiency point) is not the “sweet spot” of emissions output.
   c) Pumping loss is the major cause of efficiency losses at low speed.
   d) Friction losses (e.g. pistons, piston rings, cylinder, etc) will become more significant as engine size increases.

3) Which statement is true regarding the effects of engine fuel enrichment to achieve maximum engine torque output?
   a) Engine fuel consumption is higher, and emissions are lower when the engine is at maximum torque output.
   b) Engine fuel consumption is higher, and emissions are higher when the engine is at maximum torque output.
   c) Engine fuel consumption is lower, and emissions are higher when the engine is at maximum torque output.
   d) Engine fuel consumption is lower, and emissions are lower when the engine is at maximum torque output.
“Meddle with the Pedal: Electronic Throttle Control” Article - Examination Questions (con’t):

4) Which of the following ETC system strategies have the greatest impact on emissions performance?
   a) Dual and offset voltage outputs to PCM.
   b) Variable displacement strategies.
   c) Concise throttle position signal return to PCM.
   d) Concise throttle position strategies employed during cold engine operation.

5) What kind of redundancy does the ETC pedal angle sensor employ?
   a) There is no redundancy, because it is mitigated by the use of rationality algorithms embedded in the firmware of the ECM to test for any errors in the sensor signal.
   b) There is a redundancy by dual and equal voltage outputs from the sensor
   c) There is a redundancy by dual and offset voltage outputs from the sensor
   d) There is a redundancy by a backup TPS mounted on the other side of the throttle plate.

6) During cold start engine operation, what strategy does the ETC system employ to quickly heat the catalytic converter and ensure driver comfort?
   a) It retards the timing and leans the fuel mixture, and adjusts the throttle pedal position for driver comfort.
   b) It advances the timing and leans the fuel mixture, and adjusts the throttle pedal position for driver comfort.
   c) It retards the timing and enriches the fuel mixture, and adjusts the throttle pedal position for driver comfort.
   d) It retards the timing and leans the fuel mixture, pumps air (AIS) into the catalytic converter, and adjusts the throttle pedal position for driver comfort.

7) What strategy does the ETC system employ during acceleration and deceleration to minimize engine pumping losses?
   a) It pluses the throttle open to allow more air on deceleration and acceleration to reducing pumping losses.
   b) It adjusts the throttle to a position more favorable to reducing pumping losses than the driver selected.
   c) It activates a pulse width modulated auxiliary air bleed during deceleration and acceleration to reducing pumping losses.
   d) It advances or retards the valve timing of the exhaust camshaft to reducing pumping losses.
Questions #: 8 – 15 can be answered using the article titled “Diagnostics Using OBD II Data Bus Communication Networks” (Bosch)

8) Which of the following conditions is the most common failure of network systems?
   a) Bad system connections creating opens.
   b) Severe wet weather conditions.
   c) Shorted control system actuators.
   d) Outside bus system controller magnetism.

9) Which of the following statements describes the primary purpose of a network system?
   a) Eliminates miles of wires.
   b) Eliminates connections and splices.
   c) Eliminates voltage drop problems.
   d) All of the above.

10) What are the typical resistance values of a terminating resistor in a high speed CAN network system?
    a) 120 ohms with an operating range of 118 – 132 ohms.
    b) 118 ohms with an operating range of 110 – 140 ohms.
    c) 125 ohms with an operating range of 120 – 130 ohms.
    d) None of the above.

11) What is the purpose of a terminating resistor in a CAN system?
    a) Create proper electrical load.
    b) Prevents voltage shorts.
    c) Keeps output data clean.
    d) Allows for multiple scanner connection.

12) When diagnosing a vehicle, using strategy based diagnostics, what should be the technician’s first step?
    a) Perform published diagnostic system checks.
    b) Verify the customer’s concern.
    c) Check for bulletins and other service information.
    d) Check for stored diagnostic trouble codes?

13) What is a common operating speed of a CAN “B” network system?
    a) Medium speed
    b) High speed
    c) Low speed
    d) 1 k bit/s
Diagnosing OBD II Data Bus Communication Networks Article – Examination Questions (con’t):

14) Which of the following faults would be the most likely cause of a scanner failing to establishing communication with an OBD II vehicle?
   a) Battery voltage at pin 16  
   b) Short to ground in pin 5  
   c) Open in pin 4 or 5  
   d) Short to ground in pin 4

15) What is the purpose of flash programming modules?
   A. New control modules become the primary module.
   B. New control modules reprogram the ECU.
   C. New control modules receive the lowest of priorities.
   D. New control modules need to know how a vehicle is configured.

Turn your examination in to the instructor to obtain partial course credit.
2009 UPDATE COURSE INTERNET LABORATORY EXAMINATIONS

Name:___________________________________  Date:________________

Using a personal computer that has internet capabilities, complete all the following examination exercises:

**Note:** You cannot pass the 2009 Update Smog Check Technician Update Course unless you complete this assignment, and submit it to your instructor for grading.

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**Exam Exercise #1: Obtaining an Internet Email Address**

**Note:** If you already have an internet email address, please enter that address in the area noted in Step # 6, and continue to Exam Exercise #2.

**Step #1:** In the internet browser address box, type: www.hotmail.com and press the “Enter” button.

**Step #2:** When a new page comes up on the screen, click on the box titled “Sign Up” under the title “Windows Live Hotmail” section.

**Step #3:** When a new page comes up on the screen, click on the box titled “Get It” under the title “Windows Live Hotmail.”

**Step #4:** When a new page comes up on the screen, make up your own personal email user name, and enter it in the box next to the title “*Windows Live ID:” For security purposes, your user name (ID) should be a combination of letters, numbers, and certain characters (like: periods, underscore, hyphens). An example of an ID name might be: “JD.Johns56”. After typing your user name into the ID box, click on the “Check Availability” box. If your user ID has not already been taken, you will see green letters that will state your user ID is available (example: JD.Johns56@live.com is available”). If red letters appear, then the user ID has already been taken, so repeat Step #4 until you find an unused ID name.

**Step #5:** Complete the rest of the form: 1.) “Choose a password” 2.) “Password reset information” 3.) “Your information” 4.) “Type the characters you see in this picture,” and 5.) “Review and accept the agreements.”

**Step #6:** Click on the box titled “I accept.”

**Enter your new Hotmail email address below:**

_________________________________________________________@live.com

**OR**

**Enter your current email address below:**

_________________________________________________________@_____________________________
Exam Exercise #2: Lambda Calculations

Step #1: In the internet browser address box, type: www.smogsite.com and press the “Enter” button.

Step #2: Find the word “Calculators” on the list on the left side of the page. Place your cursor on that word, and click on it with the left mouse button.

Step #3: When a new page comes up on the screen, find the words “Lambda Calculator” on the list on the top (middle) area of the page. Place your cursor on those words, and click on them with the left mouse button.

Step #4: When a new page comes up on the screen, enter the following vehicle tailpipe emission readings in the appropriate boxes on the calculator, and then click with the left mouse button on the “calculate Lambda” button (box):

Vehicle #1 Emission Readings:

<table>
<thead>
<tr>
<th>HC</th>
<th>CO</th>
<th>CO₂</th>
<th>NOₓ</th>
<th>O₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>1088</td>
<td>1.67%</td>
<td>12.67%</td>
<td>108 ppm</td>
<td>.01%</td>
</tr>
</tbody>
</table>

Questions on Vehicle #1:

1. What is the Lambda calculation for this vehicle? _____

2. What is the A/F ratio for this vehicle? _____

3. Is Lambda within the acceptable range for a (3 way) catalytic converter to operate efficiently? Yes No (circle one)

4. Is the A/F ratio: Lean Rich Stoichiometric (circle one)

Step #5: Click on the calculator “Reset” button, and follow procedures noted in step #4 using Vehicle #2 emission readings:

Vehicle #2 Emission Readings:

<table>
<thead>
<tr>
<th>HC</th>
<th>CO</th>
<th>CO₂</th>
<th>NOₓ</th>
<th>O₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>0.01%</td>
<td>13.01%</td>
<td>1223 ppm</td>
<td>1.5%</td>
</tr>
</tbody>
</table>

Questions on Vehicle #2:

1. What is the Lambda calculation for this vehicle? _____

2. What is the A/F ratio for this vehicle? _____

3. Is Lambda within the acceptable range for a (3 way) catalytic converter to operate efficiently? Yes No (circle one)

4. Is the A/F ratio: Lean Rich Stoichiometric (circle one)
Step #6: Click on the calculator “Reset” button, and follow procedures noted in step #4 using Vehicle #3 emission readings:

**Vehicle #3 Emission Readings:**

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>HC</td>
<td>CO</td>
<td>CO₂</td>
<td>NOₓ</td>
<td>O₂</td>
</tr>
<tr>
<td>10 ppm</td>
<td>0.01%</td>
<td>14.8%</td>
<td>32 ppm</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Questions on Vehicle #2:

1. What is the Lambda calculation for this vehicle?______

2. What is the A/F ratio for this vehicle?______

3. Is Lambda within the acceptable range for a (3 way) catalytic converter to operate efficiently?  Yes  No  (circle one)

4. Is the A/F ratio:  Lean  Rich  Stoichiometric  (circle one)

---

Exam Exercise # 3: Manufacturer Websites

**Manufacturer Website Lab Exam #1:**

**Step #1:** In the internet browser address box, type: [www.kiatechinfo.com/index.asp](http://www.kiatechinfo.com/index.asp) and press the “Enter” button.

**Step #2:** Place your cursor on the box titled “Register” and click on it with the left mouse button.

**Step #3:** Enter the registration information requested on the screen (email address, password; of your own creation, and name) then click with the left mouse button on the box titled “Submit.”

**Step #4:** Enter your email address and password in the appropriate boxes, then click with the left mouse button on the box titled “Login.”

**Step #5: Case Scenario:**

You are working on a **2005 Kia Optima (production date 9/31/2004)**, that has a **P0449** (EVAP Emissions System – Vent valve/solenoid circuit) diagnostic trouble code (DTC) that has caused the MIL to illuminate. You have already performed a visual inspection of the vehicle’s EVAP system, and found no problems. You now want to see if there are any Technical Service Bulletins (TSBs) related to this DTC. Place your cursor over the letters “**TSB**” (left side of screen) and click on those letters with the left mouse button.

**Step #6:** Find the title **“Group”** and the nearby box, and then click with the left mouse button on the drop down list/menu arrow (small arrow pointing down on right of box). Find the words **“Emission Control System”** and move your cursor over these words and click with the left mouse button.

**Step #7:** Find the title **“Model”** and the nearby box, and then click with the left mouse button on the drop down list/menu arrow. Find the words **“Optima (MS) (2001 ~ 2006)”** and move your cursor over these words and click with the left mouse button.

**Step #8:** Click with the left mouse button on the box titled **“GO.”**
Manufacturer Website Lab Exam #1 (con’t):

**Step #9:** Below the box titled “TSB No.” place your course over each (KT) number and click with the left mouse button on the number. Search each TSB until you find one related to the DTC noted above. Read the entire TSB.

**Answer the following questions regarding the TSB related to the DTC noted in the Case Scenario:**

1. What is the number of the TSB? ________________________
2. What part is described in this TSB that may be of concern (no acronyms)? __________________________________________
3. What do the last two digits on the CCV housing indicate? __________________
4. Should you replace a CCV (or be concerned) if the date of manufacturing is found to be 10/03/04? YES NO (circle one)
5. Where is the EVAP canister assembly located on this Optima? __________________
6. After installing a new CCV, and mounting the canister box assembly, what action should be taken with the ECM? ______________________________________________

Manufacturer Website Lab Exam #2:

Continue using the Kia website you are currently on and perform the following steps:

**Step #1: Case Scenario:**

You are working on a 3.8 L, 2007 Kia Amanti (GH), that has a P0110 (Intake Air Temperature Circuit Malfunction) diagnostic trouble code (DTC) that has caused the MIL to illuminate. You have already performed a visual inspection of the vehicle’s intake area, and found no problems. You now want to see if there are any Technical Service Bulletins (TSBs) related to this DTC. Place your cursor over the letters “TSB” (left side of screen) and click on those letters with the left mouse button.

**Step #2:** Find the title “Group” and the nearby box, and then click with the left mouse button on the drop down list/menu arrow. Find the words “Fuel System” and move your cursor over these words and click with the left mouse button on these words.

**Step #3:** Find the title “Model” and the nearby box, and then click with the left mouse button on the drop down list/menu arrow. Find the words “Amanti (2004 ~ 2009)” and move your cursor over these words and click with the left mouse button on these words.

**Step #4:** Click with the left mouse button on the box titled “GO.”
**Step #5:** Click your left mouse button on the following TSB #: KT2008040301.
**Step #6:** Read the entire TSB.
Manufacturer Website Lab Exam #2 (con’t):

Answer the following questions regarding the TSB related to the DTC noted in the Case Scenario:

1. According to the TSB, what is the “part failure” that illuminated the MIL and set a P0110 DTC? (read TSB carefully)

__________________________________________________________________

2. According to the second *NOTICE (box), what safeguards need to be made regarding the 1.) battery 2.) battery charger and 3.) the blower motor prior to PCM upgrading?

__________________________________________________________________
__________________________________________________________________

3. When the GDS tool reports that the PCM upgrade has been successfully completed, what should you do after you click “OK”, and turn off the ignition?

__________________________________________________________________

Exam Exercise # 4: BAR’s Smog Check Website

Vehicle Smog Check History:
Step #1: In the browser address box, type the following address: www.smogcheck.ca.gov and press the enter button.

Step #2: Left click on the words “Find Vehicle Smog Check History” on the left side of the screen (under “Quick Hits”).

Step #3: Enter in the following license plate number “5Z15386” In the box next to the titled “License or VIN:” Make sure the radial dial (small circle) next to the title “License Plate” has a dot in it; if not, click on that circle. Click on the box titled “Submit.”

Step #4: Review the information on this page.

Answer the following questions regarding this vehicle’s Smog Check History:

1. What Program Area is this vehicle subject to? ________________

2. What was the name of the facility that inspected this vehicle on 3/21/2005?

____________________________________________________________
BAR’s Smog Check Website Exam Exercise (con’t):

BAR ET Blasts:
Step #1: Click on the “Industry” tab at the top of the page.
Step #2: Under the title “Industry Reference,” click on the “BAR ET Blasts”
Step #3: Click on the year “2008.”
Step #4: Click on the words “New Smog Check Manuals.”
Step #5: Read the entire BAR ET Blast.

Answer the following questions related to the Smog Check Inspection manual noted above in the BAR ET Blast:

1. What are the names of the manuals that have replaced the Smog Check Inspection Manual (Revision 6)?
   ______________________________________________________________________
   ______________________________________________________________________

2. What future action will be taken with the “draft” Smog Check Inspection Procedures Manual?
   ______________________________________________________________________

ARB Aftermarket Parts Database:
Step #1: Click on the “Home” tab at the top left of the page.
Step #2: Find the blue bar that says “INFORMATION ABOUT” (light blue with white letters rectangle box area) and place your cursor over the tab below titled “References.” Click on the title “Air Resources Databases.”
Step #3: Click on the title “Aftermarket, Performance and Add-On Parts Information.”

Case Scenario:
The following vehicle has come into your shop for an initial Smog Check inspection: 1993 Chevrolet K-5 Blazer (full size) 5.7L (T.B.I.) engine, 2WD, automatic transmission, with chrome headers. Through discussion with your customer, you find that the headers do have an Executive Order (EO) number: D-215-58. Upon a visual inspection you notice that the catalytic converter is welded to the headers.

Step #4: Enter the above noted EO number into the box below the title “Search for Executive Order” and click on the box that is titled “Search for EOs.”

Answer the following questions related to the above noted EO number:

1. Who manufacturers these headers (i.e. tubular exhaust)? _______________________

2. Using the information noted above, what is the correct header part number that applies to this vehicle? ________________________
Smog Check Technician Renewal Procedures:

Step #1: In the browser address box, type the following address:
www.smogcheck.ca.gov and press the enter button.

Step #2: Click on the “Industry” tab (at the top of the page).

Step #3: Locate the rectangular box (light blue with white letters) titled “INDUSTRY REFERENCE.” In that subject box area, locate the title “Technician Information” (bottom of box) and click on that title.

Step #4: In the dark blue rectangular box (top of screen) under the “Industry” tab, click on the title “Getting Licensed.”

Step #5: Under the title “Help With License” click on the title “1) Technician and Adjuster Licensing.”

Step #6: Under the title “Technician and Adjuster Licensing and Renewals” click on the title “I would like to renew my license.”

Step #7: Click on the title “I would like to renew my Advanced Smog Technician License.”

Step #8: Check mark all the requested information on that page, and click on the words “Go to next step.” (step #3)

Answer the following questions related to information on step #3 noted above:

1. It is BAR’s responsibility to send you a license renewal notice every two years, so you should not try to renew your license until you receive this notice.
   **True**   **False**  (circle one)

2. What date is used to determine the expiration month of a Smog Check technician license? _______________________________________________________

3. If a “Deficiency Letter” is sent to you by BAR’s Licensing Unit, advising you that they need further information (i.e. course completion certificate, etc.) to process your renewal application, what is an acceptable communication mechanism (other than mailing the material) to reply to them?
   ___________________________________________________________________

4. If a technician did not receive a renewal notice/application from BAR, where can he/she obtain a renewal application (per step #3)?
   ___________________________________________________________________

TURN IN YOUR HOMEWORK ASSIGNMENT TO YOUR INSTRUCTOR FOR PARTIAL CREDIT FOR THE COURSE.
**HC Diagnosis**  (non-computer controlled vehicle)

- **Check ignition timing**  (base and advance as applicable.)

- **Verify engine integrity**  (relative compression, engine vacuum, compression)

- **Ignition system analysis**  (firing lines, spark lines duration & slope)

- **Lean misfires**  (intake manifold leaks, defective vacuum hoses or actuators)

- **Poor fuel vaporization**  (plugged intake manifold cross-over, combustion chamber quench areas)

- **Air injection reaction (AIR) system**  (switching, operating pressure)

- **Is the catalyst operating properly?**

**Tools & Techniques**

- Timing light, magnetic timing, tachometer, base timing specifications and timing advance specifications (if available)

- Vacuum gauge / transducer diagnosis, relative compression / cylinder balance test, dry compression test

- Secondary, primary ignition system oscilloscope analysis. Look at spark lines for evidence of lean mixtures / poor flame propagation (NOx failures).

- Carburator cleaner / propane, smoke machine, vacuum leak detector, lambda calculator, secondary ignition

- Spark line diagnosis, cylinder balance test, digital pyrometer

- AIR system operation description. Use 4/5 gas analyzer and look for O2 drop with AIR supply hose pinched off or disconnected

- Manufacturer's test procedures, 4/5 gas analysis (high CO2, low O2), cranking CO2, snap O2, temperature gain, intrusive
HC Diagnosis (computer controlled vehicle)

Refer to "High HC Non-feedback" diagnostic flowchart

DTC’s?

Yes

Discern between hard and soft codes

No

Follow manufacturer’s or published diagnostic / repair procedures for hard codes

Test O₂S with DSO

O₂S in good serviceable condition?

Yes

Map O₂S signal with DSO

No

Upon repair of O₂S circuit or replacement of sensor, re-test O₂S

Propane enrichment tool, DSO minimum voltage = 0 - 175mV maximum = 800 - 1000mV rate of change = < 100 mS (175mV - 800 mV)

Tools & Techniques

Timing; mechanical, electrical lean air/fuel misfires, vaporization, AIR, catalyst

Scan tool, jumper wire, screwdriver, DTC pulling instructionis

Pull codes, record codes in the order they are displayed, erase codes, operate vehicle, pull hard codes

Scan tool, multimeter, DSO, DTC diagnostic flowcharts, diagnostic & repair information

High frequency signal = misfire Signal biased below 450 mV = lean mixture Signal biased above 450 mV = rich mixture
CO Diagnosis
(non-computer controlled vehicle)

Check air intake system for restrictions

Check for unmetered fuel entering the engine

Check carburetor operation

Check air injection system operation

Check catalyst(s) operation

Tools & Techniques

Plugged / dirty air filter, improper choke operation, plugged PCV system, improper TAC operation

Improper EVAP purge operation, saturated EVAP canister, fuel contaminated engine oil (> 500 ppm HC after 5 minutes measured at the oil filler neck engine off)

Float level, choke operation, main metering, power valve, idle circuit

Use system description / operation to verify proper switching. Check operating pressure by pinching off supply hose and verifying O₂ drop in tailpipe emissions

After upstream repairs are complete, use manufacturer's procedures to test efficiency. Combinations of cranking CO₂, snap O₂, HC efficiency, temperature gain are useful when manufacturer's procedures aren't available.
CO Diagnosis
(computer controlled vehicle)

Refer to "High CO Non-Feedback" diagnostic flowchart

DTC's?

Yes

Discern between hard and soft codes

No

Follow manufacturer's or published diagnostic / repair procedures for hard codes

Review data stream (if available) or confirm related sensor/output performance. Test O₂S with DSO.

Check for vehicle computer operation (is the fuel metering system capable of being artificially driven rich or lean, is the timing being controlled? Perform manufacturer's recommended system performance check)

Tools & Techniques

Air intake restriction, unmetered fuel, carburetor, air injection, catalyst operation

Scan tool, jumper wire, screwdriver, DTC pulling instructions

Pull codes, record codes in the order they are displayed, erase codes, operate vehicle, pull hard codes (OBD I)

Scan tool, multimeter, DCO, DTC diagnostic flowcharts, diagnostic & repair information

DMM, DSO, propane enrichment tool, break-out box

4/5 gas analyzer, timing light, sensor simulator

Tools & Techniques
NO\textsubscript{x} Diagnosis

- Check ignition timing (base and advance as applicable.)
- Check exhaust gas recirculation (EGR) system (if equipped)
- Check for lean air/fuel mixture
- Check for excessive coolant and/or intake air temperature
- Check for excessive combustion chamber pressure
- Check for proper fuel octane rating
- Check catalyst operation (vehicles equipped with a reduction catalyst only)

Tools & Techniques

- Timing light, magnetic timing, tachometer, base timing specifications and timing advance specifications (if available)
- Vacuum gauge/pump, tachometer, scantool
- Lambda calculator, gas analyzer, biased O\textsubscript{2}S pattern, fuel trim data, secondary ignition pattern
- Pyrometer, scantool, temperature probe, thermometer
- Compression gauge, borescope, TSBs
- Owner's manual, vehicle owner
- Manufacturer's test procedures, 4/5 gas analysis (high CO\textsubscript{2}, low O\textsubscript{2}), cranking CO\textsubscript{2}, snap O\textsubscript{2}, temperature gain, intrusive
OBD II Diagnostics

MIL illuminated?

Yes

Pull DTC's and record freeze frame data

Follow manufacturer's or published diagnostic / repair procedures for DTC's. Begin with the DTC referred to in freeze frame data

Review pending DTC's, monitor status, mode 6 and mode 5 data, fuel trim and misfire data

Perform a system performance check and/or a complete drive cycle as per manufacturer's instructions

Check PCM for DTC's (pending or matured), review mode 6 and mode 5 data for failed test results

No

Scan tool

Tools & Techniques

MIL functional test (KOEO bulb check)

Scan tool, paper & pencil. Do not erase DTC's unless instructed to do so by diagnostic / repair procedures

Scan tool, multimeter, DSO, DTC diagnostic flowcharts, diagnostic & repair information

Manufacturer's or published diagnostic & repair information

Scan tool
Diagnostic Preliminaries

1. Vehicle fails Smog Check
2. Prepare an estimate for diagnosis
3. Obtain customer authorization
4. Verify customer complaint (baseline inspection in pre-inspection mode, training mode, manual mode or partial pre-inspection) when appropriate
5. Select a method to document diagnosis (vehicle information datasheet, tech notes, etc.)

Diagnostic Assumptions
- Visual inspection
- TSB's and helpful hints
- Engine integrity
- Powers and grounds

Post-diagnosis process

1. Analyze diagnostic information (component test data, measurements, waveform analysis, etc.)
2. Prepare a repair strategy based on diagnostic information
3. Prepare an estimate to repair defects relative to the failure determined in the diagnosis
4. Discuss the repair strategy with the customer and obtain authorization
5. Perform authorized repairs, gauge repair effectiveness
A 1991 Honda CRX 1.6L 4 cylinder engine, failed Smog Check for excessive HC’s during the 50/15 mode. The vehicle is equipped with PCV, EVAP, CAT, SPK, FI, HO2S. The vehicle passed both the visual and functional portions of the inspection.

<table>
<thead>
<tr>
<th>Test RPM</th>
<th>MEAS CO2</th>
<th>MEAS O2</th>
<th>HC (PPM)</th>
<th>MAX CO</th>
<th>AVE MEAS</th>
<th>MAX CO</th>
<th>AVE MEAS</th>
<th>MAX NOx</th>
<th>AVE MEAS</th>
<th>MAX NOx</th>
<th>AVE MEAS</th>
<th>MEAS Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 mph</td>
<td>1827</td>
<td>14.44</td>
<td>0.10</td>
<td>134</td>
<td>31</td>
<td>847</td>
<td>237</td>
<td>548</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
</tr>
<tr>
<td>25 mph</td>
<td>2020</td>
<td>14.70</td>
<td>0.03</td>
<td>108</td>
<td>20</td>
<td>786</td>
<td>199</td>
<td>548</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
</tr>
</tbody>
</table>

The technician performed the following diagnostic tests:
- Cylinder balance test – cyl. # 4 showed low contribution
- Cylinder leakage test – cyl. # 4 = excessive leakage exhaust
- DTC’s checked – none present
- TSB – vehicle fails State I/M test due to improper warm-up procedures. Keep engine at operating temperature (cooling fan cycles on/off twice). Stabilize temperature, raise engine speed to 3500 rpm, allow throttle to snap closed.
- HO2S checked
  - Minimum voltage 200mV
  - Maximum voltage 810mV
  - Rise time 371mS

Based on this diagnostic information, the technician recommended adjusting the valves and replacing the HO2S.

The after-repairs emission readings are passing, but still reflect higher than average HC’s.

<table>
<thead>
<tr>
<th>Test</th>
<th>RPM</th>
<th>MEAS CO2</th>
<th>MEAS O2</th>
<th>HC (PPM)</th>
<th>MAX CO</th>
<th>AVE MEAS</th>
<th>MAX CO</th>
<th>AVE MEAS</th>
<th>MAX NOx</th>
<th>AVE MEAS</th>
<th>MAX NOx</th>
<th>AVE MEAS</th>
<th>MEAS Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 mph</td>
<td>1857</td>
<td>15.00</td>
<td>0.10</td>
<td>134</td>
<td>31</td>
<td>847</td>
<td>237</td>
<td>844</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
</tr>
<tr>
<td>25 mph</td>
<td>2006</td>
<td>15.03</td>
<td>0.05</td>
<td>108</td>
<td>20</td>
<td>786</td>
<td>199</td>
<td>593</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
</tr>
</tbody>
</table>

What diagnostic steps could have been performed to more thoroughly address the HC failure?
A 1995 Plymouth Neon, 2.0L 4 cylinder engine, failed Smog Check for excessive HC’s during the 25/25 mode. The technician tested the HO2S and recorded the following readings:

Minimum voltage: 104 mV

Maximum voltage: 910 mV

Rise time: 68 mS

The technician performed a cranking CO2 test on the vehicle’s catalytic converter and obtained the following readings:

HC: 9327 ppm

CO2: 10.5 %

Based on this diagnostic information, the technician recommended replacing the catalyst to resolve the HC failure.

What diagnostic steps could have been performed to more thoroughly address the HC failure?
Smog Check Vehicle Inspection Report (VIR)

Vehicle Information

Test Date/Time: 04/01/2008 @ 04:12 PM
Model-Year: 1995
Make: Plymouth
License: 5XXXXX
State: CA
Engine: 2.0L
Type: Passenger
GVWR: 0
Test Weight: 2625
Odometer: 100528
Certification: California
Fuel-Type: Gasoline
Exhaust: Single

Overall Test Results

Comprehensive Visual Inspection: PASS
Functional Check: PASS
Emissions Test: FAIL

Repairing your vehicle is necessary to help California reduce smog-forming emissions and reach our air quality goals.

Emission Control Systems Visual Inspection/Functional Check Results
(Visual/Functional tests are used to assist in the identification of crankcase and cold start emissions which are not measured during the ASM test.)

<table>
<thead>
<tr>
<th>RESULT</th>
<th>ECS</th>
<th>RESULT</th>
<th>ECS</th>
<th>RESULT</th>
<th>ECS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass-</td>
<td>PCV System</td>
<td>N/A-</td>
<td>Thermostatic Air Cleaner</td>
<td>Pass-</td>
<td>Fuel Injection</td>
</tr>
<tr>
<td>Pass-</td>
<td>Catalytic Converter</td>
<td>N/A-</td>
<td>Air Injection</td>
<td>Pass-</td>
<td>System Malfunction Light</td>
</tr>
<tr>
<td>Pass-</td>
<td>Fuel Cap Visual Test</td>
<td>N/A-</td>
<td>Other Emission Related Comp.</td>
<td>Pass-</td>
<td>Oxygen Sensor</td>
</tr>
<tr>
<td>Fail-</td>
<td>Fuel Cap Functional Test</td>
<td>Pass-</td>
<td>Liquid Fuel Leaks</td>
<td>Pass-</td>
<td>Wiring to Sensors/Switches</td>
</tr>
<tr>
<td>N/A-</td>
<td>EGR Functional</td>
<td>Pass-</td>
<td>Fuel EVAP Functional</td>
<td>Pass-</td>
<td>Ignition Spark Controls</td>
</tr>
<tr>
<td>N/A-</td>
<td>Fillpipe Restrictor</td>
<td>Pass-</td>
<td>Fuel EVAP Controls Visual</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pass-</td>
<td>Vacuum Lines to Sensors/Switches</td>
<td>N/A-</td>
<td>Ignition Timing 0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ASM Emission Test Results

<table>
<thead>
<tr>
<th>Test RPM</th>
<th>% CO2</th>
<th>% 02</th>
<th>HC (PPM)</th>
<th>CO (%)</th>
<th>NOx (PPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 mph</td>
<td>2184</td>
<td>14.4</td>
<td>0.7 93 21 93</td>
<td>0.57 0.06 0.05</td>
<td>720 150 43</td>
</tr>
<tr>
<td>25 mph</td>
<td>1988</td>
<td>14.5</td>
<td>0.5 59 13 88</td>
<td>0.55 0.05 0.05</td>
<td>774 136 6</td>
</tr>
</tbody>
</table>

MAX = Maximum Allowable Emissions  GP = Gross Polluter Limits  MEAS = Amount measured

Smog Check Inspection Station Information

BAR
10240 Systems Parkway
Sacramento, CA 95827
(916) 255-0000
Station Number: RA000000

Technician Name/Number: XXXX XXXXXXXX/EA000000
Repair Tech Name/Number: N/A
Software Version/EIS Number: 9506/XX000000

I certify, under penalty of perjury under the laws of the State of California, that I inspected the vehicle described above, that I performed the inspection in accordance with all bureau requirements, and that the information listed on this vehicle inspection report is true and correct.

4/1/08
Date

X
Technician’s Signature
Vehicle Information Data Sheet

<table>
<thead>
<tr>
<th>Vehicle Make:</th>
<th>Model:</th>
<th>Year:</th>
<th>VIN #:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plym</td>
<td>Neon</td>
<td>1995</td>
<td>1P3ES27C2SDXXXXXX</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>License #:</th>
<th># of Cylinders:</th>
<th>Engine Size:</th>
<th>Mileage:</th>
<th>Date:</th>
<th>RO #:</th>
</tr>
</thead>
<tbody>
<tr>
<td>5XXXXX2</td>
<td>4</td>
<td>2 L</td>
<td>100528</td>
<td>4/1/08</td>
<td>12345</td>
</tr>
</tbody>
</table>

Pre-repair Baseline Emissions Results

<table>
<thead>
<tr>
<th>Cut-points</th>
<th>Measured</th>
<th>Cut-points</th>
<th>Measured</th>
<th>Cut-points</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/15</td>
<td></td>
<td>25/25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HC</td>
<td>93</td>
<td>HC</td>
<td>93</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td></td>
<td>CO</td>
<td>.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOx</td>
<td></td>
<td>NOx</td>
<td>720</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOx</td>
<td></td>
<td>NOx</td>
<td>43</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lambda Calculation: 50/15 __________ Rich Lean 25/25 __________ Rich Lean

Visual/Functional Inspection

Use: P = Pass  M = Modified  S = Missing  D = Disconnected  F = Defective  N = Non-Applicable

PCV  TAC  EVAP  AIS  EGR  SPK  CAT  COMP  SENSORS

Functional Test  Idle Speed: _____  RPM Ignition Timing: _____  Spec: _____  Pass  Fail

EGR:  Pass  Fail  Cause (if fail):  Defective EGR  No Vacuum  Clogged Passages

How many inches of vacuum required to open EGR? _____ Hg.

OBD II: Communications:  Pass  Fail  Monitor Status:  Pass  Fail  MIL Command:  Pass  Fail


Secondary Air Injection

Air Injection Is AIS functioning correctly?  Yes  No  If no, why? ____________________________  ______________________________________________________________________________________

Computer Operation

Computer Code Stored?  Yes  No  If yes, are codes:  Hard  Soft  Record Codes:___________

Are codes emission related?  Yes  No  Define Codes:__________ __________ __________

Record results of diagnosis:_____________________________________________________________

Oxygen Sensor:  Good  Defective  Low Voltage 104 mV High Voltage 910 mV Rise Time 68 ms

CO Standards:  Pass  Fail

Is system in fuel control?  Yes  No  If no, is O2 biased?  Rich  Lean  Will the computer respond to artificial O2 input?  Yes  No  If no, why?__________________________________________
Visual Inspection of the Engine Performance Systems

HC Diagnosis

Misfires: Engine: Yes  No  Ignition: Yes  No  Air/Fuel: Yes  No

Notes:____________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________

CO Diagnosis

Average O2S Voltage:_______________________ Fuel Trim Data:________________________________
Air filter in good serviceable condition?:   Yes  No
Fuel Pressure: Specifications:_______________ Measured:________________________
Saturated EVAP control canister?: Yes  No  Engine oil contaminated with fuel?: Yes  No
Carburetor Operation:
  idle air/fuel adjustment_______  choke adjustment_______  float level_______ power valve operation_______

NOx Diagnosis

Ignition Timing Advance: Specifications: Centrifugal:__________ Vacuum:__________
  Measured: Centrifugal:__________ Vacuum:__________
Coolant Temperature:__________  Air Intake Temperature: TAC_________ EFE__________
Is engine compression excessive?: Yes  No  Is fuel octane correct?: Yes  No

Catalytic Converter Efficiency Diagnosis

Is catalytic converter in good serviceable condition?: Yes  No
Describe testing method(s) used: Cranking CO₂  HC 10176  CO₂ 10.4%

Diagnostic Summary:

__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________
The owner of a 1989 Dodge B150 Van complained of failing her Smog Check inspection and requested repairs. The original VIR showed the vehicle failed for tailpipe (HC, CO), visual (AIR) and functional (fuel cap).

An estimate to diagnose elevated HC and CO; to replace the frozen AIR pump and missing (presumably broken) AIR belt; and fuel cap was authorized by the customer.

The engine was recently rebuilt and functioning properly. With no DTC’s in memory, both the ECT and MAP sensors were checked and found to function normally. A labscope connected to the HO2S showed the signal fixed at 100 mV, even when the air fuel mixture was forced full rich or lean. With the HO2S disconnected from the harness the PCM did narrow the injector pulse width based on a corresponding artificial signal. The EGR system was checked and found to have excessive flow immediately off idle.

The repair strategy presented to the customer was as follows:

- Replace:
  - AIR pump and belt
  - HO2S
  - Fuel cap
  - EGR transducer

The vehicle passed the after-repairs certification inspection.

Attached are inspection reports, estimates/work orders, and diagnostic/repair strategy data.

The vehicle passed, but with emissions higher than average for other similar vehicles with passing emissions.

What diagnostic steps were missed and what potential defects were overlooked?
<table>
<thead>
<tr>
<th>QTY</th>
<th>DESCRIPTION OF PARTS</th>
<th>PRICE</th>
<th>DESCRIPTION OF LABOR</th>
<th>CHARGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AIR Pump (new)</td>
<td>$XXX</td>
<td>Diagnose Smog failure(s) – HC, CO</td>
<td>$XXX</td>
</tr>
<tr>
<td>1</td>
<td>Fuel Cap (new)</td>
<td>$XX</td>
<td>Replace AIR Pump and Belt</td>
<td>$XXX</td>
</tr>
<tr>
<td>1</td>
<td>AIR Belt (new)</td>
<td>$XX</td>
<td>Replace Fuel Cap</td>
<td>N/C</td>
</tr>
</tbody>
</table>

**SMOG CERTIFICATE**

**SUBTOTAL LABOR**

**SUBTOTAL PARTS**

**SALES TAX**

**TOTAL**

**ORIGINAL ESTIMATE $XXX.XX**

**AUTHORIZED BY MARY JONES**

“I acknowledge notice and oral approval of an increase in the original estimated price. (SIGNATURE OR INITIALS)”

**SAVE OLD PARTS**

**ADDITIONAL AUTHORIZATION: DATE__, TIME__, ADDITIONAL COST $XXX**

**REVISED ESTIMATE $407.20 AUTHORIZED BY__, PHONE#__, IN PERSON Y__, N__; SUBLET REPAIRS**

**TEARDOWN ESTIMATE: I UNDERSTAND THAT MY VEHICLE WILL BE REASSEMBLED WITHIN ____ DAYS OF THE DATE SHOWN ABOVE IF I CHOOSE NOT TO AUTHORIZE THE SERVICES RECOMMENDED.**
Smog Check Failure Diagnosis Case Study

1989 B150 Dodge Van - HC, CO, AIR, fuel cap failure

Smog Check Vehicle Inspection Report (VIR)

Vehicle Information

Test Date/Time: 2/21/2008 @ 11:56 am

Vehicle Information:

Test Date/Time: 2/21/2008 @ 11:56 am
Model-Year: 1989
Make: Dodge
Model: B150 Van
VIN: 2B7GB11X5KKXXXXXXX
Year: 1989
Make: Dodge
Model: B150 Van
Engine: 3.9L
Type: Truck
GVWR: 5300 lbs
Test Weight: 3625 lbs
Cylinders: 6
Odometer: 106,493 miles
Certification: California
Exhaust: Single
Fuel-Type: Gasoline

Overall Test Results

YOUR VEHICLE FAILED AND EXCEEDED THE GROSS POLLUTER LIMITS

Comprehensive Visual Inspection: FAIL  Functional Check: FAIL  Emissions Test: GROSS POLLUTER

Repairing your vehicle is necessary to help California reduce smog-forming emissions and reach our air quality goals.

Emission Control Systems Visual Inspection/Functional Check Results

(Visual/Functional tests are used to assist in the identification of crankcase and cold start emissions which are not measured during the ASM test.)

ASM Emission Test Results

<table>
<thead>
<tr>
<th>Test RPM</th>
<th>% CO2</th>
<th>% O2</th>
<th>HC (PPM)</th>
<th>CO (%)</th>
<th>NOx (PPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 mph</td>
<td>1395</td>
<td>7.1</td>
<td>0.0</td>
<td>124</td>
<td>311</td>
</tr>
<tr>
<td>25 mph</td>
<td>1384</td>
<td>7.1</td>
<td>0.0</td>
<td>104</td>
<td>261</td>
</tr>
</tbody>
</table>

MAX = Maximum Allowable Emissions  GP = Gross Polluter Limits  MEAS = Amount measured

Smog Check Inspection Station Information

First Street Auto
1234 1st Street
Anytown, CA 91111
(222) 333-4444
Station Number: RA12345

I certify, under penalty of perjury under the laws of the State of California, that I inspected the vehicle described above, that I performed the inspection in accordance with all bureau requirements, and that the information listed on this vehicle inspection report is true and correct.

___________________________          ____________________________________________________________
Date                                                                                                       Technician’s Signature
Smog Check Failure Diagnosis Case Study

1989 B150 Dodge Van - HC, CO, AIR, fuel cap failure

SHOP NAME: First Street Auto
1234 1st St.
Anytown, CA 91111
(222) 333-4444

ARD #: AA12345
REFERENCE REPAIR ORDER: RO444555 / 2/21/08
CAP #: 

TECH NAME: Al

TECH NOTES:

1989 Dodge B150, 106493, 3.9L V6, a/t, a/c

Noticed bad stumble/driveability problem during baseline test. Found EGR fully opening off idle. Transducer is bad. Disconnected EGR during duration of diagnostics.

Tested O2 sensor. Bad – Flat line @ 100 mV. No movement w/lean or rich condition (vacuum leak or propane).

Tested computer w/artificial signal – good response i.e., inj. pulse width drops & engine leans out.

Check MAP & ECT also – good.

Replace EGR transducer & O2S.

Air pump is bad – frozen w/belt missing (visual inspection)

Fuel cap defective

Replace & continue diagnosis
Smog Check Failure Diagnosis Case Study

1989 B150 Dodge Van - HC, CO, AIR, fuel cap failure

Vehicle Information Data Sheet

<table>
<thead>
<tr>
<th>Vehicle Make:</th>
<th>Model:</th>
<th>Year:</th>
<th>VIN #:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dodge</td>
<td>B150 Van</td>
<td>1989</td>
<td>2B7GB11X5KKXXXXXX</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>License #:</th>
<th># of Cylinders:</th>
<th>Engine Size:</th>
<th>Mileage:</th>
<th>RO #:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3XXX079</td>
<td>6</td>
<td>3.9 L</td>
<td>106493</td>
<td>R0444555</td>
<td>2/21/08</td>
</tr>
</tbody>
</table>

Pre-Diagnostic Tailpipe Readings

<table>
<thead>
<tr>
<th>Mode 1</th>
<th>Specs</th>
<th>Actual</th>
<th>Specs</th>
<th>Actual</th>
<th>Specs</th>
<th>Actual</th>
<th>Lambda Reading Mode 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC</td>
<td>HC</td>
<td>CO</td>
<td>CO</td>
<td>NO_x</td>
<td>NO_x</td>
<td>.682</td>
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<table>
<thead>
<tr>
<th>Mode 2</th>
<th>Specs</th>
<th>Actual</th>
<th>Specs</th>
<th>Actual</th>
<th>Lambda Reading Mode 2</th>
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</thead>
<tbody>
<tr>
<td>HC</td>
<td>HC</td>
<td>CO</td>
<td>CO</td>
<td>NO_x</td>
<td>.680</td>
</tr>
</tbody>
</table>

Road Test  
- Noises  
- Pings  
- Smokes  
- Misfires  
- Other bad stumble

Visual / Functional Inspection

Use: P = Pass  M = Modified  S = Missing  D = Disconnected  F = Defective  N = Non-Applicable

PCV  TAC  EVAP  AIS fail  EGR  SPK  CAT  COMP  SENSORS

Functional Test
- Idle Speed: 850 RPM  
- Ignition Timing: 10btdc Spec: 10btdc  
- EGR: Pass  
- Cause (if fail): Defective EGR  
- No Vacuum  
- Clogged Passages  
- Fuel leak: Pass  
- Fuel CAP: Pass  
- LPFET Pass  

How many inches of vacuum required to open EGR? 2 Hg.

Observations

EGR has excessive flow right off idle due to defective vacuum transducer.

Affecting vacuum and air fuel mixture
Smog Check Failure Diagnosis Case Study

1989 B150 Dodge Van - HC, CO, AIR, fuel cap failure

Vehicle Information Data Sheet

Computer Operation

Computer Code Stored? □ Yes ☑ No If yes, are codes: □ Hard □ Soft Record Codes:___________

Are codes emission related? □ Yes □ No Define Codes:_________ _________ _________

Record results of diagnosis:_____________________________________________________________

Oxygen Sensor: □ Good ☑ Defective Low Voltage: 100 mV High Voltage: 100 mV Rise Time: flatline ms

CO Standards: □ Pass ☑ Fail

Is system in fuel control? □ Yes ☑ No If no, is O2 biased? □ Rich ☑ Lean Will the computer respond to artificial O2 input? ☑ Yes □ No If no, why?______________________________________________

Air Injection Is AIS functioning correctly? □ Yes ☑ No If no, why? AIR pump frozen, belt broken/missing

Catalytic Converter Efficiency Test

O2 Snap Test CO2 Cranking Test Pre Cat / Post Cat (if used)

O2:_______% HC:________ppm Pre Cat:______ Post Cat:________

CO2:________% Efficiency:__________%

Is Cat OK? □ Yes □ No Untestable at this time due to lack of fuel control and high emissions

Final Diagnosis

1. What exhaust gas(s) caused the vehicle to fail the emission test? __________________________________________________________________________

2. Note the results of the above failed test: __________________________________________________________________________

3. Cross-reference the failed emission(s) with the related failed tests:

   HC: __________________________________________________________________________

   CO: __________________________________________________________________________

   NOx: __________________________________________________________________________

4. What component(s) or system(s) need to be repaired? __________________________________________________________________________

   __________________________________________________________________________
### Smog Check Failure Diagnosis Case Study

**1989 B150 Dodge Van - HC, CO, AIR, fuel cap failure**

<table>
<thead>
<tr>
<th>FIRST STREET AUTO</th>
<th>WORK ORDER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1234 FIRST STREET</td>
<td></td>
</tr>
<tr>
<td>ANYTOWN, CALIFORNIA 91111</td>
<td></td>
</tr>
<tr>
<td>TELEPHONE #1-222-333-4444</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CUSTOMER’S NAME</th>
<th>HOME PHONE#</th>
<th>WORK PHONE#</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MARY JONES</td>
<td>345-9876</td>
<td></td>
<td>2/21/08</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ADDRESS</th>
<th>VEHICLE MAKE &amp; MODEL</th>
<th>LICENSE #</th>
</tr>
</thead>
<tbody>
<tr>
<td>321 10TH STREET</td>
<td>1989 B150 Dodge Van</td>
<td>3XXX079</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CITY</th>
<th>VEHICLE IDENTIFICATION #</th>
<th>ODOMETER</th>
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</thead>
<tbody>
<tr>
<td>ANYTOWN, CALIFORNIA 91111</td>
<td>2B7GB11X5KXXXXXX</td>
<td>106493</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>QTY</th>
<th>DESCRIPTION OF PARTS</th>
<th>PRICE</th>
<th>DESCRIPTION OF LABOR</th>
<th>CHARGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AIR Pump (new)</td>
<td>$XXX</td>
<td>Diagnose Smog failure(s) – HC, CO</td>
<td>$XXX.00</td>
</tr>
<tr>
<td>1</td>
<td>Fuel Cap (new)</td>
<td>$XX</td>
<td>Replace AIR Pump and Belt</td>
<td>$XXX.00</td>
</tr>
<tr>
<td>1</td>
<td>AIR Belt (new)</td>
<td>$XX</td>
<td>Replace Fuel Cap</td>
<td>N/C</td>
</tr>
<tr>
<td>1</td>
<td>HO2S (new)</td>
<td>$XX.XX</td>
<td>Replace HO2S</td>
<td>$XX</td>
</tr>
<tr>
<td>1</td>
<td>EGR Transducer (new)</td>
<td>$XX.XX</td>
<td>Replace EGR Transducer</td>
<td>$XX</td>
</tr>
</tbody>
</table>

Smog Inspection: N/C

SMOG CERTIFICATE

SUBTOTAL LABOR

SUBTOTAL PARTS

SALES TAX

TOTAL

**ORIGINAL ESTIMATE:** $XXX.00  
**AUTHORIZED BY:** MARY JONES

**SAVE OLD PARTS:** Y  X  N

**ADDITIONAL AUTHORIZATION:** DATE 2/22/08  TIME 3:30 pm  
**ADDITIONAL COST:** $XXX.XX

**REVISED EST AUTHORIZED BY:**  
**IN PERSON:** Y  N  

**SUBLET REPAIRS:**

**TEARDOWN ESTIMATE:** I UNDERSTAND THAT MY VEHICLE WILL BE REASSEMBLED WITHIN ____ DAYS OF THE DATE SHOWN ABOVE IF I CHOOSE NOT TO AUTHORIZE THE SERVICES RECOMMENDED.

“I acknowledge notice and oral approval of an increase in the original estimated price.  
(SIGNATURE OR INITIALS)”
Smog Check Failure Diagnosis Case Study

1989 B150 Dodge Van - HC, CO, AIR, fuel cap failure

Smog Check Vehicle Inspection Report (VIR)

Vehicle Information

Test Date/Time: 2/25/2008 @ 7:59 am
Model-Year: 1989
Make: Dodge
Model: B150 Van
License: 3XXX079
State: CA
VIN: 2B7GB11X9KKXXXXXX
Engine: 3.9L
Type: Truck
Transmission: Automatic
GVWR: 5300
Test Weight: 3625
Cylinders: 6
Odometer: 106495
Fuel-Type: Gasoline
Exhaust: Single
Certification: California
VLT Record #: XXXX

Overall Test Results
Congratulations. Your vehicle passed the enhanced Smog Check inspection, which helps California reach its daily goal of removing an extra 100 tons of smog-forming emissions from the air. Thank you for keeping your vehicle well maintained.

Comprehensive Visual Inspection: PASS  Functional Check: PASS  Emissions Test: PASS

Smog Check Certificate Number: AA007236
DMV ID Number: X345Z4Q6145Z

Your Smog check certificate has been electronically transmitted to DMV.
Your certificate is valid for 90 days from the date of issuance.
Please keep this copy for your records.

Emission Control Systems Visual Inspection/Functional Check Results
(Visual/Functional tests are used to assist in the identification of crankcase and cold start emissions which are not measured during the ASM test.)

<table>
<thead>
<tr>
<th>RESULT</th>
<th>ECS</th>
<th>RESULT</th>
<th>ECS</th>
<th>RESULT</th>
<th>ECS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass</td>
<td>PCV System</td>
<td>Pass</td>
<td>Thermostatic Air Cleaner</td>
<td>Pass</td>
<td>Fuel Injection</td>
</tr>
<tr>
<td>Pass</td>
<td>Catalytic Converter</td>
<td>Pass</td>
<td>Air Injection</td>
<td>Pass</td>
<td>System Malfunction Light</td>
</tr>
<tr>
<td>Pass</td>
<td>Fuel Cap Visual Test</td>
<td>Pass</td>
<td>Other Emission Related Comp.</td>
<td>Pass</td>
<td>Oxygen Sensor</td>
</tr>
<tr>
<td>Pass</td>
<td>Fuel Cap Functional Test</td>
<td>Pass</td>
<td>Liquid Fuel Leaks</td>
<td>Pass</td>
<td>Wiring to Sensors/Switches</td>
</tr>
<tr>
<td>N/A</td>
<td>EGR Functional</td>
<td>Pass</td>
<td>Fuel EVAP Functional</td>
<td>Pass</td>
<td>Ignition Spark Controls</td>
</tr>
<tr>
<td>N/A</td>
<td>Fillpipe Restrictor</td>
<td>Pass</td>
<td>Fuel EVAP Controls Visual</td>
<td>Pass</td>
<td>Ignition Timing 10B</td>
</tr>
<tr>
<td>Pass</td>
<td>Vacuum Lines to Sensors/Switches</td>
<td>Pass</td>
<td>Ignition Timing 10B</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ASM Emission Test Results

| Test RPM | % CO2 | % O2 | HC (PPM) | CO (%) | NOx (PPM) MEAS AVE MAX AVE MAX AVE MAX MEAS Results |
|----------|-------|------|----------|--------|-------------|--------|--------|-------------|--------|-------------|
| 15 mph   | 1455  | 13.3 | 2.2      | 2.3    | 34          | 70     | 0.75   | 0.11       | 0.52   | 1020        | 260    | 433        | Pass    |
| 25 mph   | 1444  | 13.2 | 2.3      | 2.3    | 104         | 53     | 0.95   | 0.10       | 0.66   | 880         | 217    | 314        | Pass    |

MAX = Maximum Allowable Emissions
AVE = Average Emissions For Passing Vehicles
MEAS = Amount measured

Smog Check Inspection Station Information

First Street Auto
1234 1st St.
Anytown, CA 91111
Station Number: RA12345

I certify, under penalty of perjury under the laws of the State of California, that I inspected the vehicle described above, that I performed the inspection in accordance with all bureau requirements, and that the information listed on this vehicle inspection report is true and correct.

Date

Technician’s Signature
A 1991 Acura Integra 1.8L 4 cylinder engine, failed Smog Check for excessive CO emissions during the 50/15 mode. The vehicle is equipped with PCV, EVAP, CAT, EGR, SPK, HO2S.

<table>
<thead>
<tr>
<th>Test RPM</th>
<th>CO2 MEAS</th>
<th>O2 MEAS</th>
<th>HC (PPM) MEAS</th>
<th>CO MEAS</th>
<th>NOx (PPM) MEAS</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 mph</td>
<td>1988</td>
<td>14.6</td>
<td>0.0</td>
<td>121</td>
<td>31</td>
<td>807</td>
</tr>
<tr>
<td>25 mph</td>
<td>2204</td>
<td>14.8</td>
<td>0.0</td>
<td>96</td>
<td>20</td>
<td>746</td>
</tr>
</tbody>
</table>

The technician performed the following diagnostic tests:
- Verified closed loop operation. HO2S varying from .1V to .9V
- Catalyst outlet temperature lower than inlet temperature - FAIL

Based on this diagnostic information, the technician recommended replacing the vehicle’s catalyst.

The after-repairs emission readings are passing, but still reflect higher than average HC’s.

<table>
<thead>
<tr>
<th>Test RPM</th>
<th>CO2 MEAS</th>
<th>O2 MEAS</th>
<th>HC (PPM) MEAS</th>
<th>CO MEAS</th>
<th>NOx (PPM) MEAS</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 mph</td>
<td>1973</td>
<td>15.2</td>
<td>0.0</td>
<td>121</td>
<td>31</td>
<td>807</td>
</tr>
<tr>
<td>25 mph</td>
<td>2183</td>
<td>15.2</td>
<td>0.0</td>
<td>96</td>
<td>20</td>
<td>746</td>
</tr>
</tbody>
</table>

What diagnostic steps could have been performed to more thoroughly address the CO failure?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
A 1984 Volvo 240 DL, 2.3L engine equipped with PCV, TAC, EVAP, CAT, FI, & HO2S failed 5015 and 25/25 for NO\textsubscript{x}.

<table>
<thead>
<tr>
<th>% CO\textsubscript{2}</th>
<th>% O\textsubscript{2}</th>
<th>HC (PPM)</th>
<th>CO (%)</th>
<th>NO\textsubscript{x} (PPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>RPM</td>
<td>MEAS</td>
<td>MEAS</td>
<td>MAX</td>
</tr>
<tr>
<td>15 mph</td>
<td>1712</td>
<td>15.1</td>
<td>0.3</td>
<td>135</td>
</tr>
<tr>
<td>25 mph</td>
<td>1754</td>
<td>14.4</td>
<td>0.7</td>
<td>110</td>
</tr>
</tbody>
</table>

The technician performed the following diagnostic tests:
- HO\textsubscript{2}S checked
  - HO\textsubscript{2}S signal fixed at 540mV

Based on this diagnostic information, the technician recommended replacing the HO\textsubscript{2}S.

Repairs were authorized and performed.

The after-repairs emission readings are passing, but still reflect higher than average NO\textsubscript{x} at 50/15.

<table>
<thead>
<tr>
<th>% CO\textsubscript{2}</th>
<th>% O\textsubscript{2}</th>
<th>HC (PPM)</th>
<th>CO (%)</th>
<th>NO\textsubscript{x} (PPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>RPM</td>
<td>MEAS</td>
<td>MEAS</td>
<td>MAX</td>
</tr>
<tr>
<td>15 mph</td>
<td>1723</td>
<td>14.6</td>
<td>0.3</td>
<td>135</td>
</tr>
<tr>
<td>25 mph</td>
<td>1762</td>
<td>14.8</td>
<td>0.1</td>
<td>110</td>
</tr>
</tbody>
</table>

What diagnostic steps could have been performed to more thoroughly address the NO\textsubscript{x} failure?
2009 Technician Update Course

NOx Failure Laboratory Examination

1992 Honda Accord NOx Failure

A 1992 Honda Accord, 2.2L engine equipped with PCV, EVAP, EGR, CAT, SPK, FI, & HO2S failed 5015 and 25/25 for NOx.

<table>
<thead>
<tr>
<th>% CO2</th>
<th>% O2</th>
<th>HC (PPM)</th>
<th>CO (%)</th>
<th>NOx (PPM)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>RPM</td>
<td>MEAS</td>
<td>MEAS</td>
<td>MAX</td>
<td>AVE</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------</td>
<td>--------</td>
<td>-------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>15 mph</td>
<td>1836</td>
<td>14.4</td>
<td>0.3</td>
<td>116</td>
<td>31</td>
</tr>
<tr>
<td>25 mph</td>
<td>1907</td>
<td>14.4</td>
<td>0.2</td>
<td>91</td>
<td>20</td>
</tr>
</tbody>
</table>

The technician performed the following diagnostic tests:

- Catalyst checked
  - Catalyst failed cranking CO2 test
- EGR checked
  - Vacuum signal, passages, valve operation – Good
- Ignition timing
  - At specifications
- Lambda
  - Within specifications – 50/15 and 25/25

Based on this diagnostic information, the technician recommended replacing the catalyst.

Repairs were authorized and performed

The after-repairs emission readings are passing, but still reflect higher than average NOx at 50/15.

<table>
<thead>
<tr>
<th>% CO2</th>
<th>% O2</th>
<th>HC (PPM)</th>
<th>CO (%)</th>
<th>NOx (PPM)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>RPM</td>
<td>MEAS</td>
<td>MEAS</td>
<td>MAX</td>
<td>AVE</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------</td>
<td>--------</td>
<td>-------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>15 mph</td>
<td>1828</td>
<td>15.2</td>
<td>0.2</td>
<td>116</td>
<td>31</td>
</tr>
<tr>
<td>25 mph</td>
<td>2531</td>
<td>15.2</td>
<td>0.0</td>
<td>91</td>
<td>20</td>
</tr>
</tbody>
</table>

What diagnostic steps could have been performed to more thoroughly address the NOx failure?
Vehicle Information Data Sheet

<table>
<thead>
<tr>
<th>Vehicle Make:</th>
<th>Model:</th>
<th>Year:</th>
<th>VIN #:</th>
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</thead>
<tbody>
<tr>
<td></td>
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<table>
<thead>
<tr>
<th>License #:</th>
<th># of Cylinders:</th>
<th>Engine Size:</th>
<th>Mileage:</th>
<th>Date:</th>
<th>RO #:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pre-repair Baseline Emissions Results

<table>
<thead>
<tr>
<th>Cut-points</th>
<th>Measured</th>
<th>Cut-points</th>
<th>Measured</th>
<th>Cut-points</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HC</td>
<td>HC</td>
<td>CO</td>
<td>CO</td>
<td>NO_x</td>
<td>NO_x</td>
</tr>
<tr>
<td>25/25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HC</td>
<td>HC</td>
<td>CO</td>
<td>CO</td>
<td>NO_x</td>
<td>NO_x</td>
</tr>
</tbody>
</table>

Lambda Calculator:

Visual/Functional Inspection

Use: P = Pass  M = Modified  S = Missing  D = Disconnected  F = Defective  N = Non-Applicable

PCV ___  TAC ___  EVAP ___  AIS ___  EGR ___  SPK ___  CAT ___  COMP ___  SENSORS ___


EGR: Pass  Fail  Cause (if fail):  Defective EGR  No Vacuum  Clogged Passages

How many inches of vacuum required to open EGR? _____ Hg.

OBD II: Communications: Pass  Fail  Monitor Status: Pass  Fail  MIL Command: Pass  Fail


Computer Operation

Computer Code Stored?  Yes  No  If yes, are codes:  Hard  Soft  Record Codes:

Are codes emission related?  Yes  No  Define Codes:

Record results of diagnosis:

Oxygen Sensor: Good  Defective  Low Voltage: _____ mV  High Voltage: _____ mV  Rise Time: _____ ms

CO Standards: Pass  Fail

Is system in fuel control?  Yes  No  If no, is O2 biased?  Rich  Lean  Will the computer respond to artificial O2 input?  Yes  No  If no, why?

Air Injection Is AIS functioning correctly?  Yes  No  If no, why?

CO Diagnostic Page 1
## Visual Inspection of the Engine Performance Systems

Notes:

---

## HC Diagnosis

<table>
<thead>
<tr>
<th>Misfires</th>
<th>Engine: Yes</th>
<th>No</th>
<th>Ignition: Yes</th>
<th>No</th>
<th>Air/Fuel: Yes</th>
<th>No</th>
</tr>
</thead>
</table>

Notes:

---

## CO Diagnosis

<table>
<thead>
<tr>
<th>Average O2S Voltage:</th>
<th>Fuel Trim Data:</th>
<th>Air filter in good serviceable condition?: Yes</th>
<th>No</th>
<th>Fuel Pressure: Specifications:</th>
<th>Measured:</th>
<th>Saturated EVAP control canister?: Yes</th>
<th>No</th>
<th>Engine oil contaminated with fuel?: Yes</th>
<th>No</th>
</tr>
</thead>
</table>

Carburetor Operation:

- idle air/fuel adjustment
- choke adjustment
- float level
- power valve operation

---

## NOx Diagnosis

<table>
<thead>
<tr>
<th>Ignition Timing Advance: Specifications:</th>
<th>Centrifugal:</th>
<th>Vacuum:</th>
<th>Measured:</th>
<th>Centrifugal:</th>
<th>Vacuum:</th>
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<table>
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<tr>
<th>Coolant Temperature:</th>
<th>Air Intake Temperature: TAC</th>
<th>EFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is engine compression excessive?: Yes</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

| Is fuel octane correct?: Yes | No |

---

## Catalytic Converter Efficiency Diagnosis

<table>
<thead>
<tr>
<th>Is catalytic converter in good serviceable condition?: Yes</th>
<th>No</th>
</tr>
</thead>
</table>

Describe testing method(s) used:

---

## Diagnostic Summary:

---
Vehicle Information Data Sheet

Vehicle Make: ___________________ Model: ___________________ Year: ________ VIN #: ___________________
License #: ___________________ # of Cylinders: __________ Engine Size: ________ Mileage: ________ Date: ________ RO #: ___________________

Pre-repair Baseline Emissions Results

<table>
<thead>
<tr>
<th>Cut-points</th>
<th>Measured</th>
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<tr>
<td>50/15</td>
<td>HC</td>
<td>HC</td>
<td>CO</td>
<td>CO</td>
<td>NOx</td>
</tr>
<tr>
<td>25/25</td>
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<td>NOx</td>
</tr>
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</table>

Lambda Calculator: ________________________________________________________________

Visual/Functional Inspection

Use:  P = Pass     M = Modified     S = Missing     D = Disconnected     F = Defective     N = Non-Applicable
PCV ___ TAC ___ EVAP ___ AIS ___ EGR ___ SPK ___ CAT ___ COMP ___ SENSORS ___

Functional Test: Idle Speed: ______ RPM Ignition Timing: ______ Spec: ______ Pass Fail
EGR: Pass Fail Cause (if fail): Defective EGR No Vacuum Clogged Passages
How many inches of vacuum required to open EGR? _____ Hg.

OBD II: Communications: Pass Fail Monitor Status: Pass Fail MIL Command: Pass Fail

Computer Operation

Computer Code Stored? Yes No If yes, are codes: Hard Soft Record Codes: ______________________
Are codes emission related? Yes No Define Codes: __________ __________ __________
Record results of diagnosis: ____________________________________________________________

Oxygen Sensor: Good Defective Low Voltage: ______ mV High Voltage: ______ mV Rise Time: ______ ms
CO Standards: Pass Fail
Is system in fuel control? Yes No If no, is O2 biased? Rich Lean Will the computer respond to artificial O2 input? Yes No If no, why?
Air Injection Is AIS functioning correctly? Yes No If no, why?

HC Diagnostic Page 1
Visual Inspection of the Engine Performance Systems

Notes:________________________________________________________________________________________
_____________________________________________________________________________________________
___________________________________________________________________________________

HC Diagnosis

Misfires: Engine: Yes No Ignition: Yes No Air/Fuel: Yes No

Notes:________________________________________________________________________________________
_____________________________________________________________________________________________
___________________________________________________________________________________

CO Diagnosis

Average O2S Voltage:_________________ Fuel Trim Data:___________________________

Air filter in good serviceable condition?: Yes No

Fuel Pressure: Specifications:___________________ Measured:___________________

Saturated EVAP control canister?: Yes No

Engine oil contaminated with fuel?: Yes No

Carburetor Operation:
idle air/fuel adjustment_______ choke adjustment_______ float level_______ power valve operation_______

NOx Diagnosis

Ignition Timing Advance: Specifications: Centrifugal:__________ Vacuum:__________

Measured: Centrifugal:__________ Vacuum:__________

Coolant Temperature:__________ Air Intake Temperature: TAC_________ EFE__________

Is engine compression excessive?: Yes No

Is fuel octane correct?: Yes No

Catalytic Converter Efficiency Diagnosis

Is catalytic converter in good serviceable condition?: Yes No

Describe testing method(s) used:

Diagnostic Summary:
Vehicle Information Data Sheet

Vehicle Make: ____________________ Model: ____________________ Year: ____________________ VIN #: ____________________

License #: ____________________ # of Cylinders: ____________________ Engine Size: ____________________ Mileage: ____________________ Date: ____________________ RO #: ____________________

Pre-repair Baseline Emissions Results

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Lambda Calculator: ____________________________

Visual/Functional Inspection

Use: P = Pass  M = Modified  S = Missing  D = Disconnected  F = Defective  N = Non-Applicable

PCV___ TAC___ EVAP___ AIS___ EGR___ SPK___ CAT___ COMP___ SENSORS___

Functional Test          Idle Speed:_____        RPM Ignition Timing:_____         Spec:_____          Pass  Fail
EGR:        Pass  Fail        Cause (if fail):         Defective EGR         No Vacuum         Clogged Passages
How many inches of vacuum required to open EGR? _____ Hg.
OBD II:   Communications:  Pass  Fail     Monitor Status:   Pass  Fail     MIL Command:   Pass  Fail

Computer Operation

Computer Code Stored?  Yes  No  If yes, are codes:  Hard  Soft  Record Codes:
Are codes emission related?  Yes  No  Define Codes:__________________________
Record results of diagnosis:
Oxygen Sensor:  Good  Defective  Low Voltage:____mV High Voltage:____mV Rise Time:____ms
CO Standards:  Pass  Fail
Is system in fuel control?  Yes  No  If no, is O2 biased?  Rich  Lean  Will the computer respond to artificial O2 input?  Yes  No  If no, why?
Air Injection Is AIS functioning correctly?  Yes  No  If no, why? ____________________________

NOx Diagnostic Page 1
Visual Inspection of the Engine Performance Systems

Notes:
________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________

HC Diagnosis

Misfires: Engine:   Yes  No  Ignition:    Yes  No  Air/Fuel:   Yes  No

Notes:
________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________

CO Diagnosis

Average O2S Voltage:_________________ Fuel Trim Data:___________________________
Air filter in good serviceable condition?:   Yes  No
Fuel Pressure: Specifications:_____________ Measured:___________________________
Saturated EVAP control canister?:  Yes  No   Engine oil contaminated with fuel?:   Yes  No
Carburetor Operation:
  idle air/fuel adjustment______ choke adjustment______ float level______ power valve operation______

NOx Diagnosis

Ignition Timing Advance: Specifications:   Centrifugal:__________ Vacuum:__________
  Measured:   Centrifugal:__________ Vacuum:__________
Coolant Temperature:__________ Air Intake Temperature:  TAC_________  EFE__________
Is engine compression excessive?:   Yes  No  Is fuel octane correct?:   Yes  No

Catalytic Converter Efficiency Diagnosis

Is catalytic converter in good serviceable condition?:   Yes  No
Describe testing method(s) used:

Diagnostic Summary:
Vehicle Information Data Sheet

Vehicle Make: | Model: | Year: | VIN #: |
---|---|---|---|
| | | | |

License #: | # of Cylinders: | Engine Size: | Mileage: | Date: | RO #: |
---|---|---|---|---|---|
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Pre-repair Baseline Emissions Results

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Lambda Calculator:__________________________________________________________________________

Visual/Functional Inspection

Use: P = Pass  M = Modified  S = Missing  D = Disconnected  F = Defective  N = Non-Applicable

PCV___ TAC___ EVAP___ AIS___ EGR___ SPK___ CAT___ COMP___ SENSORS___
Functional Test  Idle Speed:_____  RPM Ignition Timing:_____  Spec:_____  Pass  Fail
EGR: Pass  Fail  Cause (if fail):  Defective EGR  No Vacuum  Clogged Passages
How many inches of vacuum required to open EGR? ____ Hg.

OBD II: Communications:  Pass  Fail  Monitor Status:  Pass  Fail  MIL Command:  Pass  Fail

Computer Operation

Computer Code Stored?  Yes  No  If yes, are codes:  Hard  Soft  Record Codes:___________
Are codes emission related?  Yes  No  Define Codes:__________ __________ __________
Record results of diagnosis:_____________________________________________________________

Oxygen Sensor:  Good  Defective  Low Voltage:____mV High Voltage:____mV Rise Time:____ms
CO Standards:  Pass  Fail
Is system in fuel control?  Yes  No  If no, is O2 biased?  Rich  Lean  Will the computer respond to artificial O2 input?  Yes  No  If no, why?__________________________________________
Air Injection Is AIS functioning correctly?  Yes  No  If no, why?__________________________

Vehicle Information Datasheet Page 1
Visual Inspection of the Engine Performance Systems

HC Diagnosis

Misfires:
- Engine: Yes  No
- Ignition: Yes  No
- Air/Fuel: Yes  No

Notes:

CO Diagnosis

Average O2S Voltage: _____________________ Fuel Trim Data: _____________________

Air filter in good serviceable condition?: Yes  No

Fuel Pressure:
- Specifications: _____________________
- Measured: _____________________

Saturated EVAP control canister?: Yes  No

Engine oil contaminated with fuel?: Yes  No

Carburetor Operation:
- idle air/fuel adjustment_______
- choke adjustment_______
- float level_______
- power valve operation_______

NOx Diagnosis

Ignition Timing Advance:
- Specifications: _____________________
- Centrifugal: ________
- Vacuum: ________
- Measured: _____________________
- Centrifugal: ________
- Vacuum: ________

Coolant Temperature: ________

Air Intake Temperature:
- TAC: ________
- EFE: ________

Is engine compression excessive?: Yes  No

Is fuel octane correct?: Yes  No

Catalytic Converter Efficiency Diagnosis

Is catalytic converter in good serviceable condition?: Yes  No

Describe testing method(s) used: _____________________

Diagnostic Summary:

______________________________

______________________________

______________________________

Vehicle InformationDatasheet Page 2