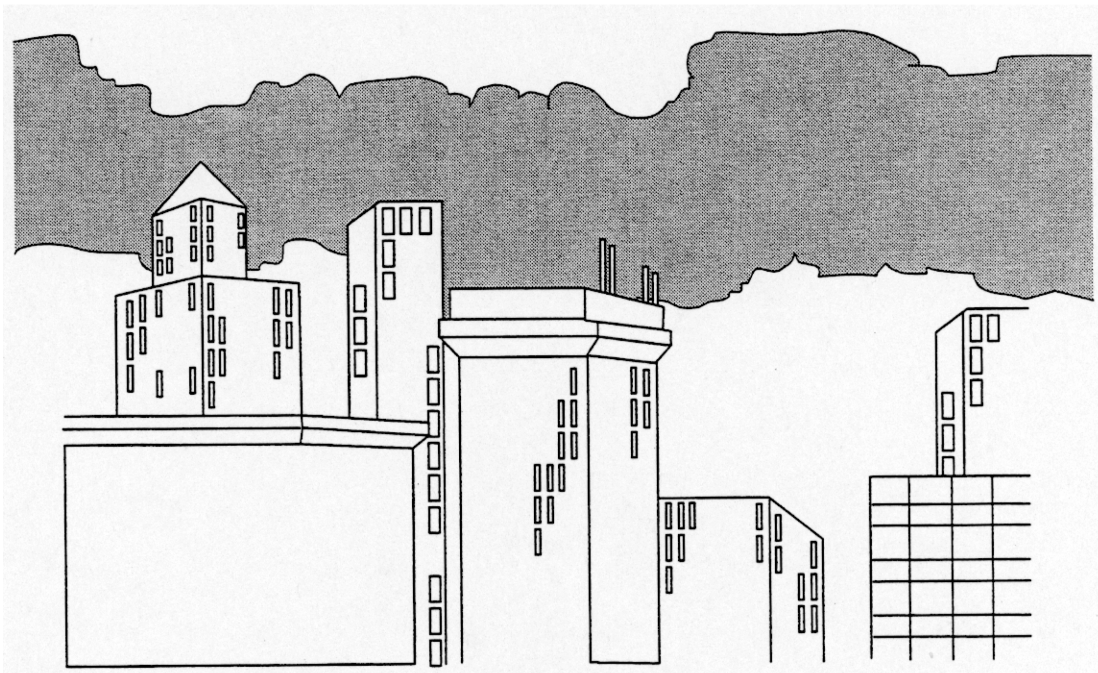
Section 1

INTRODUCTION TO ENHANCED I/M



Lesson Objectives

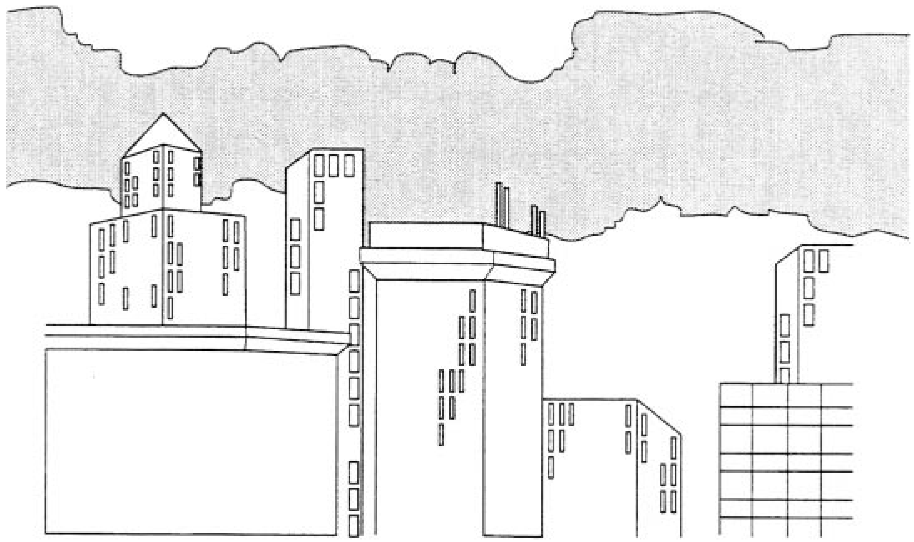
1. Identify one reason why emissions control systems are necessary on automobiles.
2. Specify the role I/M programs play in the clean air effort.
3. Specify two reasons why air quality is not improving, or is even deteriorating, in spite of the low emissions design vehicles being sold for the last decade.
4. Identify two shortcomings of Basic I/M Programs, which ultimately led to the development of the Enhanced I/M tests.
5. Specify at least three features of Enhanced I/M testing that will serve to reduce the number of gross polluting vehicles on our highways.

Notes

Vehicle Maintenance and Clean Air

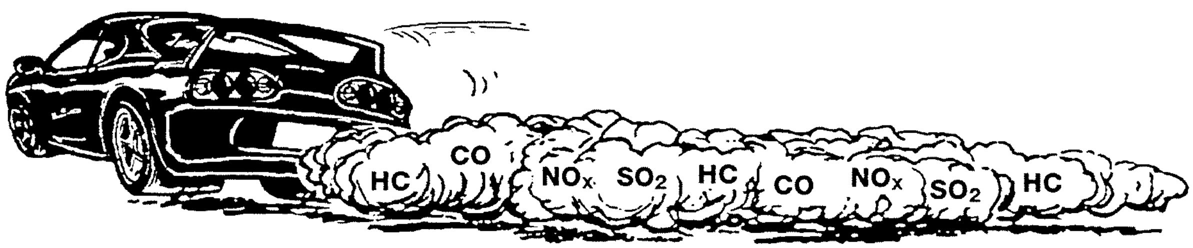
Air Pollution From Mobile Sources

The major cause of air pollution in the United States is attributable to mobile sources (cars, light trucks, etc.)



The Need For Vehicle Emission Control

Studies have indicated that automobiles, light trucks, and other mobile sources produce over 50% of all air pollution in our atmosphere. In the United States, these mobile sources alone are said to create half of the ozone and nearly all of the Carbon Monoxide air pollution. In addition, vehicle emissions react with other factors to produce the visible ground-level haze that has become known as ”smog”. It goes without saying that vehicle emissions control systems, and all factors affecting their proper operation, are critically important in reducing levels of harmful emissions emitted into our atmosphere. The following examples of vehicle pollutants have proven to be irritating and hazardous to humans and their environment.



Invisible Pollutants

Carbon Monoxide (CO) is a colorless, odorless, and highly poisonous gas that is a by-product of the combustion process. It can cause dizziness, headaches, impaired judgement, and in large doses, death by oxygen starvation.

Sulfur Dioxide (SO2) is a colorless gas that carries a pungent rotten egg odor. In automobiles it is caused by high sulfur content in the gasoline that results in SO2 production in the catalytic converter. It can cause respiratory irritation, heart problems, and increased risk of asthma.

Visible Pollutants

Photochemical Smog is created when **Hydrocarbons (HC)** and **Oxides of Nitrogen (NOx)** are combined with **Sunlight** to create the brownish ground-level haze that appears over congested metropolitan areas. Smog can cause many respiratory problems including shortness of breath, coughing and wheezing, as well as chest pains and eye irritation.

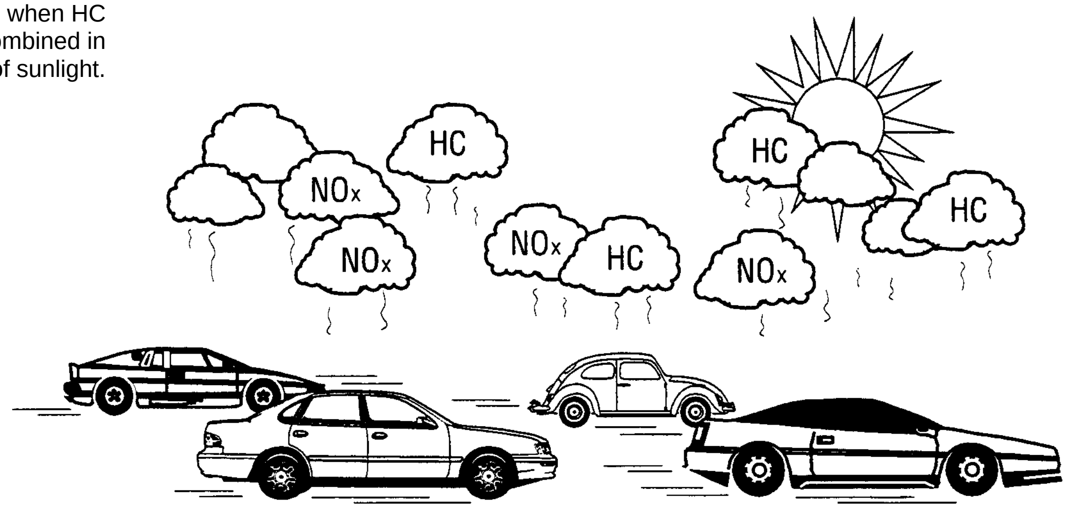
Specifically, **Hydrocarbons (HC)** is raw, unburned fuel leftover from the combustion process. In addition, HC can enter the atmosphere as a result of evaporation from fuel storage sources (gas tank, gas pump hose, etc.)

Oxides of Nitrogen (NOx) are various nitrogen-based gases that are produced from excessive heat and pressure during the combustion process. Exposure to NOx can increase a person's susceptibility to respiratory infection.

Photochemical "Smog"

The ground level haze known as photochemical "smog" is created when HC and NOx is combined in the presence of sunlight.

Photochemical Smog = HC + NO_X + Sunlight

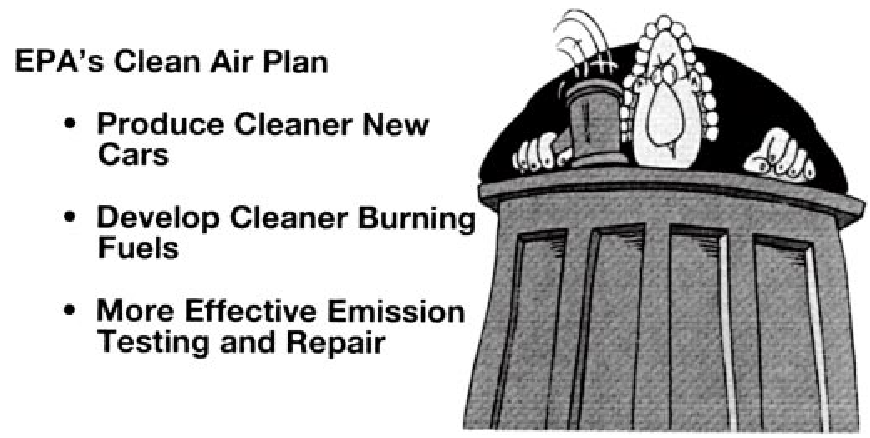


Recognizing the Problem

The problem with motor vehicle emissions is not that cars are polluting more now than in the past, rather that Americans are driving more now than ever before. In the twenty year period since 1974, vehicle miles traveled has more than doubled, to more than 2 trillion miles per year! In addition, the technical progress made in emissions control system effectiveness was overshadowed by the sharp increases in miles traveled. Thus, the only alternative to limiting the use of motor vehicles (limiting the total miles driven) is to establish a means to reduce their contribution to the total air pollution problem.

WPA's 3-Step Clean Air Plan

In addressing the increasing problem of air pollution, the EPA enacted a 3-step plan that targets pollutants generated by mobile sources.



Multi-Facet Approach to Clean Air

In addressing this problem, the **U. S. Environmental Protection Agency (EPA),** as a part of the Clean Air Act, is requiring the most polluted areas to reduce their overall emission levels 24% by the year 2000. In order to meet this goal, the EPA unveiled a strategy that was specifically designed to lower overall motor vehicles emissions.

First, they're requiring vehicle manufacturers to produce cleaner new vehicles. For instance, the tightening of new car standards provides small incremental improvements in new vehicles which are already very clean. This also means that newer, cleaner burning cars will eventually replace the older "gross" polluting vehicles.

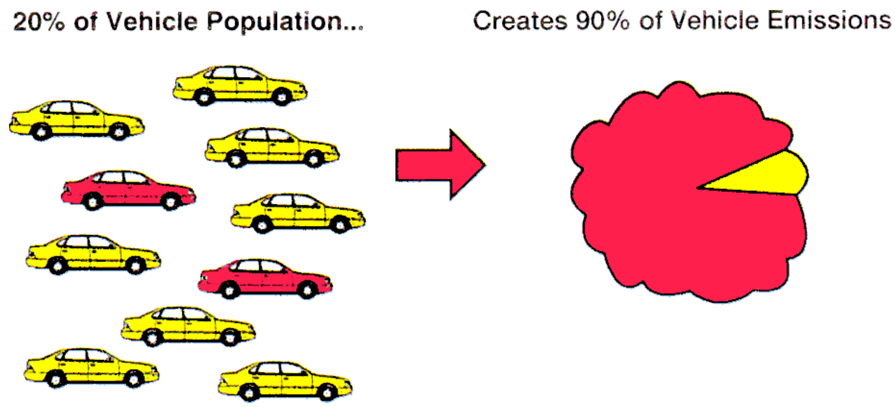
Secondly, EPA is requiring the development of cleaner-burning fuels. This includes the elimination of leaded fuels and the increased use of oxygenated and reformulated fuels that inherently produce lower emissions.

More Effective Inspection & Maintenance Programs

Thirdly, and this is where you come in, vehicles will be subject to stricter inspection and maintenance programs, such as the new IM240. It is important to remember that regardless of how "clean" the vehicle operated when new, lack of maintenance will eventually turn the cleanest car into a polluter. Studies indicate that poorly maintained vehicles comprise about 20% of the vehicle population; however, they produce more than 90% of total emissions emitted from mobile sources!

Target of "Enhanced" I/M Programs

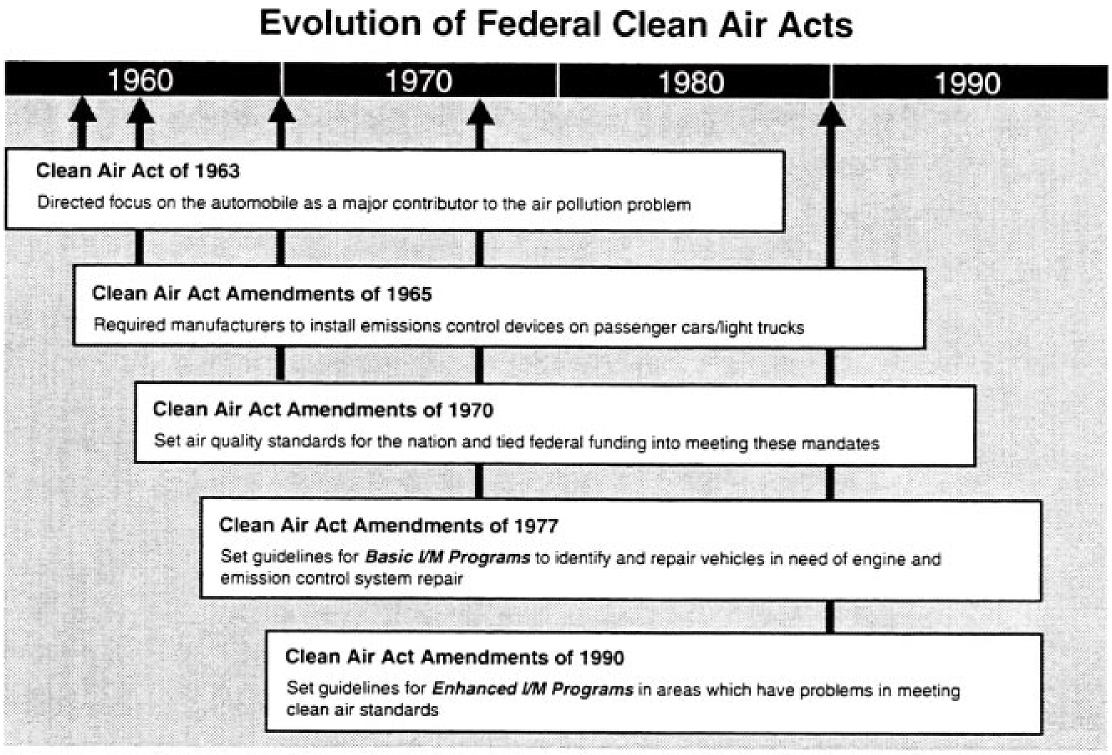
Enhance I/M Programs were designed to identify the "grossest" polluting vehicles that constitute the greatest problem in resolving the clean air problem.



Technician's Role in Clean Air Solution

The new "Enhanced" I/M Programs were designed to target these vehicles by using tighter emission standards, more precise measuring equipment, and testing procedures that use "loaded", real-world driving conditions. Once identified, these failed vehicles will require maintenance or repair before they may be registered.

Although some technicians may play a role in the inspection process; vehicle maintenance, emission diagnosis and repair will be your most important contribution to the new I/M programs. By repairing the dirtiest 20% of the vehicle population and keeping these vehicles properly maintained, technicians play the largest and most important role in the clean air solution.



Evolution of Inspection & Maintenance Programs

Before we get into the details of the new I/M program, a short review of the evolution of clean air programs is in order. The following summaries explain the Federal Clean Air Acts that are the driving force behind the latest, most comprehensive I/M programs:

- *Clean Air Act of 1963* (CAA '63) initiated the focus on the automobile as a major contributor to the air pollution problem. At that time, it was estimated that automobile engines were responsible for as much as 40% of all airborne emissions.
- *Clean Air Act Amendments of 1965* (CAAA '65) required manufacturers to install emissions control equipment on passenger cars and light trucks by the 1968 model year.
- *Clean Air Act Amendments of 1970* (CAAA '70) set air quality standards for the nation and mandated that areas which did not meet these standards must implement further emissions control strategies or suffer sanctions on building and highway funds.
- *Clean Air Act Amendments of 1977* (CAAA '77) set guidelines for noncompliance areas to establish vehicle ***Basic Inspection and Maintenance*** programs (Basic I/M) to identify and repair vehicles in need of maintenance of the engine/emissions control system.
- *Clean Air Act Amendments of 1990* (CAAA '90) is latest and most far reaching amendments, set guidelines for ***Enhanced Inspection and Maintenance*** programs (Enhanced I/M) in areas which have a serious, severe or extreme problem in meeting clean air standards.

Early Efforts at Clean Air

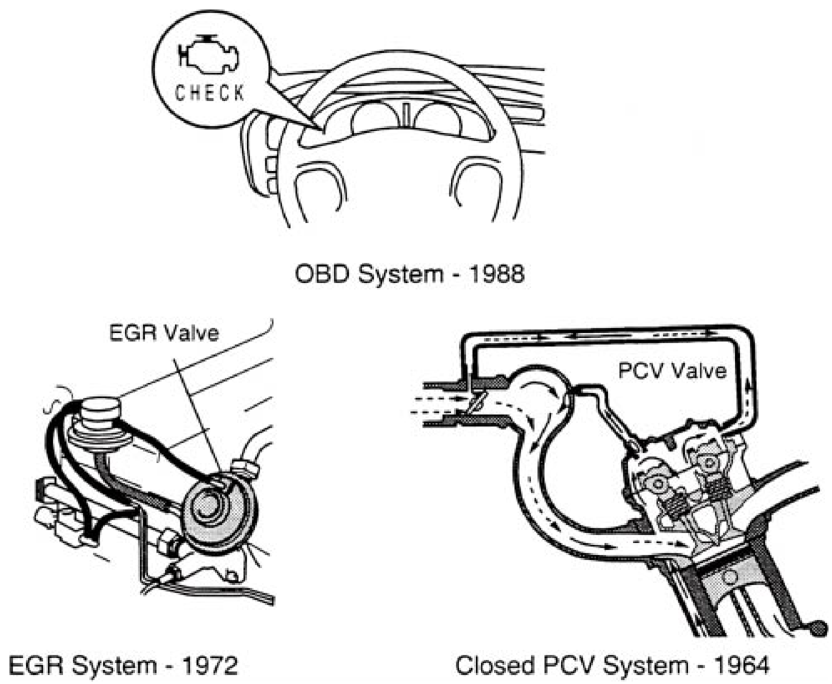
As you can see by the history behind Clean Air Acts, efforts to address and implement clean air standards and procedures are not new. For instance, since 1968, auto manufacturers have been required to meet stringent emissions standards for HC, CO and NOx.

Also, to ensure that new vehicles met the standards, the **Federal Test Procedure (FTP)** was established to ”certify” new vehicle emissions systems. The FTP uses precise emission measuring equipment, and a dynamic, ”loaded” driving cycle to certify new vehicles. The new Enhanced I/M programs, will be discussed in detail later.

In addition, the **California Air Resources Board (CARB)** has traditionally taken an active role in establishing emissions standards and engine/ emissions control system requirements. California, due to its extreme air pollution problems, has historically implemented emissions standards stricter than those required under Federal legislation. Traditionally, many other states (and even other countries) have implemented similar requirements to those established by CARB.

CARB Driven Advancements in Emission Technology

Examples of advancements attributable to CARB. Most of these standards have been adopted by other states.



California standards and related legislation have driven technology in emissions control equipment through tighter standards and specific equipment requirements. The following systems are examples of some of these advancements.

- **Closed Positive Crankcase Ventilation (PCV) Systems** that eliminate HC emissions from the engine crankcase.

- **Exhaust Gas Recirculation (EGR) Systems** and engine modifications that reduce the amount of NOx produced by the engine
- **On-Board Diagnostic (OBD) Systems** that improve technician success rate in diagnosing and repairing engine and emissions systems.

Basic Inspection and Maintenance Programs

”Basic” I/M Programs were introduced starting in the late 1970’s. These programs evolved over the decade of the ’80s and have been periodically refined to improve their effectiveness. Basic I/M requires vehicle inspections to identify and repair vehicles which are in need of engine and emissions control system maintenance.

With this program, vehicles are periodically tested for tailpipe emissions and inspected for the presence of key emissions control equipment originally installed by the manufacturer. Typically, this includes a two-speed idle emission test. If the vehicle does not pass tailpipe and visual inspection, it could be denied registration until it is repaired.

Required repairs are often subject to a statutory limitation known as a **waiver limit.** This essentially means that a motorist does not have to spend more than a specified amount to bring a vehicle into compliance. The waiver allows vehicles to be registered even though it does not comply with tailpipe standards.

Generally, waivers can only be issued if:

- Repair costs reach or exceed the waiver limit dollar amount.
- Repairs are performed by a licensed technician on systems which will reduce the failed emission level.
- Total emissions from the vehicle are reduced by the repairs.

Shortcomings to Basic A/M Programs

Although Basic I/M Programs have made some inroads into solving the clean air problem, they continue to have several inherent flaws. One of the shortcomings of Basic I/M is that emissions systems were originally designed to comply with emissions standards by passing the FTP. However, some studies show the correlation between the FTP and Basic I/M two-speed idle tests to be very poor. These studies have found Basic I/M to false pass and false fail vehicles when test results were correlated to the FTP.

Also, the two-speed idle test used by most Basic I/M Programs were not designed to work on the feedback engine control systems which now comprise the majority of the vehicle fleet. This means vehicles are not tested under conditions when most emissions are created. In addition, emission mass is not calculated.

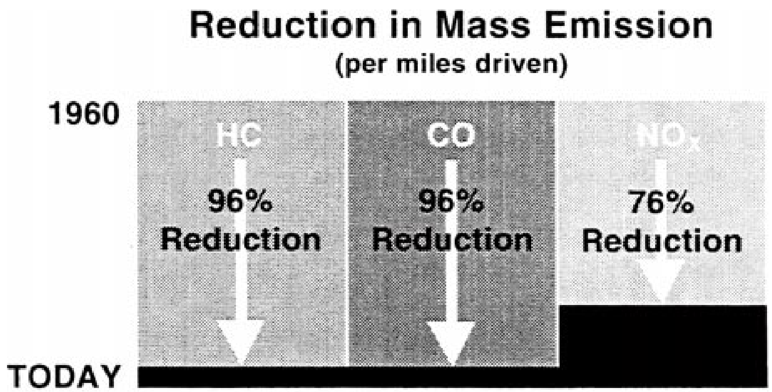
Improper testing procedures, and in some cases outright fraud, have compromised the effectiveness of many Basic I/M Programs. For example, improper testing procedures have been identified in over 50%

of the test and repair stations audited by EPA, often leading to false pass of a Basic I/M test.

Additionally, Basic I/M does not test the integrity of the evaporative emissions system, the source of more than half of the HC emissions from mobile sources.

Air Pollution From Mobile Sources

Significant gains have been made in the past 25 years; however, enactment of tighter standards will continue to provide further reductions.



Gains Made Between 1960 and 1994

In the past, new vehicle emissions standards and Basic I/M Programs were responsible for significantly reducing the amount of mass emissions produced per vehicle miles driven. Since 1960, mass emissions from passenger cars have been reduced by 96% for both HC and CO and by 76% for NOx.

These reductions will improve to 98% for CO and 90% for NOx with the implementation of Federal TIER 1 standards that are currently being phased into new cars ('94 - '96). Although other factors are involved, the following is a general comparison between '93 Federal standards and '94 Federal TIER 1 standards:

- '93 Federal Standards: HC: 0.41, CO: 3.4, NOx: 1.0
- '94 Federal TIER 1: HC: 0.25, CO: 3.4, NOX: 0.4

While some areas have experienced improvements in air quality, many geographic areas did not gain enough improvement in air quality to meet the standards originally mandated in the CAAA of'70. In fact, some areas that have experienced significant growth actually experienced a degradation of air quality standards in spite of all efforts toward improvement. This has been the EPA's driving force behind implementing the stricter requirements set forth by the CAAA of'90.

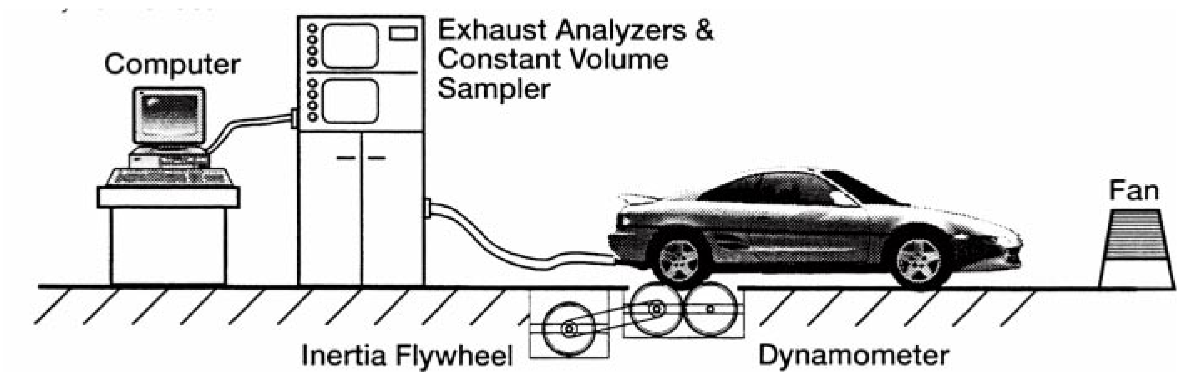
Recent Efforts at Cleaner Air

Federal exhaust emissions standards continue to tighten in an effort to produce cleaner new cars today and in the future. This strategy will help replace older vehicles with newer, cleaner-running vehicles. In addition, incentive programs are being proposed, at the state level, to reduce the number of older "dirtier" vehicles currently on the road.

In areas which fail to meet ambient CO standards, ”oxygenated” gasoline is required to chemically lean the air/fuel mixture, thereby reducing the amount of CO produced by the engine. Additionally, the nine worst ozone non-attainment areas are required to use ”reformulated” gasoline to reduce the amount of evaporative HC and other compounds emitted into the atmosphere.

Enhanced I/M

The EPAs suggested Enhanced I/M Program is the IM240 test. This test closely emulates the Federal Test Procedure (FTP) used to certify new vehicles.



Enhanced Inspection and Maintenance Programs

Enhanced I/M Programs are now being implemented in targeted counties nationwide in an effort to identify and repair the vehicles that contribute the majority of atmospheric pollutants. At this time, IM240 is the EPA’s suggested Enhanced I/M Program. The name IM240 refers to the length of time (in seconds) it takes to complete the entire driving portion of the inspection.

IM240 Key Points

The following summary highlights some of the more important aspects of IM240:

- Closely emulates the Federal Test Procedure (FTP) loaded driving cycle that is used to certify new vehicles.
- Tests vehicles under ”real world” loaded driving conditions.
- Uses highly sophisticated and precise test equipment similar to that which is used in the FTP.
- Correlates well with FTP test results, including calculating emissions *mass* in grams per mile (g/mile).
- Tests for NOx output in addition to HC and CO levels.
- Incorporates a dynamic test of the evaporative emissions system, including purge volume and fuel tank pressure test.
- Centralized testing is used to reduce the likelihood of improper testing procedures or outright fraud
- Distribution of a repair shop/technician report card
- Specific state/local technician training requirements
- Higher waiver limits and more stringent rules on repeat waivers

NOTE

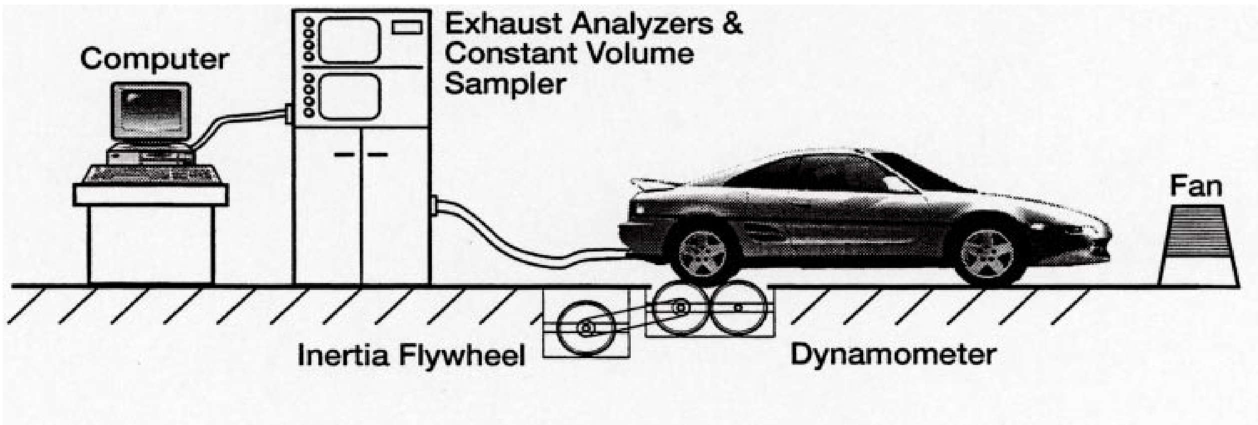
It is important to realize that IM240 is the EPA’s suggested method of implementing an Enhanced I/M Program; however, as of this printing, many states are experimenting with alternative or ”hybrid” programs that they feel will work as effectively as IM240. These programs may deviate from some of the key points mentioned; therefore, it is imperative that you learn specific details and procedures of the program your local area implements.

The following section provides detailed descriptions of both the Federal Test Procedure (FTP) and the current EPA approved Enhanced I/M Test (IM240).

Notes

Section 2

EMISSION TESTING & ENHANCED I/M



Lesson Objectives

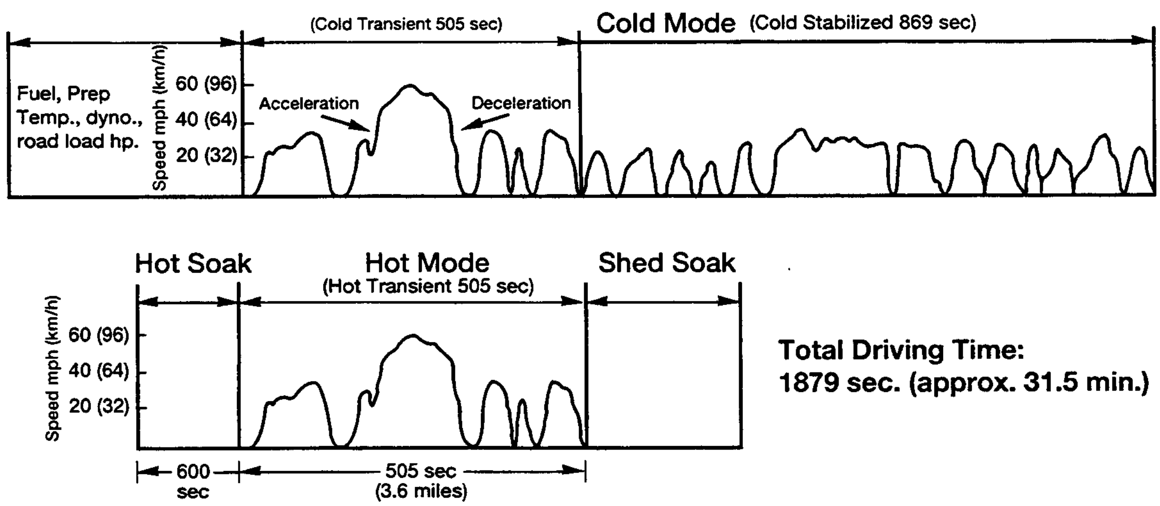
1. Explain the three phases of the Federal Test Procedure (FTP) used to certify new vehicle emission standards.
2. Explain how FTP certification standards have become more stringent and how they relate to IM240 emission certification standards.
3. Identify the specific FTP test equipment used to collect and measure vehicle emissions during the FTP drive cycle.
4. Specify three differences between FTP and traditional emission inspection programs.
5. Identify the shortcomings of Basic I/M Programs, when compared to the FTP.
6. Explain in detail the three distinct elements or tests that make up IM240.
7. Explain the specific tests procedures and criterions used during each of the three IM240 tests.

Federal Test Procedure

The Federal Test Procedure (FTP) is used to verify that a particular powertrain meets strict federal new car emissions standards. It is performed on randomly selected "pre-production" sample vehicles under rigidly controlled test conditions.

The FTP uses an Inertia Weight Dynamometer and Constant Volume Sampling (CVS) system to measure the mass, in grams per mile, of HC, CO, CO_2 and NOx emitted from the vehicle. In addition, this test is used to calculate the vehicle's fuel mileage performance.

FTP Transient Drive Cycle



FTP Three Phase Drive Cycle

The transient or driving portion of the test is performed in three phases and incorporates an on-road simulation of cold start-up, hot start-up, idle, acceleration, deceleration, and various part throttle speed/load conditions. The drive cycle is modelled after a typical Los Angeles commute during heavy traffic and is referred to as the Urban Dynamometer Driving Schedule (UDDS). The three phases of the driving test are as follows:

- **UDDS Phase 1**: Cold Start and Cold Transient
  - vehicle is cold soaked between 68° F and 86° F
  - vehicle is started and "driven" on dyno for the first 505 seconds of the drive cycle
  - constitutes 3.6 miles of the urban drive cycle
  - samples collected during this phase are stored in Bag #1

- **UDDS Phase 2**: Cold Stabilized
  - vehicle is driven for an additional 867 seconds
  - constitutes 3.9 miles of the urban drive cycle
  - samples collected during this phase are stored in Bag #2
  - at the end of Phase 2, the vehicle is hot soaked for 10 minutes
- **UDDS Phase 3**: Hot Start
  - vehicle is driven for an additional 505 seconds
  - repeats the 3.6 mile urban driving cycle from cold transient phase
  - sample collected during this phase are stored in Bag #3

At the completion of Phase 3, the **SHED (Sealed Housing for Evaporative Determination) test** is performed by measuring the evaporative emission produced from the vehicle after being parked in a sealed housing for 1 hour.

FTP Certification Standards

The Federal exhaust emission standards for the FTP are very stringent. The following are FTP cut points for 1977 and 1996 model vehicles:

- 1977 FTP: HC = 1.5 g/m, CO = 15.0 g/m, NOx = 2.0 g/m
- 1996 FTP: HC = 0.25 g/m, CO = 3.4 g/m, NOx = 0.4 g/m

As you can easily see, the FTP standards for 1996 are at least 4 times ”tighter” than those standards established for 1977, which shows that new car emissions output has dropped dramatically over the past 20 years.

FTP Standards vs. IM240 Standards

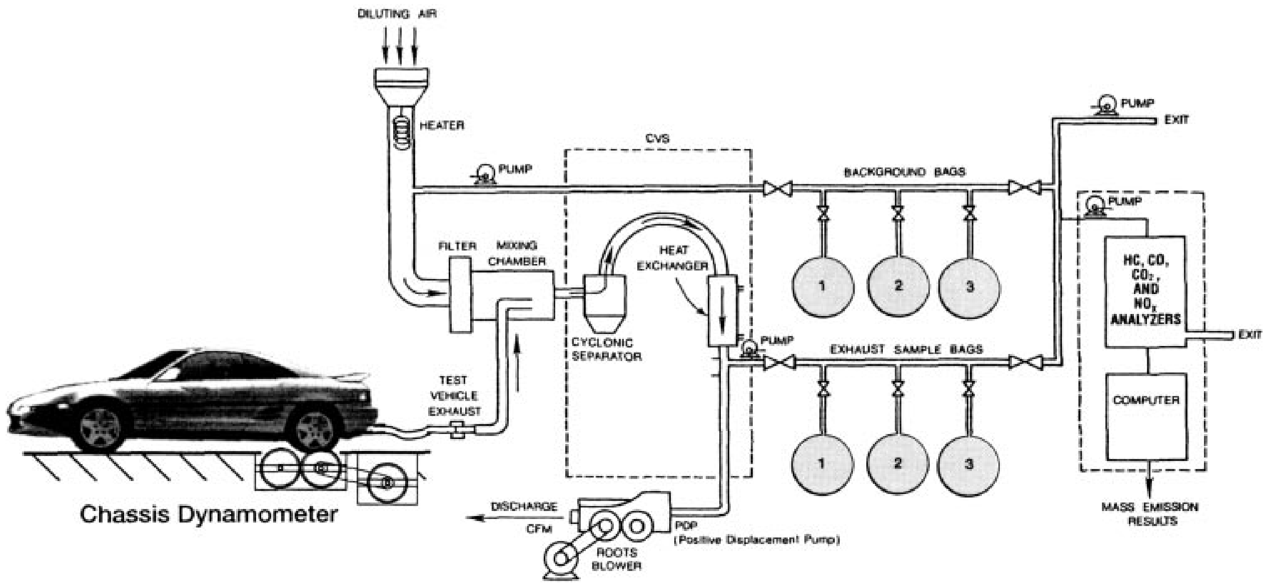
Next, compare the FTP standards above to IM240 standards for 1977 and 1996 model years:

- 1977 IM240: HC = 7.5 g/m, CO = 90 g/m, NOx = 6.0 g/m
- 1996 IM240: HC = 0.8 g/m, CO = 15.0 g/m, NOx = 2.0 g/m

Roughly speaking, the new IM240 cut points are at least 3 times greater than the FTP requirements for the car when it was new. This leniency accounts for the normal aging of the vehicle’s engine/drivetrain and emission componentry.

FTP Test Equipment

FTP test equipment includes a chassis dyno, constant volume sampler, sample storage bags, and extremely accurate emission analyzers.



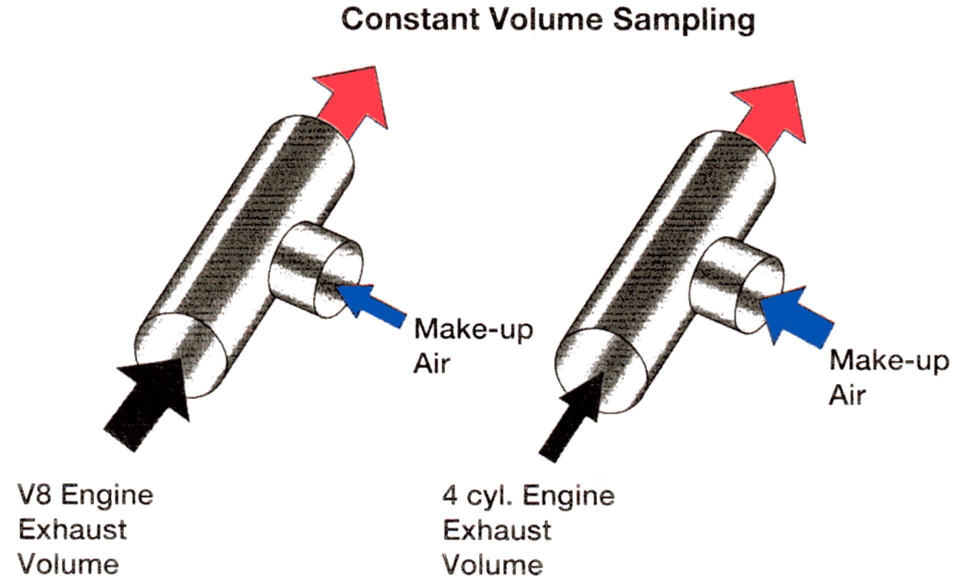
FTP Test Equipment

The FTP transient test uses a **Variable Inertia Weight Dynamometer** that is capable of constantly changing the load applied to the drive wheels. This feature allows the dyno to simulate the actual "loaded" driving conditions the test vehicle would encounter out on the highway.

Emission levels are captured and sampled using a **Constant Volume Sampler (CVS)**. The CVS equipment samples 100% of exhaust output coming from vehicle, rather than just a small portion of exhaust like with shop grade exhaust analyzers.

Constant Volume Sampling (CVS)

The CVS used in FTP testing captures 100% of the vehicle's exhaust output; thereby allowing mass emissions output to be calculated.



Sophisticated and precise measuring equipment is used to test and calculate the exact grams per mile produced of HC, CO, CO2, and NOX. This highly accurate and precise collection of test equipment includes:

- **Non-Dispersive Infrared (NDIR) Analyzer** is used to detect CO and CO2 in the exhaust flow, it is similar to shop grade exhaust analyzers; however, it is much more accurate.
- **Flame lonization Detector (FID)** is used to detect HC in the exhaust flow. It is much more expensive and accurate than the Infrared Analyzer typically used in shop grade HC analyzers.
- **Chemiluminescence Detector** is used to detect Nitric Oxides (NO) in the exhaust flow. Nitric Oxides (NO) constitutes approximately 98% of total NOx emissions produced by motor vehicles. This detection method is more accurate and much more expensive than the electrochemical detection method used in shop grade five gas analyzers.

FTP Test Results

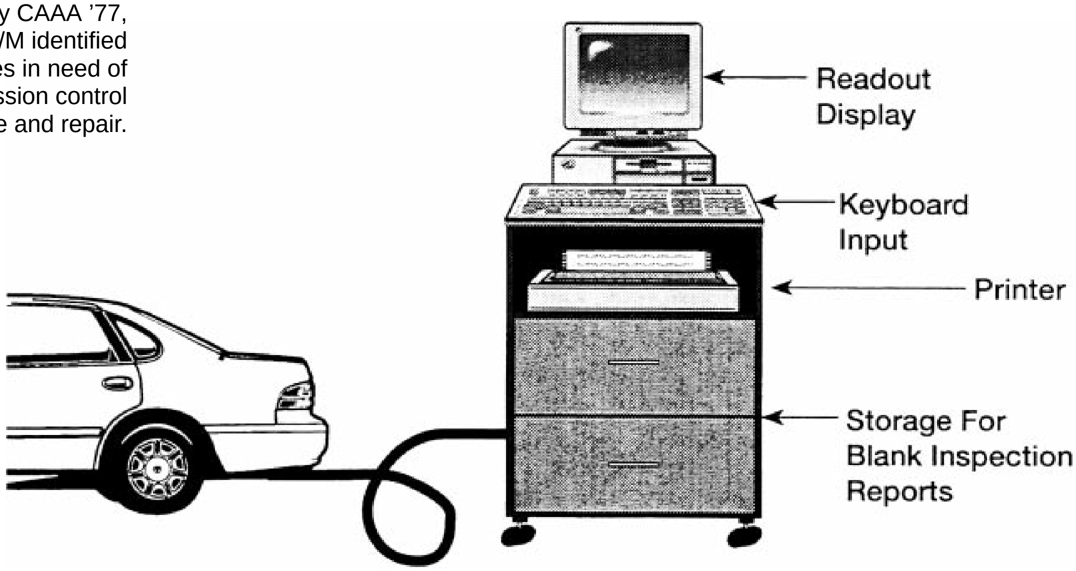
By using the equipment above, all the factors needed to accurately calculate the grams per mile of detected gases are provided. The calculated factors include the volume of vehicle exhaust (from the CVS), the concentration of the four gases (from the emission analyzers), and the total distance the vehicle travelled (from the dynamometer). As you can see, the FTP test procedure and its measured results vary greatly from the concentration-based emission testing you may be familiar with.

Basic Inspection & Maintenance Programs

As required by the Clean Air Act Amendments of 1977, Basic I/M Programs are currently active in many metropolitan areas nationwide. They are used by State and local government to certify in-use vehicles and are usually required for vehicle registration. The goal of these Basic programs is to ensure that engine/emissions control systems are properly maintained and that emission related componentry have not been tampered with.

Basic I/M Programs

Established by CAAA '77, Basic I/M identified vehicles in need of engine/emission control maintenance and repair.



Basic I/M Tests

Basic I/M testing typically consists of:

- **Visual Inspection** of key emissions control subsystems and components. This may include a visual check of the PCV system, air management system, EGR system, catalytic converter, and fuel inlet restrictor.

  The visual inspection is intended to confirm that the subsystem or component "appears functional" and usually doesn't include a "functional test". In some state programs, however, certain emissions subsystems must be functionally tested. For instance, California requires a functional test of the EGR system to confirm that it is operational.

- **Non-Loaded Tailpipe Test** for HC and CO concentrations. CO2 is also measured to check for possible exhaust dilution (exhaust leak). The tailpipe test is typically a "two speed idle test" which requires that emission readings are taken at idle, then at 2500 rpm, and again at idle. For this, the lowest of two idle readings and 2500 rpm reading are used to determine the pass/fail status of a vehicle.

The exhaust analyzers used for this test measure **HC and CO concentration** in parts per million (ppm) and parts per hundred (percentage) respectively. NOx is not checked during this test since the engine cannot be "loaded" adequately to produce significant amounts of NOx.

Basic I/M certification standards are much "looser" than FTP standards. Because Basic I/M measures "exhaust concentration" and FTP measures "mass emissions", it is difficult, if not impossible, to compare the results of these tests against one another.

Required Equipment and Certification

Various grades **of California Bureau of Automotive Repair (BAR)** certified infrared exhaust analyzers are used in the Basic *I/M* Programs. BAR establishes equipment standards for exhaust analyzers used in the California "Smog Check" program. Typically, other States have adopted or modified equipment approved by BAR for their own I/M program. The most common equipment used in Basic I/M Programs are the BAR 84 and BAR 90.

Certification also helps to establish requirements for equipment accuracy, ability to prevent test results tampering, ability to prompt technician through diagnosis and test procedures, as well as the ability to store data on tested vehicles and communicate with mainframe computers.

Shortcomings of Basic I/M Programs

One of the objectives of I/M programs is to ensure that vehicle engine/ emission systems continue to operate as designed as the car gets older. To ensure systems function as intended, vehicle emissions should not be significantly higher than the standards to which they were designed. In short, vehicles should be tested against the FTP standards for the model year it was certified.

The problem with the Basic Two Speed Idle test is its failure to consistently correlate with the FTP test. According to one study done by the EPA, approximately half of all the vehicles which pass a two speed idle test, would fail an FTP test. This equates to about 50% false errors or **errors of omission.**

The same study indicates that about one out of every 75 vehicles fails a two speed idle test, but would pass the FTP test. This equates to about 1.3% **errors of commission.**

Enhanced Inspection & Maintenance Programs

As a part of the Clean Air Act Amendments of 1990, the EPA is requiring Enhanced I/M in areas which have a serious, severe, or extreme problem in meeting clean air standards. The certification goal of Enhanced I/M is basically the same as with Basic I/M Programs, that is, to ensure that vehicles are properly maintained and that emissions systems have not been tampered with.

Introduction to IM240

As previously mentioned, the EPA's suggested Enhanced I/M Program is called IM240. IM240 identifies the car's "true" emission output level by determining the *volume* of emissions it produces. It also incorporates a functional test of the evaporative emissions system.

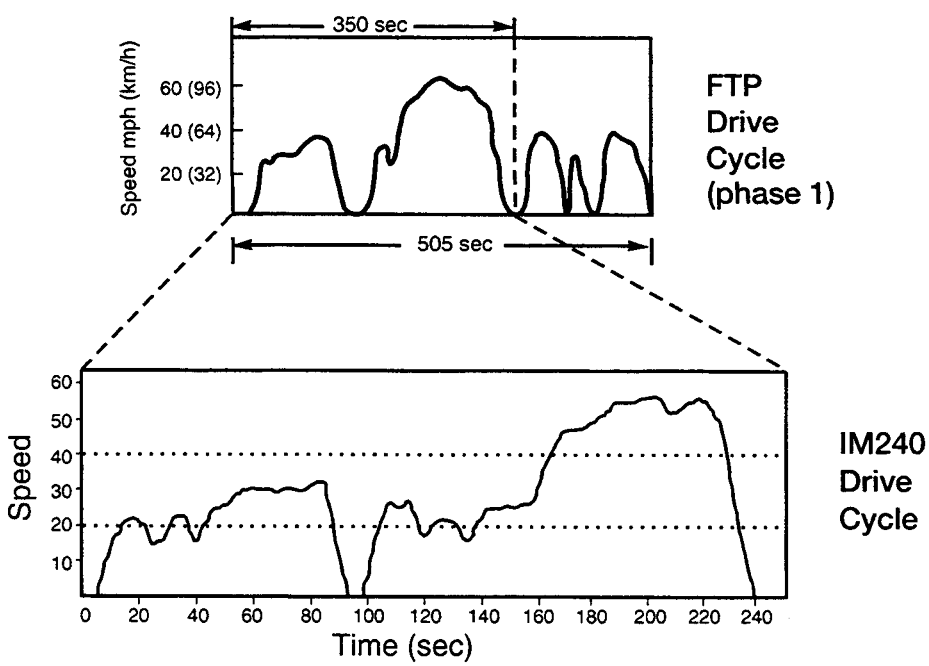
IM240 is composed of three distinct tests:

1. **Transient, Mass Emission Tailpipe Test**
2. **Evaporative System Purge Flow Test**
3. **Evaporative System Pressure Test**

The IM240 differs from traditional I/M tests in that the emissions are measured while the vehicle is driven on a dynamometer. A few states currently test vehicles on a dynamometer, but only operate the vehicle at one speed. With IM240, the vehicle is operated over a driving cycle that has many different speeds, and includes vehicle acceleration and deceleration in a manner similar to city driving. Acceleration and deceleration can be significant sources of emissions from malfunctioning vehicles.

IM240 Transient Drive Cycle

The IM240 drive cycle is a shortened version of the first 350 seconds to the FTP phase 1 drive cycle.

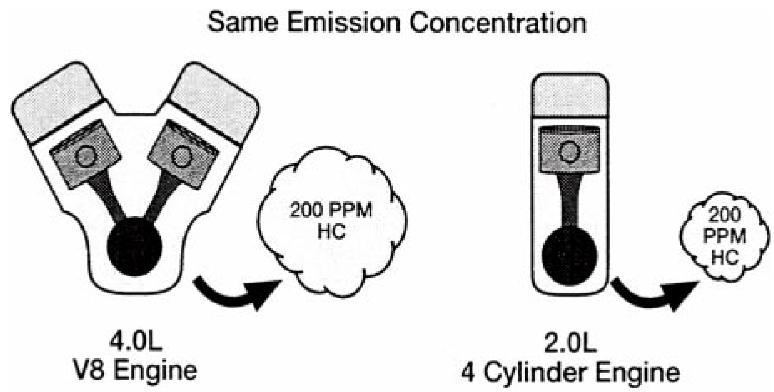


IM240 Transient Test

The IM240 transient test is essentially a shortened version of the first 350 seconds of the FTP UDDS (Urban Dynamometer Driving Schedule) that is compressed to fit into a 240 second drive cycle. IM240 also includes the same test elements except the cold start test phase. Also, it is designed to have a close correlation with FTP while allowing for high throughput at centralized I/M test lanes. Hydrocarbon (HC), Carbon Monoxide (CO), and Oxides of Nitrogen (NO\) emissions are tested during the IM240 drive cycle. Remember, only HC and CO emissions are tested in most traditional I/M tests.

Drawbacks of Concentration Based Sampling

Shop analyzers that measure exhaust gas concentrations cannot measure the total volume of emissions emitted from the tailpipe.



Another important difference between IM240 and traditional I/M tests is that the IM240 captures the entire exhaust stream during the test and measures the total mass of emissions from the vehicle (that is grams of pollutant per mile driven) *as* opposed to the concentration of emissions in the tailpipe (% or ppm). Mass emissions are a more accurate way of measuring the emission performance of large and small engines, and are more directly related to the contribution that each car makes to air pollution. The IM240 is also capable of measuring fuel economy. If you recall, this is the same as the test procedures used for the FTP.

IM240 Evaporative System Purge and Pressure Test

The purge and pressure tests check for proper functioning of the evaporative emission system on the vehicle. The evaporative emission system is used to prevent fuel vapors from escaping into the atmosphere. In fact, evaporative HC emissions from motor vehicles actually exceed exhaust HC emissions, making them a vital aspect of Enhanced I/M Programs.

The evaporative emission system uses engine vacuum to draw fuel vapors temporarily stored in the evaporative canister, into the engine for combustion. The purge test determines whether this system is functioning properly by measuring the flow of vapors into the engine during the IM240. The pressure test checks the evaporative emission system for leaks that would allow fuel vapors to escape into the atmosphere.

IM240 Test Procedures

The IM240 begins by driving the vehicle onto the dynamometer, activating vehicle restraints, positioning the exhaust collection device, and positioning the auxiliary engine cooling fan. An inspector then conducts the test by driving the vehicle according to a prescribed cycle displayed on a video screen. The inspector follows the driving cycle by using the accelerator pedal and the brake to speed-up and slow-down the vehicle in the same manner as if the vehicle were being driven on a city street. The vehicle speed is indicated by a cursor on the video screen, and the inspector adjusts the vehicle speed to keep the cursor on the driving cycle trace. This technique is easily and quickly learned by anyone who can drive a car.

The length of the IM240 test can vary depending on the emissions levels from the vehicle. The emission standards are about two to three times higher than the new car standards used to certify the vehicle. To determine emission levels, second-by-second instantaneous emission measurements are taken and integrated by a computer. The computer continually monitors the vehicle's emission levels during each phase of the test and uses fast pass/fail algorithms to identity exceptionally clean or dirty vehicles. As soon as the emission rates indicate that a vehicle is exceptionally clean or dirty, the computer automatically notifies the inspector to stop emission testing. For vehicles that are close to maximum allowable emission levels, the test may continue for a full 240 seconds. Thus, while the complete driving cycle is 240 seconds long (4 minutes), the average test time per vehicle should only be two to three minutes.

The IM240 transient test can be broken down into two phases that incorporates an on-road simulation of hot start-up, idle, acceleration, deceleration, and a several part throttle speed/load conditions. Details of the phases are as follows:

- **IM240 Phase 1:**
  - comprises the first 93 seconds of the drive cycle
  - samples collected during this phase are stored in Bag #1
- **IM240 Phase 2:**
  - comprises the remaining 147 seconds of the drive cycle
  - sample collected during this phase are stored in Bag #2

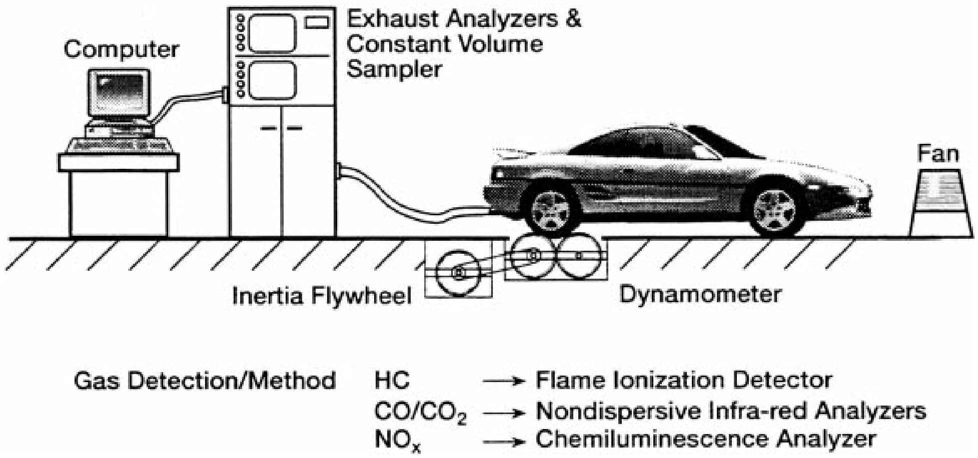
If the test requires the entire 240 second duration, the vehicle will have covered approximately 1.95 miles. As you can see, the certification standards for IM240 are very stringent; the 1994 certification standards are as follows:

- HC = 0.8 g/m, CO = 15 g/m, NOx = 2 g/m

Keep in mind, these standards are about 3 times "looser" than the FTP standards that were used to test the same model vehicle when it was new. This allows for some tolerance from new car standards as a result of vehicle age. Additionally, when IM240 is compared to traditional I/M programs, the test results are much more indicative of emission levels that would result from "real world" driving conditions (loaded conditions, acceleration, deceleration, etc.)

IM240 Test Equipment

IM240 test equipment is similar to FTP test equipment. It includes a variable inertia dyno, CVS and highly accurate emission analyzers.



IM240 Transient Test Equipment

The equipment needed for IM240 is essentially the same as that used for FTP; however, it differs greatly from the equipment used to perform either an idle test, which is used in most currently operating I/M programs, or the single-speed dynamometer tests used by some I/M programs. These differences include dynamometer capabilities, video driver trace monitors, special sampling systems, and emission analyzers. In addition, the high-tech test system will use computer controls with integrated quality assurance functions and will be completely automated.

The following test equipment is used in IM240:

- Variable Inertia Weight Dynamometer
- Constant Volume Sampler (CVS)
- Sophisticated Emission Measurement Equipment:
  - Non-Dispersive Infrared (NDIR) for CO and CO2
  - Flame lonization Detector (FID) for HC
  - Chemiluminescence detection for NOx

The primary difference between the **Variable Inertia Weight Dynamometer** used for the IM240 and those used for single speed I/M tests is the addition of inertia flywheels. The inertia flywheels selected are based on the weight of the car being tested, and allows the inspection test to simulate vehicle inertia during acceleration and deceleration. This allows the emissions of the vehicle operating under these normal driving conditions to be measured. This type of dynamometer is widely available and is similar to the ones used by EPA and car manufacturers for new car certification.

The selection of the inertia weight and test horsepower for an individual vehicle will be automatically determined by computer so that the I/M inspector is only required to drive the vehicle onto the dynamometer. Even the system used to hold the vehicle on the dynamometer will be automatic in order to minimize test setup and improve testing throughput.

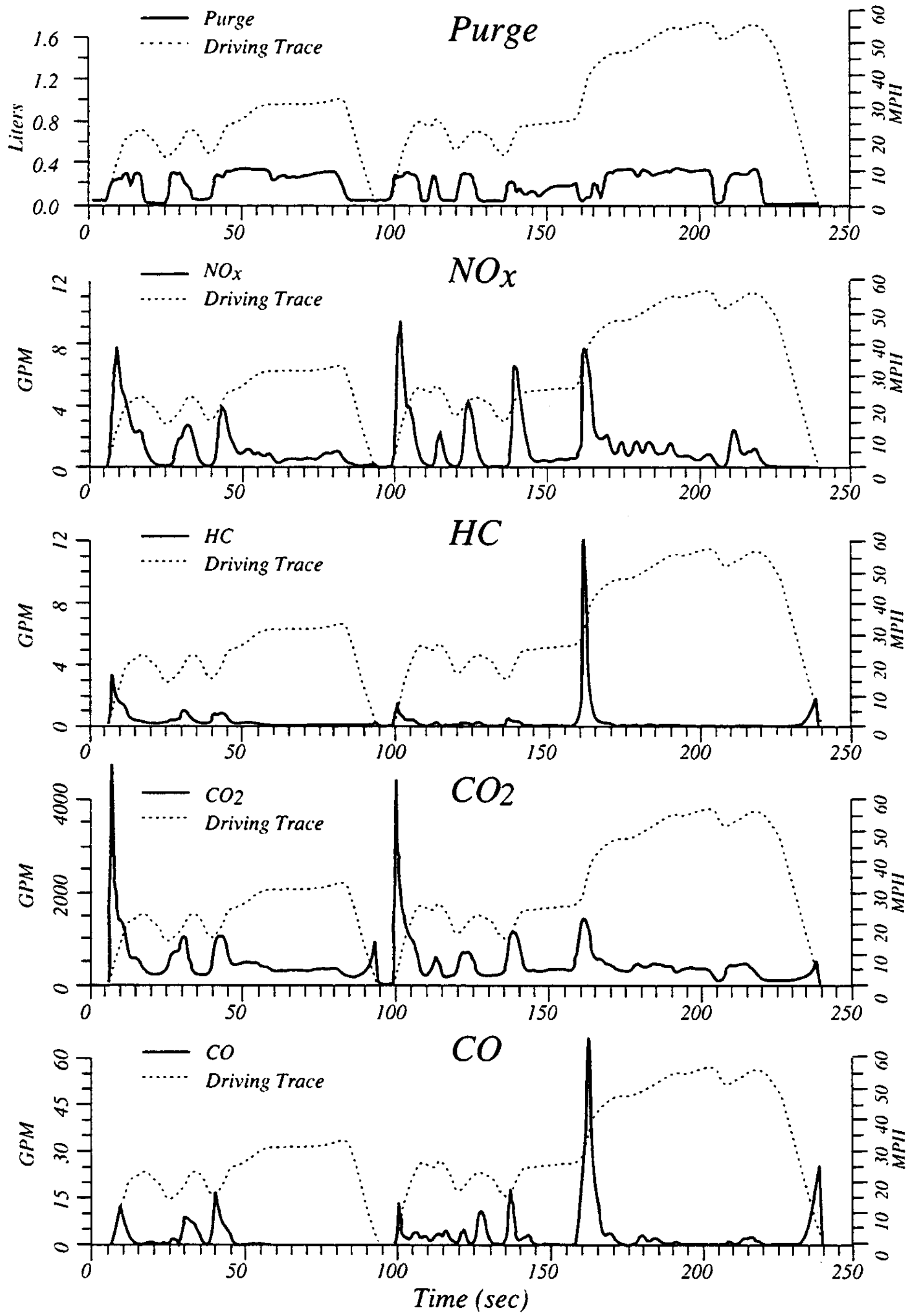
The mass of emissions emitted by a vehicle are determined by collecting the entire exhaust flow from the vehicle with a device known as a **Constant Volume Sampler (CVS)**. Within the CVS, the exhaust is diluted by fresh air, and the total volume of the exhaust mixture is measured. Combining the total volume measurement with the concentration levels of pollutants in the mixture (i.e., % or ppm) allows the total mass of emissions to be calculated.

The fresh air dilution is vital because it ensures capture of the entire exhaust sample and it protects the emission analyzers from high concentrations of water vapor produced by the vehicle. The dilution process also allows the measurement system to accommodate the difference in exhaust flow between small engines and large engines while measuring the true amount of emission from each type of engine.

The diluted sample, however, lowers the concentration of the pollutants to be measured, and hence, requires more sensitive emission analyzers than those used by traditional I/M programs. In addition, the method for measuring HC emission uses a different technique than traditional programs. HC emissions are measured with a **Flame lonization Detector (FID),** while CO and carbon dioxide emissions are measured using **Non-Dispersive Infrared Analyzers.** NOx emissions are measured with a **Chemiluminescence analyzer.**

Sample IM240 Transient Test Results

The IM240 drive trace is superimposed over graphs representing output levels for tested gases. These readings can then be analyzed against various IM240 operating conditions (acceleration, deceleration, cruise, etc.)



Evaporative System Purge Test

Since 1971, fuel tanks on cars have been designed to be a closed system in which vapors that evaporate from the gasoline in the tank are not released into the atmosphere. The system is sealed and under pressure so that excess vapors are shunted to a charcoal canister; also known as the evaporative canister.

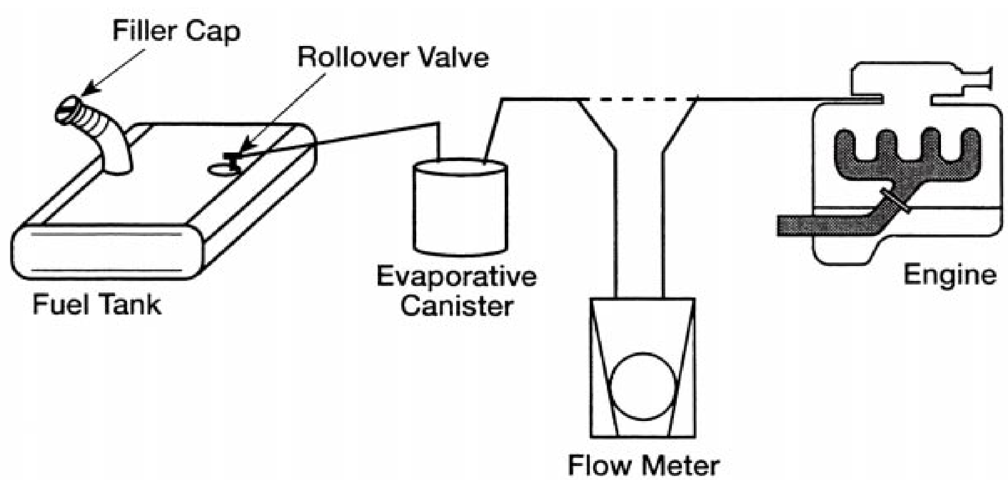
The evaporative system purge test is used to determine whether fuel vapor stored in the evaporative canister are being properly drawn into the engine for combustion while the car is being driven. If the purge system is not working properly, then the evaporative canister can become saturated with fuel vapor and start to leak hydrocarbons into the atmosphere.

The purge test is conducted while the vehicle is driven on the dynamometer. Purge flow is measured by simply inserting a flow transducer in-line with the canister purge hose.

Purge failures are determined based on the total flow observed during the IM240 transient test, not by instantaneous flow rates. The vehicle must have a minimum of **1 liter of flow** in order to pass. Most cars in proper working order will accumulate as much as 25 liters or more during the IM240 transient cycle. As soon as a vehicle exceeds 1 liter of flow the purge test is complete. For this reason, the purge test time is usually very short for most vehicles.

The purge test requires a flow meter that can measure the total vapor flow over the transient cycle. Hoses and universal fittings are used to hook up the flow meter as shown below and a computer is used to control the test process, collect and record test data.

EVAP System Purge Test

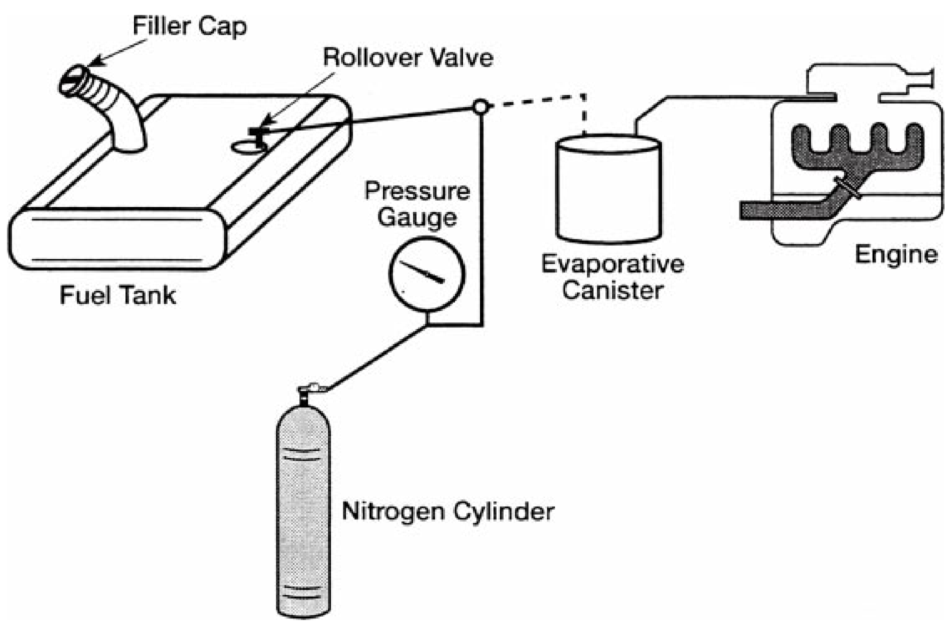


Evaporative System Pressure Test

The pressure test checks the tank vent system for leaks that would allow fuel vapors to escape into the atmosphere. A ”pressure decay” method is used to monitor for pressure losses in the system. In this pressurized method, the vapor lines to the fuel tank, and the fuel tank itself are filled with nitrogen to 14 inches of water (about 0.5 psi). To pressurize these components, the inspector must locate the evaporative canister, remove the vapor line from the fuel tank and hook up the pressure test equipment to the vapor line. After the system is filled, the pressure supply system is closed off, and the loss in pressure is measured. If the system remains **above 8 inches of water after two minutes,** the vehicle passes the test.

A source of nitrogen, a pressure gauge, a valve, and associated hoses and fittings are needed to perform the pressure test. In addition, a computer is used to automatically meter the nitrogen, monitor the pressure, and collect and process the results. In addition, algorithms are used to optimize the test so that a pass/ fail decision can be made in less than two minutes.

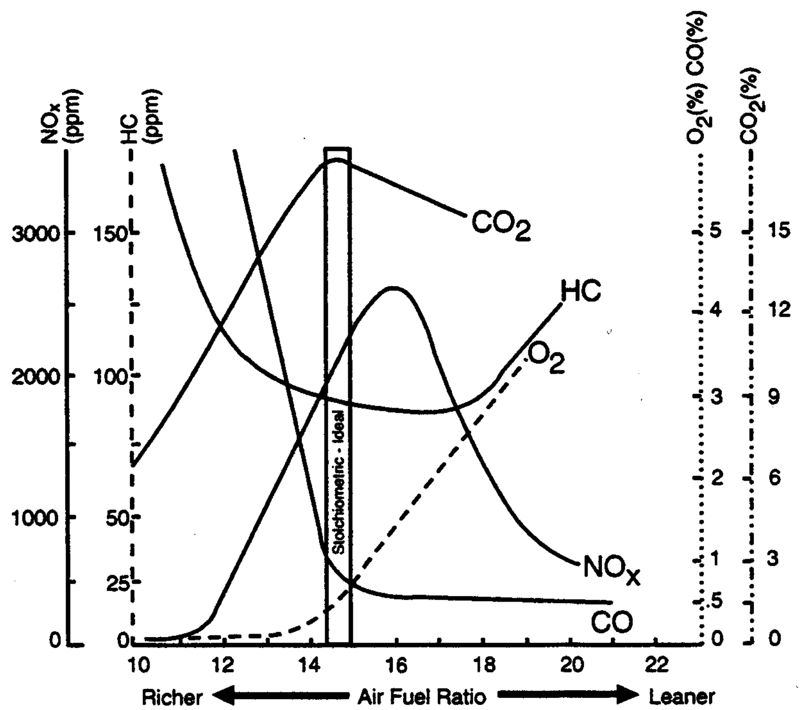
EVAP System Pressure Test



At this point, you should now have a thorough understanding of the evolution and theory behind Basic and Enhanced I/M programs. It is important to note that emissions failures will not necessarily cause a resulting drive-ability symptom, nor will driveability concerns always result in emissions failure. However, many times these problems may be related and may lead to the same system component failure. In any case, whether it’s a drive-ability *symptom* or an emission system *failure,* you would troubleshoot each in the same manner.

Section 3

COMBUSTION CHEMISTRY & EMISSION ANALYSIS



Lesson Objectives

1. Explain the basic combustion chemistry process and how it relates to exhaust gas production.
2. Identify the driving factors behind the development of the Closed Loop Control system.
3. Explain the process in which HC, CO, and NO_x emissions are produced and identify specific conditions that promote its production.
4. Understand the effects air/fuel ratio has on the creation of HC, CO, and NO_x emissions.
5. Identify the specific causes (and related sub-system) directly responsible for high HC, CO, and NO_x levels.
6. Understand the catalytic converters role in oxidizing and reducing engine-out gases.

Notes

Introduction to Combustion Chemistry

The gasoline-powered internal combustion engine takes air from the atmosphere and gasoline, a hydrocarbon fuel, and through the process **of combustion** releases the chemical energy stored in the fuel. Of the total energy released by the combustion process, about 20% is used to propel the vehicle, the remaining 80% is lost to friction, aerodynamic drag, accessory operation, or simply wasted as heat transferred to the cooling system.

Modern gasoline engines are very efficient compared to predecessors of the late '60s and early '70s when **emissions control** and fuel economy were first becoming a major concern of automotive engineers. Generally speaking, the more efficient an engine becomes, the lower the exhaust emissions from the tailpipe. However, as clean as engines operate today, exhaust emission standards continually tighten. The technology to achieve these ever-tightening emissions targets has led to the advanced closed loop engine control systems used on today's Toyota vehicles. With these advances in technology comes the increased emphasis on maintenance, and when the engine and emission control systems fail to operate as designed, diagnosis and repair.

Understanding the Combustion Process

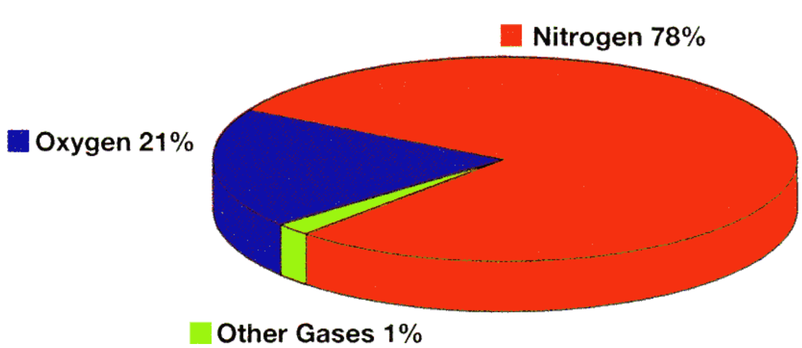
To understand how to diagnose and repair the emissions control system, one must first have a working knowledge of the basic **combustion chemistry** which takes place within the engine. That is the purpose of this section of the program.

The gasoline burned in an engine contains many chemicals, however, it is primarily made up **of hydrocarbons** (also referred to as HC). Hydrocarbons are chemical compounds made up of hydrogen atoms which chemically bond with carbon atoms. There are many different types of hydrocarbon compounds found in gasoline, depending on the number of hydrogen and carbon atoms present, and the way that these atoms are bonded.

Inside an engine, the hydrocarbons in gasoline will not burn unless they are mixed with air. This is where the chemistry of combustion begins. Air is composed of approximately 21% oxygen (O_2), 78% nitrogen (N_2), and minute amounts of other inert gasses.

Atmospheric Make-Up

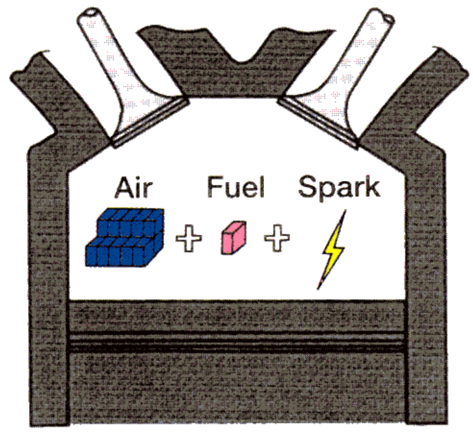
Approximately 99% of "air" is made up of Nitrogen (N_2) and Oxygen (O_2). The "other gasses" include Argon (Ar), CO_2, HC, NO_x, SO_2, and trace amounts of other gases.



The hydrocarbons in fuel normally react only with the oxygen during the combustion process to form water vapor (H2O) and carbon dioxide (C02), creating the desirable effect of heat and pressure within the cylinder. Unfortunately, under certain engine operating conditions, the nitrogen also reacts with the oxygen to form **nitrogen oxides** (NOx), a criteria air pollutant.

Components of Basic Combustion

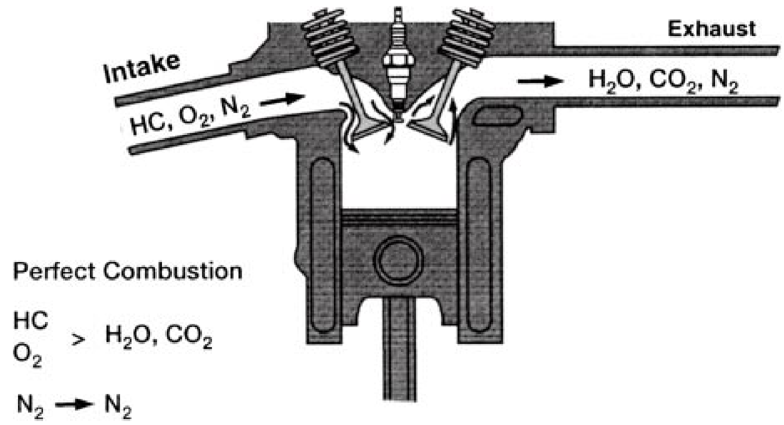
These components, along with other very specific conditions, are needed in order for basic combustion to occur.



The ratio of air to fuel plays an important role in the efficiency of the combustion process. The ideal air/fuel ratio for optimum emissions, fuel economy, and good engine performance is around 14.7 **pounds of air for every one pound of fuel.** This ”ideal air/fuel ratio” is referred to as **stoichiometry,** and is the target that the feedback fuel control system constantly shoots for. At air/fuel ratios richer than stoichiometry, fuel economy and emissions will suffer. At air/fuel ratios leaner than stoichiometry, power, driveability and emissions will suffer.

"Ideal" Combustion

If "perfect" combustion were to occur, hydrocarbons (HC) would be oxidized into water (H_2O) and carbon dioxide (CO_2). Also, nitrogen (N_2) would pass through unaffected.



Under "Ideal" Combustion Conditions

In a perfectly operating engine with ideal combustion conditions, the following chemical reaction would take place:

- Hydrocarbons would react with oxygen to produce **water vapor (H_2O)** and **carbon dioxide (CO_2)**
- **Nitrogen (N_2)** would pass through the engine without being affected by the combustion process.

In essence, only harmless elements would remain and enter the atmosphere. Although modern engines are producing much lower emission levels than their predecessors, they still inherently produce some level of harmful emission output.

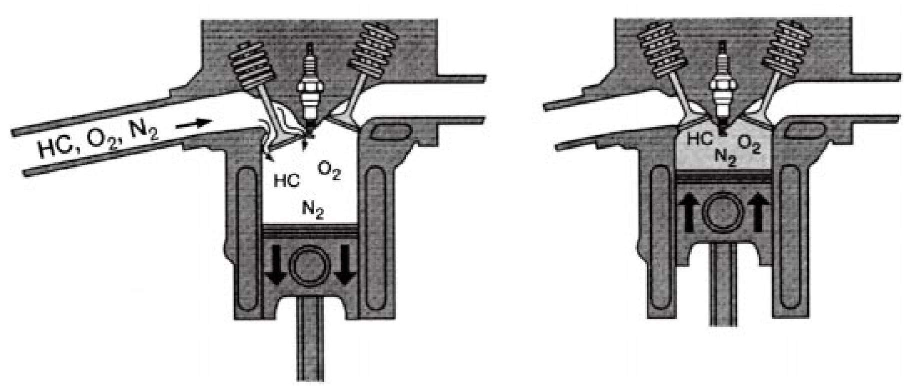
The Four Stroke Combustion Cycle

During the **Intake Stroke,** air and fuel moves into the low pressure area created by the piston moving down inside the cylinder. The fuel injection system has calculated and delivered the precise amount of fuel to the cylinder to achieve a 14.7 to 1 ratio with the air entering the cylinder.

As the piston moves upward during the **Compression Stroke,** a rapid pressure increase occurs inside the cylinder, causing the air/fuel mixture to superheat. During this time, the antiknock property or **octane rating** of the fuel is critical in preventing the fuel from igniting spontaneously (exploding). This precise superheated mixture is now prime for ignition as the piston approaches Top Dead Center.

Intake and Compression Stroke

During intake, air and fuel is drawn into the cylinder by the downward motion of the piston. During compression, cylinder pressure is increased making the air/fuel charge prime for ignition.

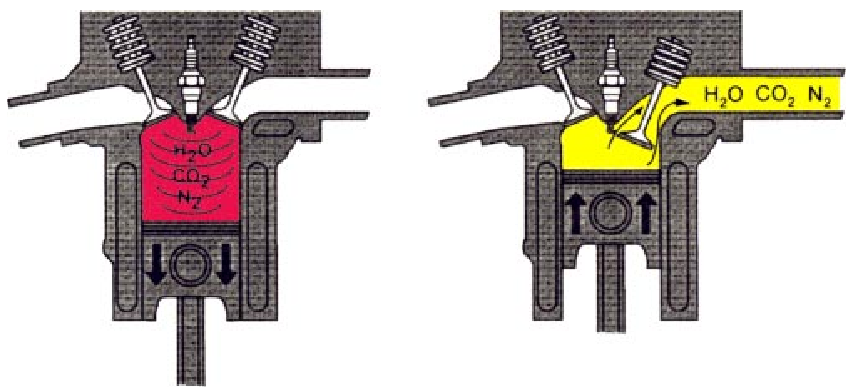


Just before the piston reaches top dead center to start the **Power Stroke,** the spark plug ignites the air/fuel mixture in the combustion chamber, causing a flame-front to begin to spread through the mixture. During combustion, hydrocarbons and oxygen react, creating heat and pressure. Ideally, the maximum pressure is created as the piston is about 8 to 12 degrees past top dead center to produce the most force on the top of the piston and transmit the most power through the crankshaft. Combustion by-products will consist primarily of water vapor and carbon dioxide if the mixture and spark timing are precise.

After the mixture has burned and the piston reaches bottom dead center, the **Exhaust Stroke** begins as the exhaust valve opens and the piston begins its return to top dead center. The water vapor, carbon dioxide, nitrogen, and a certain amount of unwanted pollutants are pushed out of the cylinder into the exhaust system.

Power and Exhaust Stroke

During power stroke, the air/fuel charge is ignited and the combustion pressure is exerted on the piston. During exhaust stroke, combustion gases are expelled into the exhaust system.

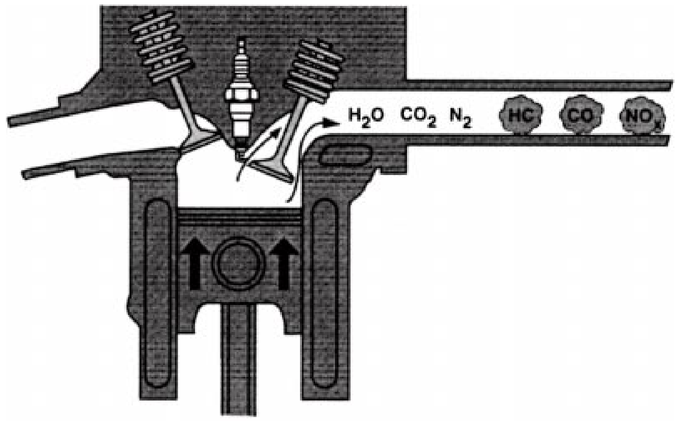


Harmful Exhaust Emissions

As previously mentioned, even the most modern, technologically advanced automobile engines are not ”perfect”; they still inherently produce some level of harmful emission output. There are several conditions in the combustion chamber which prevent perfect combustion and cause unwanted chemical reactions to occur. The following are examples of harmful exhaust emissions and their causes.

Exhaust Emissions

Automobile engines inherently produce some level of harmful emission output.



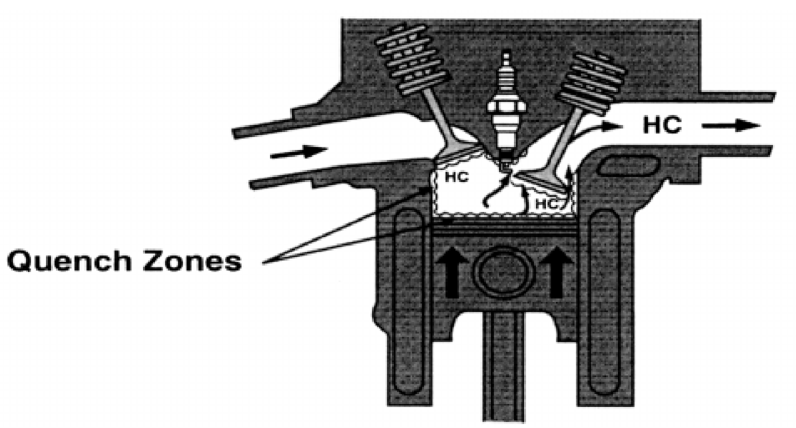
Hydrocarbon (HC) Emission

Hydrocarbons are, quite simply, raw unburned fuel. When combustion does not take place at all, as with a misfire, large amounts of hydrocarbons are emitted from the combustion chamber.

A small amount of hydrocarbon is created by a gasoline engine due to its design. A normal process called wall quenching occurs as the combustion flame front burns to the relatively cool walls of the combustion chamber. This cooling extinguishes the flame before all of the fuel is fully burned, leaving a small amount of hydrocarbon to be pushed out the exhaust valve.

”Quenching”

Quenching occurs when the front combustion flame-front is extinguished before all the fuel is burned.



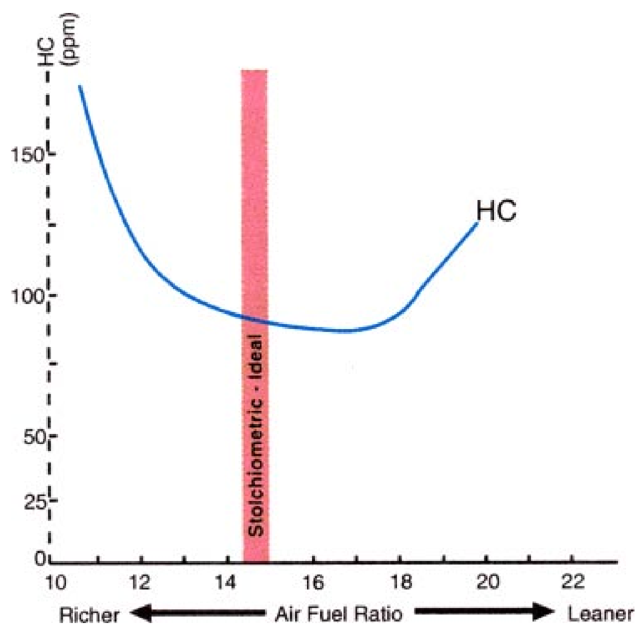
Another cause of excessive hydrocarbon emissions is related to combustion chamber deposits. Because these carbon deposits are porous, hydrocarbon is forced into these pores as the air/fuel mixture is compressed. When combustion takes place, this fuel does not burn, however, as the piston begins its exhaust stroke, these hydrocarbons are released into the exhaust stream.

The most common cause of excessive hydrocarbon emissions is **misfire** which occurs due to ignition, fuel delivery, or air induction problems. Depending on how severe the misfire, inadequate spark or a noncombustible mixture (either too rich or too lean) will cause hydrocarbons to increase to varying degrees. For example, a total misfire due to a shorted spark plug wire will cause hydrocarbons to increase dramatically. Conversely, a slight lean misfire due to a false air entering the engine, may cause hydrocarbons to increase only slightly.

Excess hydrocarbon can also be influenced by the temperature of the air/ fuel mixture as it enters the combustion chamber. Excessively low intake air temperatures can cause poor mixing of fuel and air, resulting in partial misfire.

Effects of A/F Ratio on Exhaust HC

As shown, exhaust HC production is lowest when A/F ratio is slightly leaner than "ideal"; however, HC's increases dramatically when the mixture becomes too rich or too lean to the point of misfire

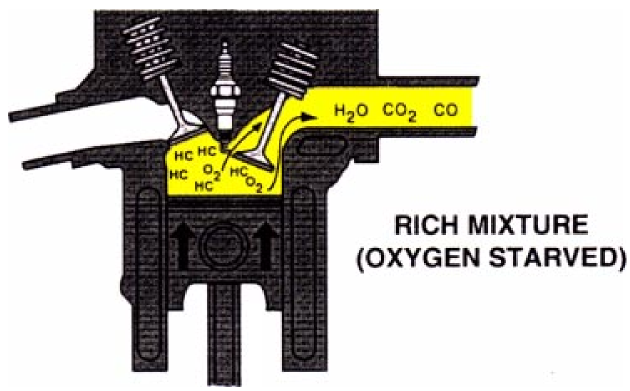


Carbon Monoxide (CO) Emission

Carbon monoxide (CO) is a byproduct *of incomplete* combustion and is essentially *partially* burned fuel. If the air/fuel mixture does not have enough oxygen present during combustion, it will not burn completely. When combustion takes place in an oxygen starved environment, there is insufficient oxygen present to fully oxidize the carbon atoms into carbon dioxide (CO2). When carbon atoms bond with only one oxygen atom carbon monoxide (CO) forms.

Oxygen Starved Combustion

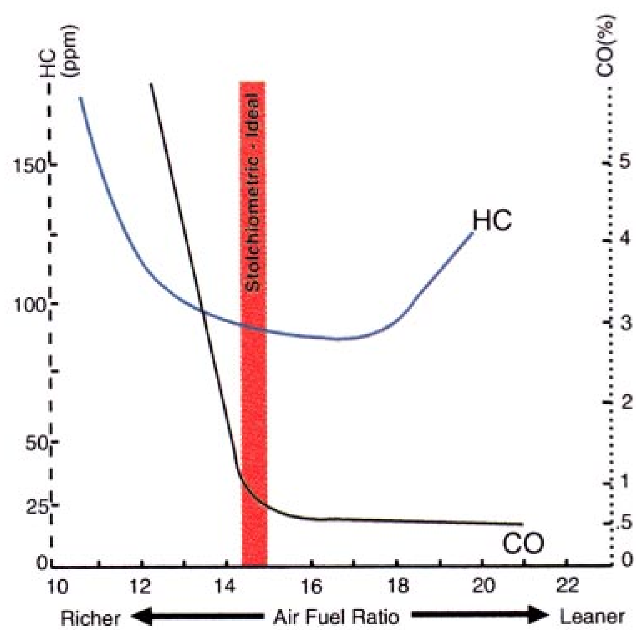
During combustion with rich A/F mixtures, the carbon from HC only partially oxidizes, resulting in carbon monoxide (CO) rather than carbon dioxide (CO_2).



An oxygen starved combustion environment occurs as a result of air/fuel ratios which are richer than stoichiometry (14.7 to 1). There are several engine operating conditions when this occurs normally. For example, during cold operation, warm-up, and power enrichment. It is, therefore, normal for higher concentrations of carbon monoxide to be produced under these operating conditions. Causes of excessive carbon monoxide includes leaky injectors, high fuel pressure, improper closed loop control, etc.

Effects of A/F Ratio on Exhaust CO

Exhaust CO is lowest when A/F ratio is leaner than ”ideal”; however, CO increases dramatically with richer mixtures.



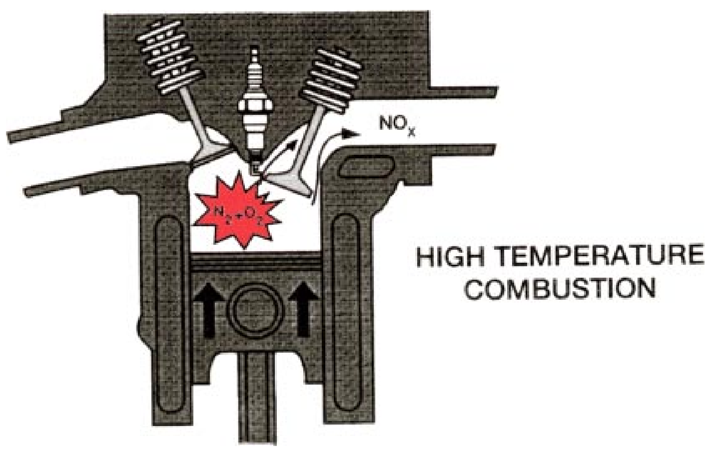
When the engine is at warm idle or cruise, very little carbon monoxide is produced because there is sufficient oxygen available during combustion to fully oxidize the carbon atoms. This results in higher levels of carbon dioxide (CO2) the principal by-product of efficient combustion.

Oxides of Nitrogen (NO_X) Emission

High cylinder temperature and pressure which occur during the combustion process can cause nitrogen to react with oxygen to form Oxides of Nitrogen (NOx). Although there are various forms of nitrogen-based emissions that comprise Oxides of Nitrogen (NOx), nitric oxide (NO) makes up the majority, about 98% of all NOx emissions produced by the engine.

High Temperature Combustion

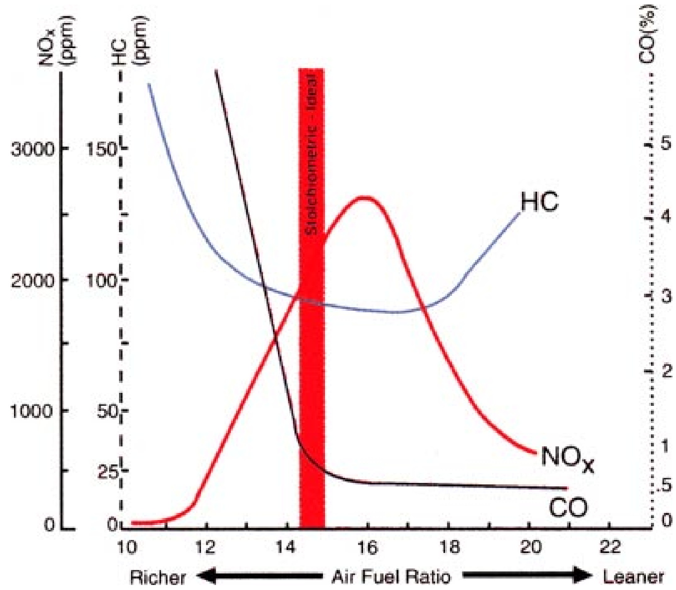
High combustion temperature (typical during heavy load conditions), causes the nitrogen to combine with oxygen to form Oxides of Nitrogen (NO_X).



Generally speaking, the largest amount of NOx is produced during moderate to heavy load conditions when combustion pressures and temperatures are their highest. However, small amounts of NOx can also be produced during cruise and light load, light throttle operation. Common causes of excessive NOx include faulty EGR system operation, lean air/fuel mixture, high temperature intake air, overheated engine, excessive spark advance, etc.

Effects of A/F Ratio on Exhaust NO_X

Exhaust NO_X production is highest when A/F ratio is slightly leaner than "ideal". This inverse relationship with HC and CO production poses a problem when attempting to lower all three emission levels at once.



Air/Fuel Mixture Impact on Exhaust Emissions

As you can see in the graph above, HC and CO levels are relatively low near the theoretically ideal 14.7 to 1 air/fuel ratio. This reinforces the need to maintain strict air/fuel mixture control. However, NO_x production is very high just slightly leaner than this ideal mixture range. This inverse relationship between HC/CO production and NO_x production poses a problem when controlling total emission output. Because of this relationship, you can understand the complexity in reducing all three emissions at the same time.

Exhaust Analysis Using 4 and 5 Gas Analyzers

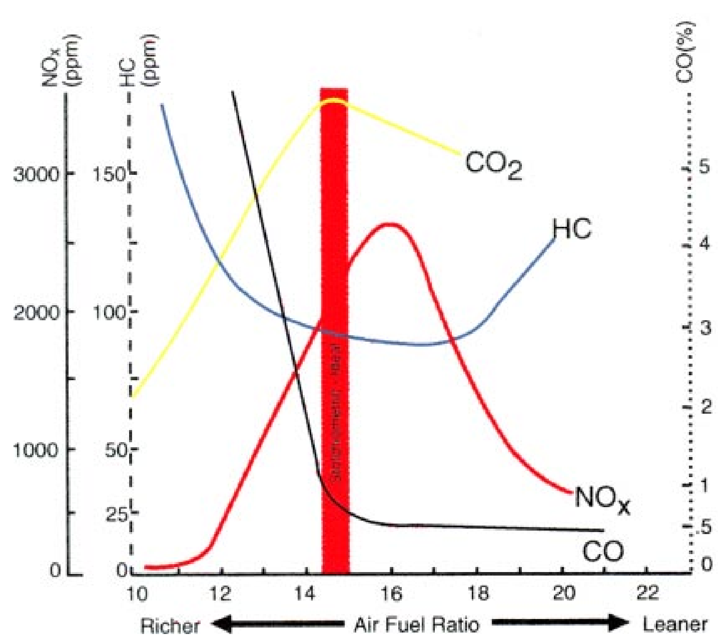
So far we've discussed how harmful exhaust emissions are produced during combustion. However, in addition to these harmful emissions, both carbon dioxide (CO_2) and oxygen (O_2) readings can provide additional information on what's going on inside the combustion chamber.

Carbon Dioxide (CO_2)

Carbon dioxide, or CO_2, is a desirable byproduct that is produced when the carbon from the fuel is fully oxidized during the combustion process. As a general rule, the higher the carbon dioxide reading, the more efficient the engine is operating. Therefore, air/fuel imbalances, misfires, or engine mechanical problems will cause CO_2 to decrease. Remember, "ideal" combustion produces large amounts of CO_2 and H_2O (water vapor).

Effects of A/F Ratio on Exhaust CO2

Exhaust CO_2 production is highest when A/F mixture is at the "ideal" 14.7/1 ratio. CO_2 is an excellent indicator of efficient combustion.

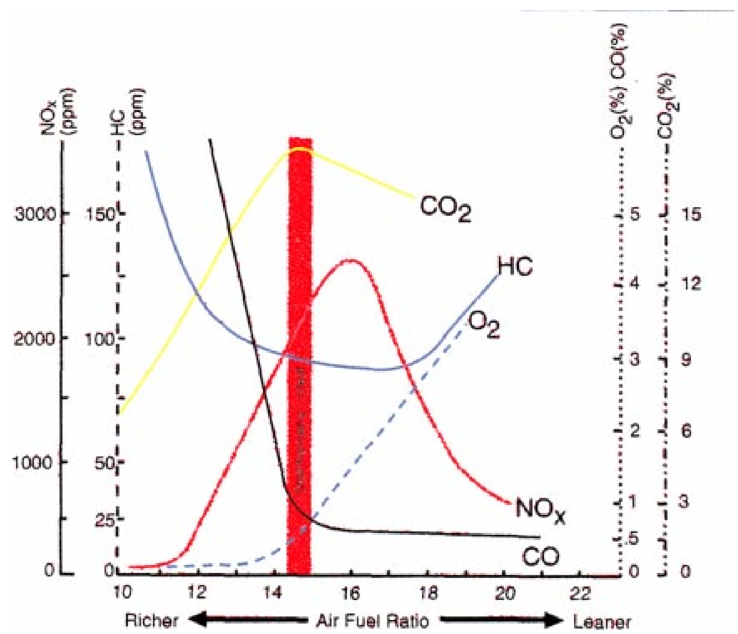


Oxygen (O_2)

Oxygen (0_2) readings provide a good indication of a lean running engine, since O_2 increases with leaner air/fuel mixtures. Generally speaking, O_2 is the opposite of CO, that is, O_2 indicates leaner air/fuel mixtures while CO indicates richer air/fuel mixtures. Lean air/fuel mixtures and misfires typically cause high O_2 output from the engine.

Effects of A/F Ratio on Exhaust O_2

Exhaust O_2 is lowest when A/F ratio is richer than "ideal"; however, O_2 increases dramatically with leaner mixtures.



Other Exhaust Emissions

There are a few other exhaust components which impact driveability and/or emissions diagnosis, that are not measured by shop analyzers. They are:

- Water vapor (H_2O)
- Sulfur Dioxide (SO_2)
- Hydrogen (H_2)
- Particulate carbon soot (C)

Sulfur dioxide (SO_2) is sometimes created during the combustion process from the small amount of sulfur present in gasoline. During certain conditions the catalyst oxidizes sulfur dioxide to make SO_3, which then reacts with water to make H_2SO_4 or sulfuric acid. Finally, when sulfur and hydrogen react, it forms hydrogen sulfide gas. This process creates the rotten egg odor you sometimes smell when following vehicles on the highway. Particulate carbon soot is the visible black "smoke" you see from the tailpipe of a vehicle that's running very rich.

Causes of Excessive Exhaust Emissions

As a general rule, excessive HC, CO, and NO_X levels are most often caused by the following conditions:

- Excessive **HC** results from ignition misfire or misfire due to excessively lean or rich air/fuel mixtures
- Excessive **CO** results from rich air/fuel mixtures
- Excessive **NO_X** results from excessive combustion temperatures

There are lesser known causes to each of these emissions that will be discussed later. When troubleshooting these types of emissions failures, you will be focusing on identifying the cause of the conditions described above. For example, to troubleshoot the cause of excessive CO emissions, you need to check all possible causes of too much fuel *or* too little air (rich air fuel/ratio). The following lists of causes will help familiarize you with the sub-systems most often related to excessive CO, HC and NOx production.

Causes of Excessive Hydrocarbons

As mentioned, **high hydrocarbons** is most commonly caused by engine misfires. The following list of problems could cause high HC levels on fuel injected vehicles. *As with any quick reference, there are other less likely causes that may not be included in the list.* Here are some of the more common causes:

- Ignition system failures
  - faulty ignition secondary component
  - faulty individual primary circuit on distributorless ignition system
  - weak coil output due to coil or primary circuit problem
- Excessively lean air/fuel mixture
  - leaky intake manifold gasket
  - worn throttle shaft
- Excessive EGR dilution
  - EGR valve stuck open or excessive EGR flow rate
  - EGR modulator bleed plugged
- Restricted or plugged fuel injector(s)
- Closed loop control system incorrectly shifted lean
- False input signal to ECM
  - incorrect indication of load, coolant temp., O2 content, or throttle position
- Exhaust leakage past exhaust valve(s)
  - tight valve clearances
  - burned valve or seat
- Incorrect spark timing
  - incorrect initial timing
  - false input signal to ECM

- Excessive combustion blowby
  - worn piston rings or cylinder walls
- Insufficient cylinder compression
- Carbon deposits on intake valves

Causes of Excessive Carbon Monoxide

High carbon monoxide levels are caused by anything that can make the air/mixture richer than "ideal". The following examples are typical causes of rich mixtures on fuel injected vehicles:

- Excessive fuel pressure at the injector(s)
- Leaking fuel injector(s)
- Ruptured fuel pressure regulator diaphragm
- Loaded/malfunctioning EVAP system *(two speed idle test)*
- Crankcase fuel contamination (two speed idle test)
- Plugged PCV valve or hose *(two speed idle test)*
- Closed loop control system incorrectly shifted rich
- False input signal to ECM
  - incorrect indication of load, coolant temp., O2 content, or throttle position

NOTE

It should be pointed out that due to the reduction ability of the catalytic converter, **increases in CO emissions tend to reduce NOx emissions.** It is not uncommon to repair a CO emissions failure and, as a result of another sub-system deficiency, have NOx increase sufficiently to fail a loaded-mode transient test.

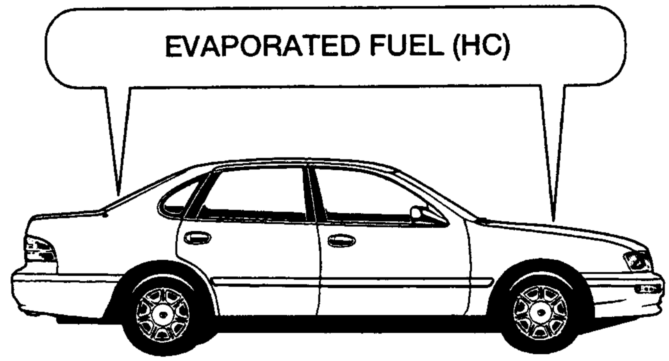
Causes of Excessive Oxides of Nitrogen

Excessive oxides of nitrogen can be caused by anything that makes combustion temperatures rise. Typical causes of high combustion temperature on fuel injected vehicles include:

- Cooling system problems
  - insufficient radiator airflow
  - low coolant level
  - poor cooling fan operation
  - thermostat stuck closed or restricted
  - internal radiator restriction
- Excessively lean air/fuel mixture
  - leaky intake manifold gasket
  - worn throttle shaft
- Closed loop control system incorrectly shifted lean
- Improper oxygen sensor operation
  - slow rich to lean switch time
  - rich biased O2 sensor voltage
- Improper or inefficient operation of EGR system
  - restricted EGR passage
  - EGR valve inoperative
  - EGR modulator inoperative
  - plugged E or R port in throttle body
  - faulty EGR VSV operation
  - leaky/misrouted EGR hoses
- Improper spark advance system operation
  - incorrect base timing
  - false signal input to ECM
  - improper operation of knock retard system
- Carbon deposits on intake valves

HC From Evaporative Sources

HC emissions can also originate from evaporative sources, such as the crankcase, fuel tank, and EVAP system components.



Evaporative Emissions

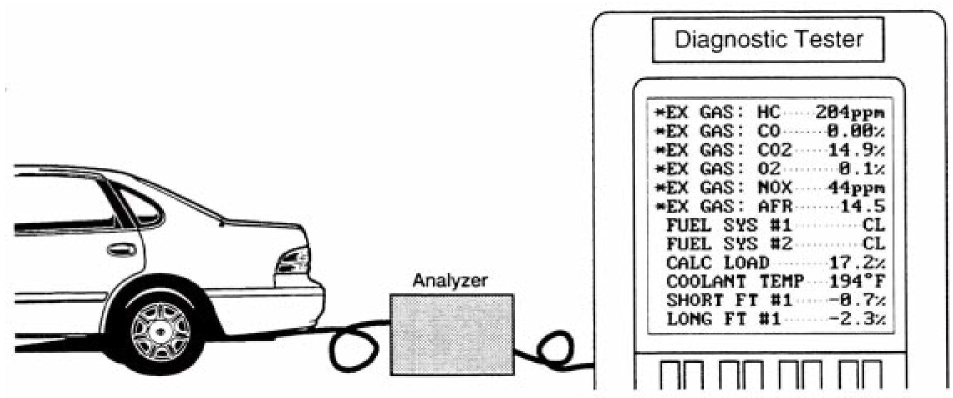
Up to now, we've only discussed the creation and causes *of tailpipe* or exhaust emission output. However, it should be noted that hydrocarbon (HC) emissions come from the tailpipe, as well as other evaporative sources, like the crankcase, fuel tank and evaporative emissions recovery system.

In fact, studies indicate that as much as 20% of all HC emissions from automobiles comes from the fuel tank and carburetor (on carbureted vehicle, of course). Because hydrocarbon emissions are Volatile Organic Compounds (VOCs) which contribute to smog production, it is just as important that evaporative emission controls are in as good a working order as combustion emission controls.

Fuel injected vehicles use an evaporative emissions system to store fuel vapors from the fuel tank and burn them in the engine when it is running. When this system is in good operating order, fuel vapor cannot escape from the vehicle unless the fuel cap is removed. The subject of Evaporative Emissions Systems is addressed in the next section of this program.

Exhaust Gas Analyzers

5-Gas Exhaust Analyzers are now available that allow you to ”zero-in” on potential causes of emission and driveability concerns.



Diagnosis Using an Exhaust Gas Analyzer

Use of a four or five gas exhaust analyzer can be helpful in troubleshooting both emissions and driveability concerns. Presently, shop grade analyzers are capable of measuring from as few as two exhaust gasses, HC and CO, to as many as five. The five gasses measured by the latest technology exhaust analyzers are: HC, CO, C02, O2 and NOx- Remember, HC, CO, CO2, and NOx are measured in Enhanced I/M programs.

All five of these gasses, especially O2 and CO2, are excellent troubleshooting tools. Use of an exhaust gas analyzer will allow you to narrow down the potential cause of driveability and emissions concerns, focus your troubleshooting tests in the area(s) most likely to be causing the concern, and save diagnostic time. In addition to helping you focus your troubleshooting, an exhaust gas analyzer also gives you the ability to measure the effectiveness of repairs by comparing *before* and *after* exhaust readings.

In troubleshooting, always remember the combustion chemistry equation: Fuel (hydrogen, carbon, sulfur) + Air (nitrogen, oxygen) = Carbon dioxide + water vapor + oxygen + carbon monoxide + hydrocarbon + oxides of nitrogen + sulfur oxides

In any diagnosis of emission or driveability related concern, ask yourself the following questions:

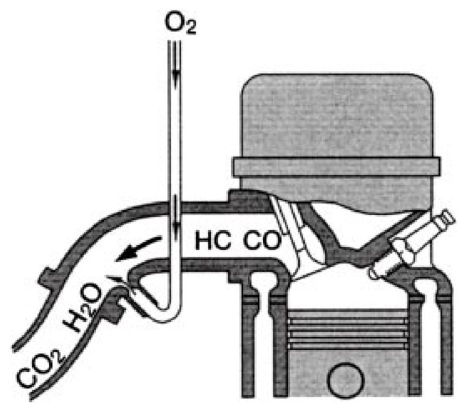
- What is the symptom?
- What are the ”baseline” exhaust readings? At idle, 2500 rpm, acceleration, deceleration, light load cruise, etc.
- Which sub-system(s) or component(s) could cause the combination of exhaust gas readings measured?

The Effects of Secondary Air

Some Toyota engines use a secondary air system to supplement the oxygen supply for the oxidation catalyst. This supplementary air is introduced into the exhaust stream upstream of the catalytic converter. Secondary air increases the oxygen content of the exhaust stream and reduces the carbon dioxide by diluting it.

Secondary Air Systems

Secondary air systems introduces oxygen into the exhaust stream to further oxidize engine out-gases. It is important to keep in mind the effect these systems have on tailpipe emission readings.



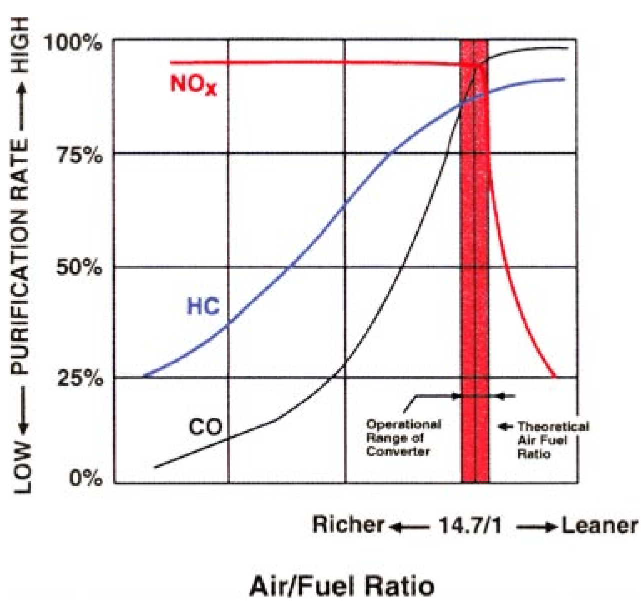
- **Hydrocarbons** are measured by an exhaust analyzer in parts per million (ppm). As you know, HC is unburned fuel that remains as a result of a misfire. When combustion doesn't take place or when only part of the air/fuel charge burns, hydrocarbon levels goes up.
- **Carbon Monoxide** is measured by an exhaust analyzer in percent (%) or parts per hundred. CO is a byproduct of combustion, therefore, if combustion does not take place, carbon monoxide will not be created. Based on this premise, when a misfire occurs, the carbon monoxide that would have normally been produced during the production process is not produced. Generally speaking, on fuel injected vehicles, high CO means too much fuel is being delivered to the engine for the amount of air entering the intake manifold.
- **Nitrogen Oxides** measured by an exhaust analyzer in parts per million (ppm). Nitrogen oxides are a by-product of combustion. NOx is formed in large quantities when combustion temperatures exceed about 2500° F. Anything which causes combustion temperatures to rise will also cause NOx emissions to rise. Misfire can also cause NOx to rise because of the increase in oxygen that it causes in the catalytic converter feed gas.
- **Carbon Dioxide** measured by an exhaust analyzer in percent (%) or parts per hundred. Carbon dioxide is a by-product of efficient and complete combustion. Near perfect combustion will result in carbon dioxide levels which approach the theoretical maximum of 15.5%. Carbon dioxide levels are effected by air/fuel ratio, spark timing, and any other factors which effect combustion efficiency.

- **Oxygen** is measured by an exhaust analyzer in percent (%) or parts per hundred. The amount of oxygen produced by an engine is effected by how close the air/fuel ratio is to stoichiometry. As the mixture goes lean of stoichiometry, oxygen increases. As mixture goes rich of stoichiometry, oxygen falls close to zero. Because oxygen is used up in the combustion process, concentrations at the tailpipe will be very low. If misfire occurs, however, oxygen will increase dramatically as it passes unused through the combustion chamber.

Another factor in analyzing NO_X emissions are the two primary emissions sub-systems designed to control NO_X levels, the EGR and reduction catalyst systems. NOx emissions will increase when the EGR system malfunctions or when the reduction catalyst efficiency falls. Efficiency of the reduction catalyst is closely tied to normal operation of the closed loop fuel control system. Reduction efficiency falls dramatically when **catalyst feed gas** carbon monoxide content is too low (oxygen content too high.)

Catalyst Efficiency

As shown, catalyst purification efficiency is highest (100%) when A/F mixture is maintained at the "ideal" 14.7/1 ratio.

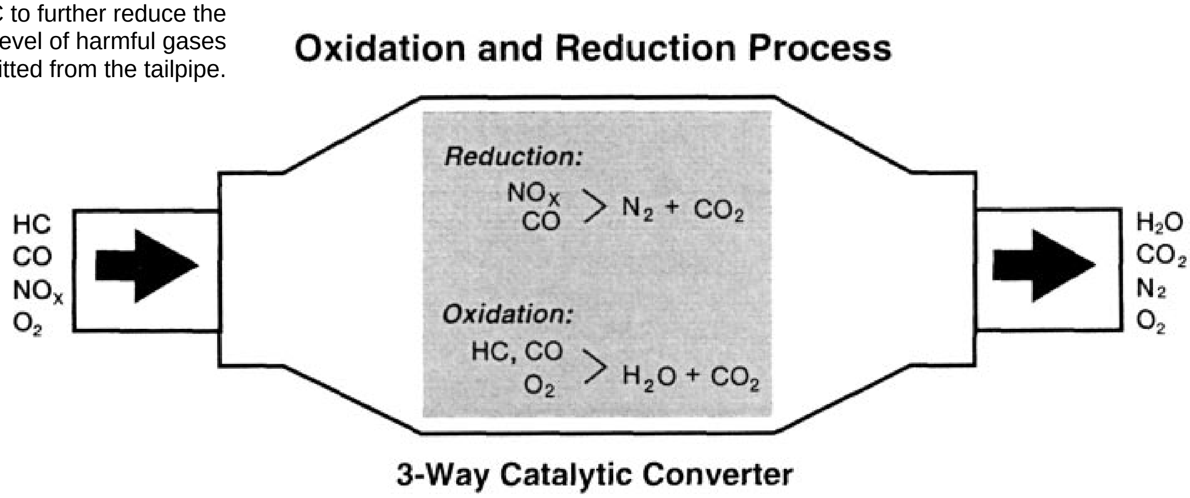


Pre-Catalyst Versus Post-Catalyst Testing

When using an exhaust analyzer as a diagnostic tool, it is important to remember that *combustion takes place twice* before reaching the tailpipe. First, primary combustion takes place in the engine. This determines the composition of catalyst feed gas, which dramatically effects catalyst efficiency. When the exhaust gases reach the three-way catalytic converter, two chemical processes occur.

Secondary Combustion

Catalyst reduction and oxidation occurs in the TWC to further reduce the level of harmful gases emitted from the tailpipe.



Catalyst Reduction

- First, nitrogen oxide gives up its oxygen. This only occurs when a sufficient amount of carbon monoxide is available for the oxygen to bond with. This chemical reaction results in reduction of nitrogen oxide to pure nitrogen and oxidation of the carbon monoxide to form carbon dioxide.

Catalyst Oxidation

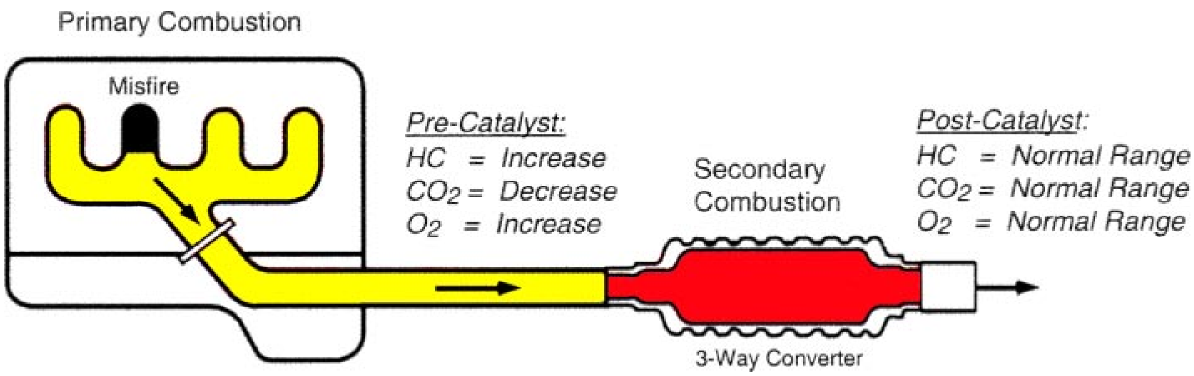
- Second, hydrocarbon and carbon monoxide continue to burn. This occurs only if there a sufficient amount of oxygen available for the hydrogen and carbon to bond with. This chemical reaction results in oxidation of hydrogen and carbon to form water vapor (H2O) and carbon dioxide (CO2).

Examples of Deceiving Post-Catalytic Analysis

When troubleshooting an emissions failure, your primary concern will be what comes out of the tailpipe. In other words, it doesn't matter whether the efficient burn occurred in the engine or the catalyst. However, when troubleshooting a driveability concern, the catalytic converter may mask important diagnostic clues which can be gathered with your exhaust analyzer. The following are examples of situations where post-catalyst reading may be deceiving.

Example 1:

Effects of secondary combustion on engine misfire condition.



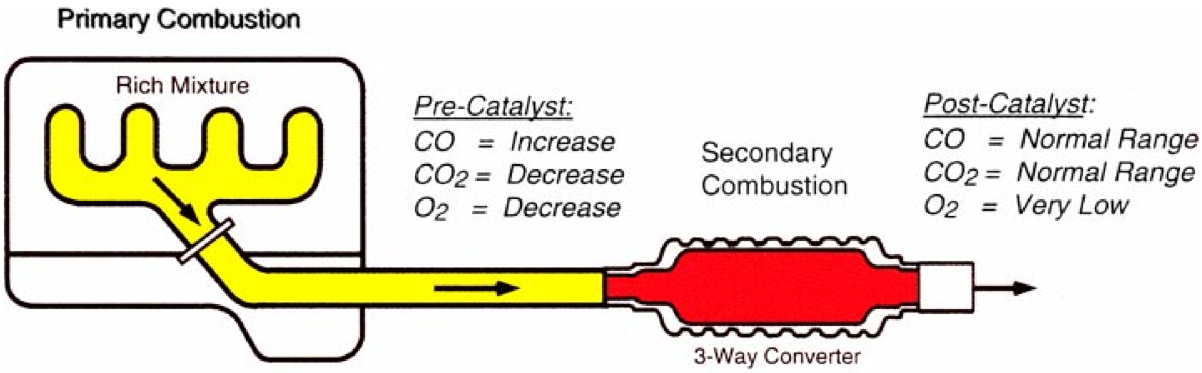
- **Example 1:** A minor misfire under load is causing a vehicle to surge. The exhaust gas from the engine would show an increase in HC and 02, and a reduction in CO2. However, once this exhaust gas reaches the catalytic converter, especially a relatively new and efficient catalyst, the oxidation process will continue. The excess HC will be oxidized, causing HC and O2 to fall, and CO2 to increase. At the tailpipe, the exhaust readings may look perfectly normal.

  In this example, it is interesting to note that NOx readings will increase because of the reduced carbon monoxide and increased oxygen levels in the catalyst feed gas. This could be detected with a five gas analyzer.

- **Example 2:** A small exhaust leak upstream of the exhaust oxygen sensor is causing a false lean indication to the ECM. This resulted in excessively rich fuel delivery to bring oxygen sensor voltage back to normal operating range. The customer concern is a sudden decrease of 20% in fuel economy.

Example 3:

Effects of secondary combustion on rich A/F mixture condition.

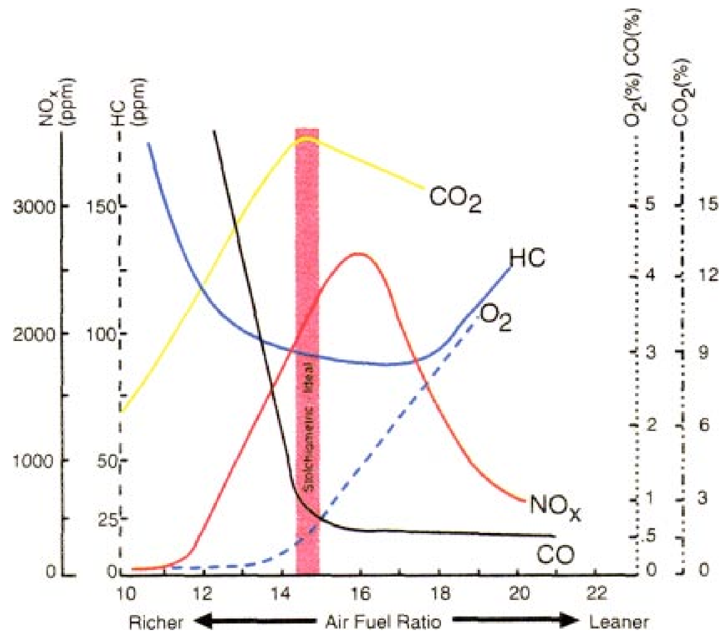


- **Example 3:** A restriction in the fuel return line elevates pressure causing an excessively rich air/fuel ratio and a 20% decrease in fuel economy. Although carbon monoxide emissions from the engine are elevated as a result of this rich air/fuel ratio, the catalytic converter is able to oxidize most of it into carbon dioxide. The resulting tailpipe readings appear to be normal, except for oxygen, which is extremely low for two reasons. First, the increase in CO caused a proportionate decrease in O2 in the converter feed gas. Second, the little oxygen left over was totally consumed oxidizing the CO into CO2.

  Based on this example, you can see that oxygen is a better indicator of lean or rich air/fuel ratios than carbon monoxide when testing post catalytic converter.

Effects of A/F Ratio on Engine-Out Gases

Use the following graph to study the relationship A/F mixture has on exhaust gas output levels.



General Rules of Emission Analysis

- If CO goes up, O_2 goes down, and conversely if O_2 goes up, CO goes down. Remember, CO readings are an indicator of a rich running engine and O_2 readings are an indicator of a lean running engine.
- If HC increases as a result of a lean misfire, O_2 will also increase
- CO2 will decrease in any of the above cases because of an air/fuel imbalance or misfire
- An increase in CO does not necessarily mean there will be an increase in HC. Additional HC will only be created at the point where rich misfire begins (3% to 4% CO)
- High HC, low CO, and high O_2 at same time indicates a misfire due to lean or EGR diluted mixture
- High HC, high CO, and high O_2 at same time indicates a misfire due to excessively rich mixture.
- High HC, Normal to marginally low CO, high O_2, indicates a misfire due to a mechanical engine problem or ignition misfire
- Normal to marginally high HC, Normal to marginally low CO, and high O_2 indicates a misfire due to false air or marginally lean mixture

To verify that the exhaust readings are not being diluted in the exhaust system or analyzer sampling point, combine the CO reading with the CO2 reading. An undiluted sample should always have a sum of greater than 6%. Remember, the secondary air system may be diluting the sample if it is not disabled during analysis. In fact, engines with secondary air injection systems will have relatively high oxygen concentrations in the exhaust because of the extra air pumped into the exhaust, post combustion.

Factors That Degrade Emissions & Driveability

The following major factors contribute to the overall increase in exhaust emissions levels and degraded vehicle driveability:

- Lack of scheduled maintenance
  - Sub-system failures
  - Combination of multiple marginal sub-systems
- Tampering
  - Removal of emissions sub-system equipment
  - Modification of engine/emissions sub-systems
- Use of leaded fuels or incompatible additives in closed loop control systems

Notes

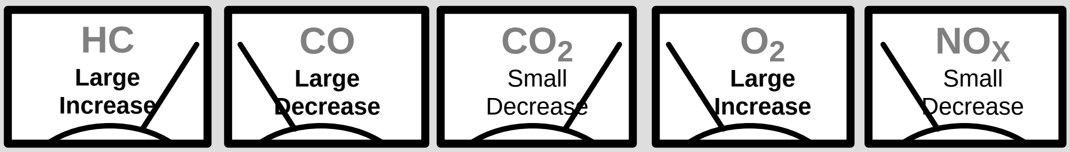
WORKSHEET 1 (CLASSROOM)
Engine-Out Emission Analysis

Accurate and efficient exhaust emission analysis first requires that you have a solid understanding of the basics of 5-gas emission formation. In this worksheet, you will analyze various 5-gas engine-out emission readings and then apply your understanding of emission theory to determine the sub-systems that could cause the indicated readings. *Please keep in mind these samples are theoretical, engine-out (pre-catalyst) emission readings.*

Exhaust Reading #1:

Conditions:

- *Engine warm*
- *Light cruise*
- *No Load*



Based on the information above, answer the following questions:

1. Generally speaking, what *condition(s)* is most likely causing the readings above (rich mixture, misfire, etc.)?

____

____

2. Next, place a check mark at the most likely sub-systems that could cause the readings above. Then list some very specific causes within each of the sub-systems checked.

❑ **Engine Mechanical:** . . . . *specific causes:*

____

❑ **Air Induction System:** . . . . *specific causes:*

____

❑ **Fuel Delivery System:** . . . . *specific causes:*

____

❑ **Ignition, Spark Advance:** . . . . *specific causes:*

____

❑ **Closed Loop Control:** . . . . *specific causes*

____

❑ **EGR System:** . . . . *specific causes:*

____

❑ **EVAP System:** . . . . *specific causes:*

____

❑ **PCV System:** . . . . *specific causes:*

____

❑ **Catalytic Converter:** . . . . *specific causes:*

____

❑ **Secondary Air Injection:** . . . . *specific causes:*

____

❑ **Idle Air Control:** . . . . *specific causes:*

____

❑ **Other?**____ *specific causes:*

____

3. List the *major data parameters* that could help identify the cause of exhaust reading #1:

____

____

4. What affect will the TWC have on the pre-catalyst emissions indicated in exhaust reading #1 ? Explain.

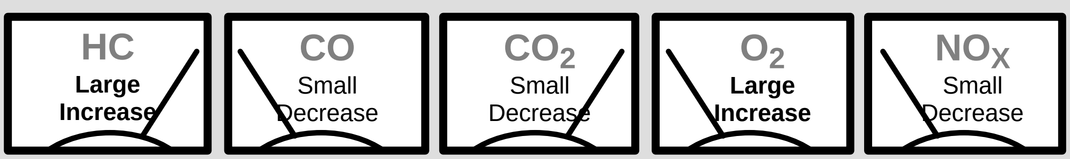
____

____

Exhaust Reading #2:

Conditions:

- *Engine warm*
- *Light cruise*
- *No Load*



Based on the information above, answer the following questions:

1. Generally speaking, what *condition(s)* is most likely causing the readings above (rich mixture, misfire, etc.)?

2. Next, place a check mark at the most likely sub-systems that could cause the readings above. Then list some very specific causes within each of the sub-systems checked.

❑ **Engine Mechanical:** . . . . *specific causes:*

____

❑ **Air Induction System:** . . . . *specific causes:*

____

❑ **Fuel Delivery System:** . . . . *specific causes:*

❑ **Ignition, Spark Advance:** . . . . *specific causes:*

❑ **Closed Loop Control:** . . . . *specific causes*

❑ **EGR System:** . . . . *specific causes:*

❑ **EVAP System:** . . . . *specific causes:*

❑ **PCV System:** . . . . *specific causes:*

❑ **Catalytic Converter:** . . . . *specific causes:*

❑ **Secondary Air Injection:** . . . . *specific causes:*

❑ **Idle Air Control:** . . . . *specific causes:*

❑ **Other?**____ *specific causes:*

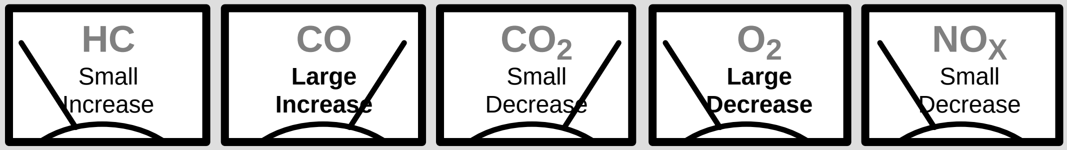
3. List the *major data parameters* that could help identify the cause of exhaust reading #2:

4. What affect will the TWC have on the pre-catalyst emissions indicated in exhaust reading #2? Explain.

Exhaust Reading #3:

Conditions:

- *Engine warm*
- *Light cruise*
- *No Load*



Based on the information above, answer the following questions:

1. Generally speaking, what *condition(s)* is most likely causing the readings above (rich mixture, misfire, etc.)?

2. Next, place a check mark at the most likely sub-systems that could cause the readings above. Then list some very specific causes within each of the sub-systems checked.

❑ **Engine Mechanical:** .... *specific causes:*

❑ **Air Induction System:** .... *specific causes:*

❑ **Fuel Delivery System:** .... *specific causes:*

❑ **Ignition, Spark Advance:** .... *specific causes:*

❑ **Closed Loop Control:** .... *specific causes*

❑ **EGR System:** .... *specific causes:*

❑ **EVAP System:** .... *specific causes:*

❑ **PCV System:** .... *specific causes:*

❑ **Catalytic Converter:** .... *specific causes:*

❑ **Secondary Air Injection:** .... *specific causes:*

❑ **Idle Air Control:** . . . . *specific causes:*

❑ **Other?**____*specific causes:*

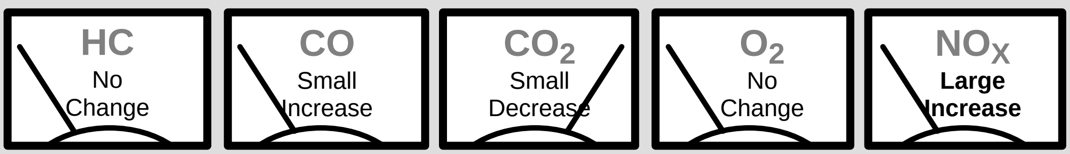
3. List the *major data parameters* that could help identify the cause of exhaust reading #2:

4. What affect will the TWC have on the pre-catalyst emissions indicated in exhaust reading #2? Explain.

Exhaust Reading #4:

Conditions:

- *Engine warm*
- *Light cruise*
- *No Load*



Based on the information above, answer the following questions:

1. Generally speaking, what *condition(s)* is most likely causing the readings above (rich mixture, misfire, etc.)?

2. Next, place a check mark at the most likely sub-systems that could cause the readings above. Then list some very specific causes within each of the sub-systems checked.

❑ **Engine Mechanical:** . . . . *specific causes:*

❑ **Air Induction System:** . . . . *specific causes:*

❑ **Fuel Delivery System:** . . . . *specific causes:*

❑ **Ignition, Spark Advance:** . . . . *specific causes:*

❑ **Closed Loop Control:** . . . . *specific causes*

❑ **EGR System:** . . . . *specific causes:*

____

❑ **EVAP System:** . . . . *specific causes:*

____

❑ **PCV System:** . . . . *specific causes:*

____

❑ **Catalytic Converter:** . . . . *specific causes:*

____

❑ **Secondary Air Injection:** . . . . *specific causes:*

____

❑ **Idle Air Control:** . . . . *specific causes:*

____

❑ **Other?**_______________________________________ *specific causes:*

____

3. List the *major data parameters* that could help identify the cause of exhaust reading #4:

____

____

4. What affect will the TWC have on the pre-catalyst emissions indicated in exhaust reading #4? Explain.

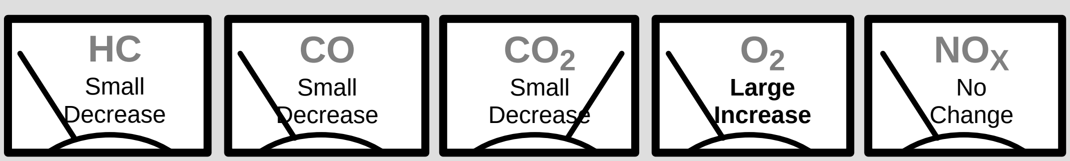
____

____

Exhaust Reading #5:

Conditions:

- *Engine warm*
- *Light cruise*
- *No Load*



Based on the information above, answer the following questions:

1. Generally speaking, what *condition(s)* is most likely causing the readings above (rich mixture, misfire, etc.)?

2. Next, place a check mark at the most likely sub-systems that could cause the readings above. Then list some very specific causes within each of the sub-systems checked.

❑ **Engine Mechanical:** . . . . *specific causes:*

❑ **Air Induction System:** . . . . *specific causes:*

❑ **Fuel Delivery System:** . . . . *specific causes:*

❑ **Ignition, Spark Advance:** . . . . *specific causes:*

❑ **Closed Loop Control:** . . . . *specific causes*

❑ **EGR System:** . . . . *specific causes:*

❑ **EVAP System:** . . . . *specific causes:*

❑ **PCV System:** . . . . *specific causes:*

❑ **Catalytic Converter:** . . . . *specific causes:*

❑ **Secondary Air Injection:** . . . . *specific causes:*

❑ **Idle Air Control:** . . . . *specific causes:*

❑ **Other?**____ *specific causes:*

3. List the *major data parameters* that could help identify the cause of exhaust reading #5:

4. What affect will the TWC have on the pre-catalyst emissions indicated in exhaust reading #5? Explain.

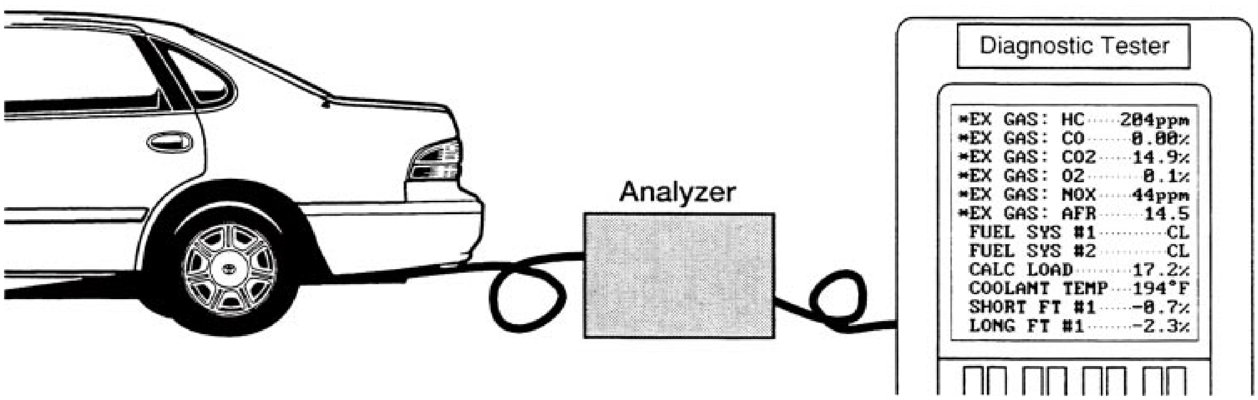
Notes

WORKSHEET 2 (ON-CAR)

Fundamentals of 5-Gas Exhaust Emission Analysis

Vehicle	**Year/Prod. Date**	**Engine**	**Transmission**

In this worksheet, you will apply your knowledge of 5-gas emission fundamentals to analyze changes in exhaust emission composition using a test vehicle. By deliberately creating various engine operating conditions and then studying the resulting change in out-gas composition, fundamentals of exhaust emissions analysis are reinforced. Carefully perform all worksheet tasks and answer all questions pertaining to your results.



Worksheet Preparation:

- Prepare the 5-Gas Emission Analyzer by performing all warm-up and preconditioning procedures as outlined in the Operator’s Manual. Properly calibrate the analyzer to ensure accurate test results.
- Record all emission readings with electric cooling fan and accessories off.
- ***Caution:*** *Some of the following engine operating conditions may cause the catalyst to overheat, therefore, do not maintain any of these conditions for extended periods or permanent converter damage may result!*

Post-Catalyst Exhaust Gas Emission Readings

1. *Disconnect the 0_2 sensor connector to keep the feedback system in open loop.* For purposes of this worksheet, closed loop control is disabled to better demonstrate the changes to catalyst out-gases.
2. Connect the Diagnostic Tester with the 5-gas emission analyzer to the vehicle and warm-up the analyzer.
3. Perform the required zeroing procedures prior to measuring emission readings.
4. Access the 5-gas emission readings on the Diagnostic Tester data list.
5. With the vehicle cold soaked, start the engine and immediately take a screen print of the data list (with the 5-gas emission reading) at idle. **Also, let engine return to idle between readings.**

6. Paste the screen print into the space below:

Paste Screen Print Here

7. Next, bring engine and catalytic converter to operating temperature and then maintain engine speed at a steady 1500 **rpm.**

8. After the readings stabilize, take a new screen print of the data list (with the 5-gas readings) while engine speed is maintained at **1500 rpm.**

9. Paste the new screen print into the space below:

Paste Screen Print Here

10. Compare the readings above with those obtained in step 6. Write the *change* to the 5-gas readings in the boxes below. Indicate whether the reading went up or down by writing a"+" or"-" next to the reading (example: +100 ppm, -2%, etc). Also, place a check in the appropriate box to indicate any changes from step 6.

Open Loop 1500 rpm:	**Compared to Step 6 Readings**
HC:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
CO:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
CO_2:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
O_2:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
NO_X:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*

11. Did any readings change dramatically from step 6? Why or why not?

____

____

____

12. ***Remove an intake manifold vacuum hose to create a large vacuum leak.***

13. Maintain engine speed at **1500 rpm** and after the readings stabilize, take a new screen print of the data list (with the 5-gas readings).

14. Paste the new screen print into the space below:

Paste Screen Print Here

15. Compare the readings above with those obtained in step 9. Next, write the *change* to the 5-gas readings in the boxes below. Be sure to indicate whether the readings went up or down by writing a"+" or"-" next to the reading. Also, place a check in the appropriate box to indicate changes, if any, from step 9.

Lean A/F Mixture:	**Compared to Step 9 Readings:**
HC:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
CO:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
CO_2:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
O_2:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
NO_X:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*

16. Which gas (or gases) changed most dramatically? Which gas was the best indicator of this lean mixture condition? Explain why.

____

____

____

17. In this case, what is the relationship between CO and O_2?

____

____

18. Is the vacuum leak you created causing a ”lean misfire”? How can you tell?

____

____

19. Did NOx readings change with this leaner air/fuel mixture? Explain why it did or didn’t.

____

____

20. Replace the vacuum hose back onto the intake manifold.

21**. *Remove the vacuum sensing hose to the fuel pressure regulator and plug it.***

22. Maintain engine speed at **1500 rpm** and after the readings stabilize, take a new screen print of the data list (with the 5-gas readings). Paste the new screen print into the space below:

Paste Screen Print Here

23. Compare the readings above with those obtained in step 9. Next, write in the *change* to the 5-gas readings in the boxes below. Be sure to indicate whether the readings went up or down by writing a”+” or”-” next to the reading. Also, place a check in the appropriate box to indicate changes, if any, from step 9.

Rich A/F Mixture:	**Compared to Step 9 Readings:**
HC:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
CO:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
CO_2:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
O_2:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
NO_X:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*

SECTION 3

24. Which gas (or gases) changed most dramatically? Which was the best rich mixture indicator? Explain.

____

____

25. Did HC levels change much with this richer mixture? Explain why it did or didn't.

____

____

26. In this case, what is the usefulness and limitation of the change in CO2 reading?

____

____

27. Replace the vacuum hose to the fuel pressure regulator.

28. ***Carefully disconnect a secondary wire from the spark plug and ground it.***

29. Maintain engine speed at **1500 rpm** and after the readings stabilize, take a new screen print of the data list (with the 5-gas readings). Paste the new screen print into the space below:

Paste Screen Print Here

30. Compare the readings above with those obtained in step 9. Next, write in the *change* to the 5-gas readings in the boxes below. Be sure to indicate whether the readings went up or down by writing a"+" or"-" next to the reading. Also, place a check in the appropriate box to indicate changes, if any, from step 9.

Engine Misfire:	**Compared to Step 9 Readings:**
HC:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
CO:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
CO_2:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
O_2:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
NO_X:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*

31. Which gas (or gases) changed most dramatically? Which was the best misfire indicator? Explain.

____

____

32. What caused HC to initially rise and then drop after removing the plug wire? Explain.

____

____

33. Did O_2 readings increase or decrease as a result of the misfire? Explain the significance of this.

____

____

34. Reattach the secondary wire back onto the spark plug.

35. *Disconnect the connector from one injector.*

36. Maintain engine speed at **1500 rpm** and after the readings stabilize, take a new screen print of the data list (with the 5-gas readings). Paste the new screen print into the space below:

Paste Screen Print Here

37. Compare the readings above with those obtained in step 9. Next, write in the *change* to the 5-gas readings in the boxes below. Be sure to indicate whether the readings went up or down by writing a "+" or"-" next to the reading. Also, place a check in the appropriate box to indicate changes, if any, from step 9.

Engine Misfire:	**Compared to Step 9 Readings:**
HC:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
CO:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
CO_2:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
O_2:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*
NO_X:	❑ *No Change*, ❑ *Increase*, ❑ *Decrease*

SECTION 3

38. Which gas (or gases) changed most dramatically? Which was the best misfire indicator? Explain.

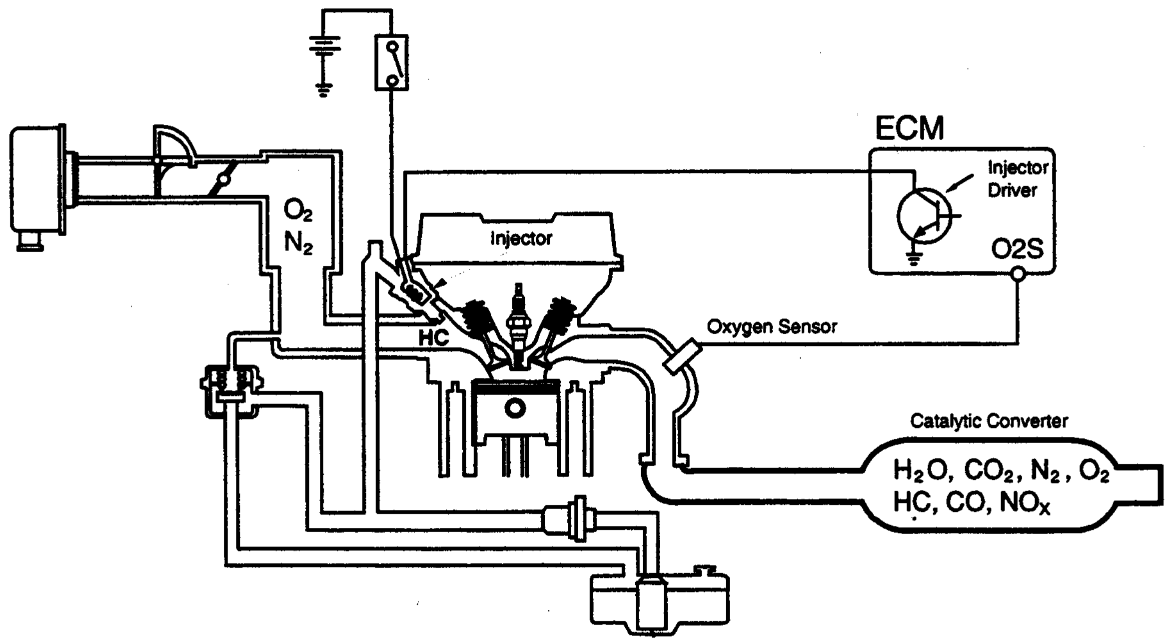
39. In terms of its effect on emission output, how does this misfire condition differ from the misfire caused in step 28? Explain.

40. Reattach the connector back onto the injector.

Return the vehicle to normal condition. Clear any stored diagnostic trouble codes.

Notes

ENGINE & EMISSION SUB-SYSTEMS



Lesson Objectives

1. Explain how the engine's mechanical condition can directly and indirectly effect exhaust emissions and vehicle driveability.
2. Correctly identify three emission and driveability problems that may result from the improper operation of the Spark Advance system.
3. Understand the importance of the O2S signal on the Closed Loop Control system's ability to maintain strict 14.7 to 1 air/fuel ratio.
4. Identify two emission and driveability conditions that may result from improper EGR system operation.
5. Explain two methods of testing the EVAP system that are similar to the methods used in an Enhanced I/M inspection.
6. Explain the effects a slow O2S rich > lean switch time has on Closed Loop Control operation and catalyst efficiency.
7. Explain how the IACV step count or duty cycle may be used to identify a problem in the Air Induction system.

Notes

Engine Mechanical

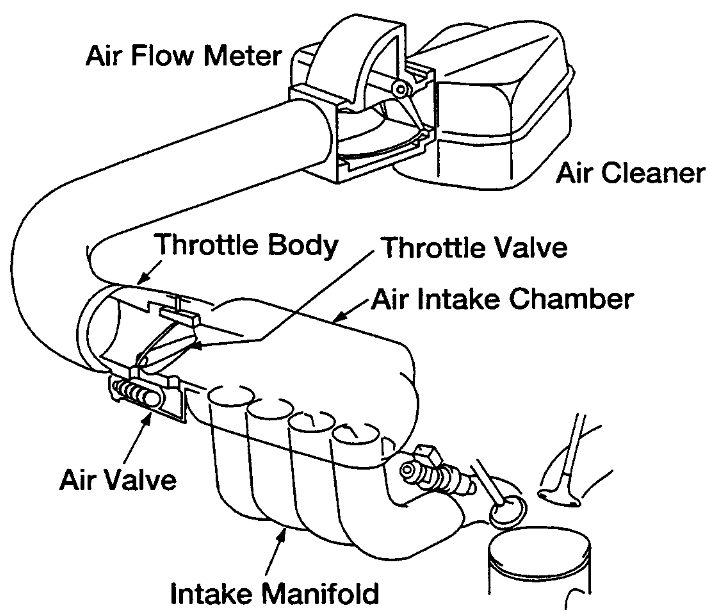
The engine control and emissions sub-systems all rely on good mechanical condition of the engine to operate normally and effectively. Mechanical malfunctions effect exhaust emissions and driveability, both directly and indirectly:

- **Directly,** any mechanical malfunction will likely cause significant increases in exhaust emissions by causing misfire, allowing combustion gasses to escape past exhaust valves or piston rings, by altering air/fuel ratios, or any number of other possibilities.
- **Indirectly,** mechanical malfunctions change the composition of catalyst feed gas, preventing the catalytic converter from operating efficiently.

Examples of mechanical problems that can increase exhaust emission output include; low cylinder compression causing poor combustion and/or misfire, worn oil control rings that allow excessive engine oil (HC) to be consumed during combustion, etc. Remember, always check the integrity of basic engine mechanical systems before moving on to more complex engine or emission sub-systems.

Air Induction System

The Air Induction System must accurately meter and measure intake airflow or emission driveability concerns result.



Air Induction System

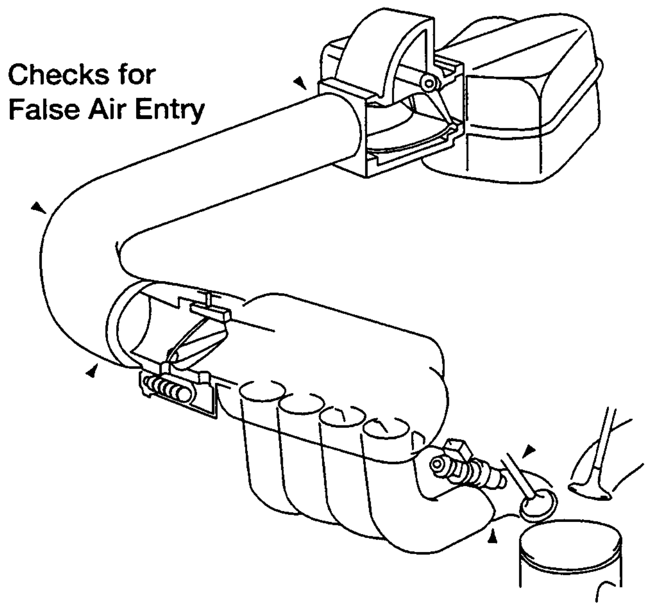
The air induction sub-system meters and measures engine air based on driver demand. In the event that unmetered air enters the engine or if it is not measured accurately, the imbalanced air /fuel ratio will cause increases in exhaust emissions and/or driveability concerns. The following areas of the air induction system may require your attention when troubleshooting an emissions or driveability concern.

False Intake Air Entry

If unmeasured air enters engines equipped with L-type injection, they may exhibit lean surges, misfire and rough idle. Lean operating conditions can also cause increases in hydrocarbons, due to misfire, and in NO_X due to leaner air/fuel ratios, increased combustion temperatures and decreased reduction catalyst efficiency.

False Intake Air Entry

Typical false air entry locations include: intake manifold gasket, intake air ducting, throttle shaft bushing, etc.



Engines equipped with D-type injection will exhibit an elevated engine idle speed if unmeasured air enters the induction system. Generally, this will not cause exhaust emissions to increase significantly.

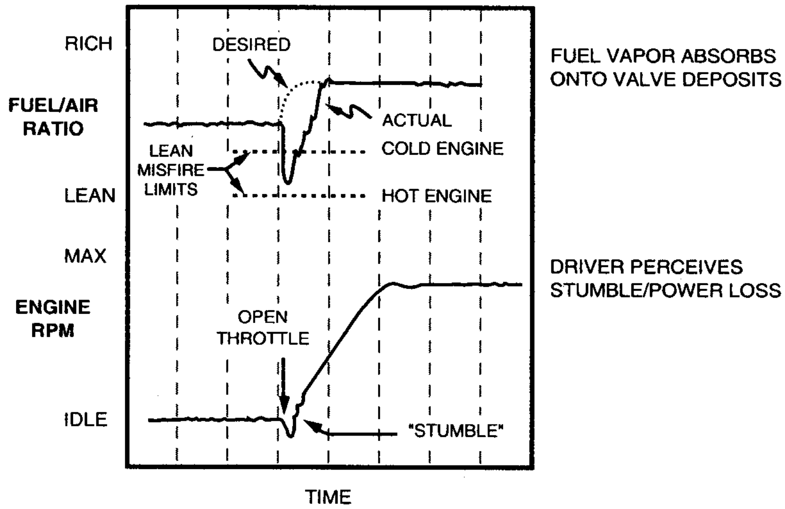
Intake Valve Deposits

Intake valve deposits are hardened carbon deposits which form on the back side of the intake valve. The degree of deposits vary depending on many factors like fuel properties, driving habits, and engine family. Intake valve deposits can cause driveability concerns as well as increased exhaust emissions.

Excessive intake valve deposits can cause an engine to run excessively lean while cruising and accelerating, and excessively rich during deceleration. During lean operating periods, NOx emissions are elevated. During rich operating periods, CO emissions are elevated. The amount of emissions increase has a linear relationship with the degree of deposits on the valves. At some point, deposits can effect emissions enough to put a vehicle out of compliance in an Enhanced I/M test.

Effects of Intake Valve Deposits

The graphs show the effects of intake valve deposits on both A/F ratio (top and engine rpm (bottom). The symptoms are more noticeable during cold engine operation.



There are several common driveability symptoms which can be caused by intake valve deposits; stumble, hesitation and loss of power under load. Stumble and hesitation, especially when the engine is cold, are by far the most common problems caused by excessive intake valve deposits. The porous carbon deposits act like a sponge, absorbing enough fuel vapor to cause these symptoms.

Severe carbon deposits can also cause a loss of power at high engine rpm. When deposits accumulate sufficiently to restrict airflow through the intake valve, the volumetric efficiency of the engine is effected, causing the engine to loose power.

Intake Valve Deposits

The following are examples of unacdceptable intake valve deposit levels (require cleaning).

The best way to confirm excessive deposits is to visually inspect the valves using a borescope. If repairs are necessary, equipment is available to clean the valves without removing the cylinder head. Refer to Toyota Technical Service Bulletins for more information on procedures and special service tools.

Fuel Delivery System

The fuel delivery system is responsible for maintaining constant fuel pressure across the injectors, in addition to metering the correct amount of fuel into the intake manifold.

Fuel Delivery System

The fuel delivery and injection control system delivers fuel to the engine and meters the amount of fuel which is injected into the intake manifold. There are two factors which, under normal conditions, should determine the air/fuel ratio; **fuel pressure and injection duration.** In the event that either of these factors is incorrect, normal air/fuel ratio will be upset.

One factor which can upset the normal air/fuel ratio is unmeasured fuel. Leaking injectors, a leaking fuel pressure regulator diaphragm, Crankcase oil diluted with gasoline, or a saturated evaporative emissions system can all cause an excessively rich air/fuel ratio.

Finally, the air fuel ratio can also be upset by restriction in the injector nozzle or problems with the injector spray pattern. Symptoms caused by fuel injector spray pattern and restrictions are similar to those caused by intake valve deposits; stumble, hesitation, loss of power, etc.

Fuel Injector Test Methods

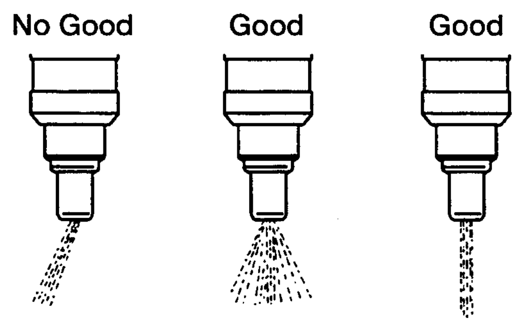
Testing fuel injectors for restriction and/or spray pattern can be accomplished one of two ways; visual inspection and pressure drop method.

Visual Inspection

Visual inspection requires that the suspect injector(s) be removed from the engine, connected to a test apparatus, and electrically energized for a fixed time period. The injector should deliver the specified volume and spray pattern should appear uniformly conical (specifications and procedures can be found in Course 850 Technician Handbook or the Repair Manual.)

Injector Spray Patterns

Injectors should have a conical spray pattern and disperse fuel evenly.



Pressure Drop Test

The pressure drop method requires the use of a fuel pressure gauge and an injector pulse timer available from specialty tool vendors. Generally speaking, this test can be performed without removing the injector from the engine. By energizing the injector for a fixed pulse width and observing the pressure drop on the fuel system, the relative fuel flow can be compared for each injector. If all injectors exhibit a consistent pressure drop, it follows that all injectors are flowing the same volume of fuel. There are three shortcomings with this type of test which limit its usefulness, they are:

- Actual injector flow volume can not be determined, only relative flow
- Spray pattern cannot be observed during this test
- There are no specifications for the pressure drop test.

Incorrect Injection Duration

In addition to the problems mentioned above, false sensor input from any of the **six major input sensors** can also cause the air/fuel ratio to shift sufficiently to cause driveability and/or emissions concerns. If engine load is incorrectly calculated, fuel requirements are also miscalculated, resulting in a driveability or emissions concern. This type of a condition can be identified by reading sensor signals and comparing them to standard values. With this type of condition, the ECM adaptive fuel program will probably be making major corrections to bring the air/fuel ratio back into a neutral range (stoichiometry).

Fuel Trim Data Interpretation

As shown, fuel trim parameters and interpretation methods differ depending on the vehicle's diaagnostic system.

Diagnostic System	Long Fuel Trim Data Parameter	Normal Operating Range *possible problem indicated outside of this range	Diagnostic Interpretation
OBD (w/o serial data)	Learned Voltage Feedback (LVF)* *Access at VF1 terminal of check connector, TE1 off	2.50 ± 1.25 volts	LVF represents command to injection system 5.0 volts = lean condition 0 volts = rich condition
OBD (with serial data)	Target A/F	2.50 ± 1.25 volts	Target A/F represents command to injection system 5.0 volts = lean condition 0 volts = rich condition
OBD-II	Long FT	0% ± 10%	Long FT represents command to injection system > 10% = lean condition < 10% = rich condition

The best way to confirm that a neutral air/fuel ratio is being delivered to the engine, is to monitor the **adaptive fuel correction** to injection duration. This can be accomplished several different ways, depending on the engine being tested:

1. OBD vehicles without serial data: Use a voltmeter on terminal VF1 at DLC 1 (check connector)
2. OBD vehicles with serial data: Use a scan tool to monitor Target A/F data
3. OBD-II vehicles: Use a scan tool to monitor Fuel Trim data

Refer to Course 873 section on fuel trim for more information about accessing and using fuel system adaptive memory for diagnosis.

A Few Words on Fuel

Effects of Octane Rating on Engine Performance and ”Knocking”

When diagnosing any customer concern related to poor engine performance or engine ”knocking”, always suspect fuel quality, or more specifically the **octane** rating of the fuel being used. The octane rating is a reflection of the fuel’s ability to withstand engine knock, and is rated by its Antiknock Index (or pump octane rating). This number is displayed on a yellow sticker on the side of each gas pump.

Since octane requirements differ from vehicle to vehicle, always check in the Owner’s Manual for vehicle’s exact octane requirement and verify with the customer that their concern *is* not the result of low octane fuel. On vehicles with Knock Control systems, low octane may not cause the engine to knock, since the system has the ability to retarded spark advance; however, the engine may perform poorly as a result of a conservative spark advance strategy. If the engine knocking or performance concern is not the result of a sub-system problem, you may want to suggest to the customer a change in fuel grade or retailer.

Gasoline Volatility and Seasonal Fuel Blends

Volatility refers to a fuel’s ability to change from a liquid to a vapor. This characteristic of fuel is very important in maintaining satisfactory vehicle driveability. If fuel volatility is too low, hard starting and poor warm-up driveability problems may result. If fuel volatility is too high, vapor lock, hot driveability problems, and excessive evaporative emissions may result.

Since fuel vaporization is naturally sensitive to ambient temperature change, refiners typically provide a more volatile fuel blend in the winter to provide easy start-up and cold weather driveability. Conversely, in the summer, a less volatile fuel blend is provided to lessen the chance of vapor lock or hot driveability problems.

Occasional driveability concerns may arise when retailers change blends between seasons (typically spring or fall). For example, if a change was made to a winter blend, yet the weather remained uncharacteristically hot, a hot driveability problem may arise (and vice versa).

Oxygenated Fuels

As a result of the 1990 Clean Air Act Amendments, the use of oxygenated and reformulated fuels has already occurred in many metropolitan areas across the United States. Oxygenated gasoline contain oxygen carrying compounds (usually ethanol or MTBE) that chemically enleans the A/F mixture. This leaner A/F mixture results in lower carbon monoxide (CO) emissions from the tailpipe.

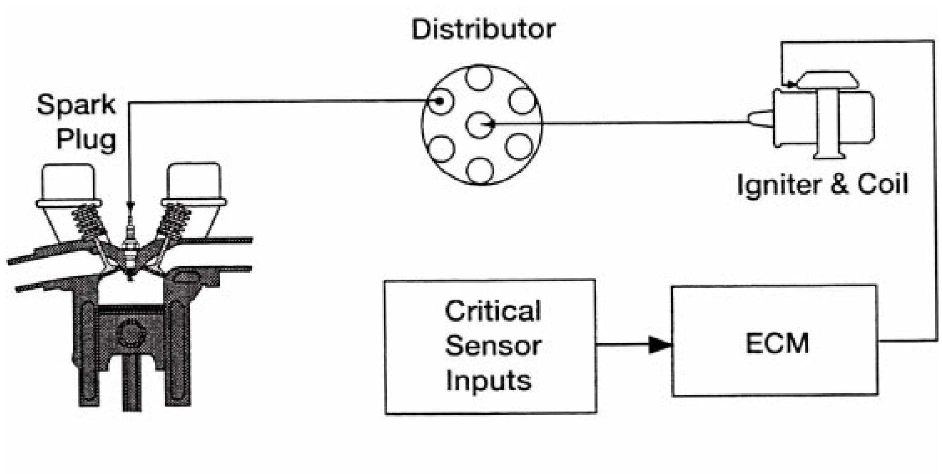
A few points require clarification concerning oxygenated fuels. First, late model feedback control vehicles may see a slight fuel economy loss (around 2%) when using oxygenated fuels. This occurs as a result of feedback system enrichening the mixture when the O2 sensor detects the additional oxygen provided by the fuel. Second, fuel system components in older model vehicles may experience swelling (hoses, O-rings, gaskets, etc.) from the alcohol used in some oxygenated fuels. The Owner’s Manual contains detailed information on the allowable percentages of both MTBE and ethanol.

Spark Advance Control

The Spark Advance Control system maximizes engine efficiency by continuously adjusting spark advance timing to deliver peak combustion pressures when the piston reaches about 10° after TDC. Incorrect spark timing can have a significant effect on emission output and vehicle drive-ability. If ignition timing is excessively advanced during certain conditions, detonation will occur resulting in increased HC and NOx levels. Since NOx production is most predominant under loaded engine operating conditions, the spark advance system must ensure accurate ignition timing during these conditions. If ignition timing is incorrectly retarded, only partial combustion will take place resulting poor engine performance and increased emission levels.

Spark Advance

Proper spark timing is critical to good vehicle driveability and reduced emission output. On systems using ECM computed spark advance, incorrect sensor information will impact driveability and emission levels.



Causes of Incorrect Spark Timing

On systems that use the ECM to compute ignition spark advance, there are only two conditions which are likely to cause spark timing to be incorrect; initial timing or a false input signal to the ECM.

The first step in troubleshooting emissions and driveability concerns should always include a quick check **of initial ignition timing.** Any error in initial timing will be reflected throughout the entire spark advance curve.

If engine load is miscalculated because of **incorrect input signals,** spark advance angle will not be appropriate for engine operating conditions. This will result in driveability and emission problems. Refer to course 850 for additional information on spark advance strategy.

The Effects of Fuel Octane

Toyota engines equipped with a knock detection system are very sensitive to fuel octane levels. Motor fuels with **low octane ratings** will cause the engine to detonate, which will in turn, cause the detonation retard system to retard timing. On some vehicles with advanced ECM operating strategies, an adaptive memory factor is used to track signals from the knock sensor. When detonation occurs frequently, the ECM relearns the basic spark advance curve, retarding spark throughout the entire engine operating range. This retarded spark curve will negatively effect engine performance and fuel economy under all driving conditions, even after a tank of higher octane fuel is purchased. The retarded spark curve will remain stored in the ECM keep alive memory until the engine is operated for a substantial amount of time on the higher octane fuel, or until the ”keep alive memory” is cleared by removing power from the BATT terminal.

Purpose of Spark Advance Control Systems

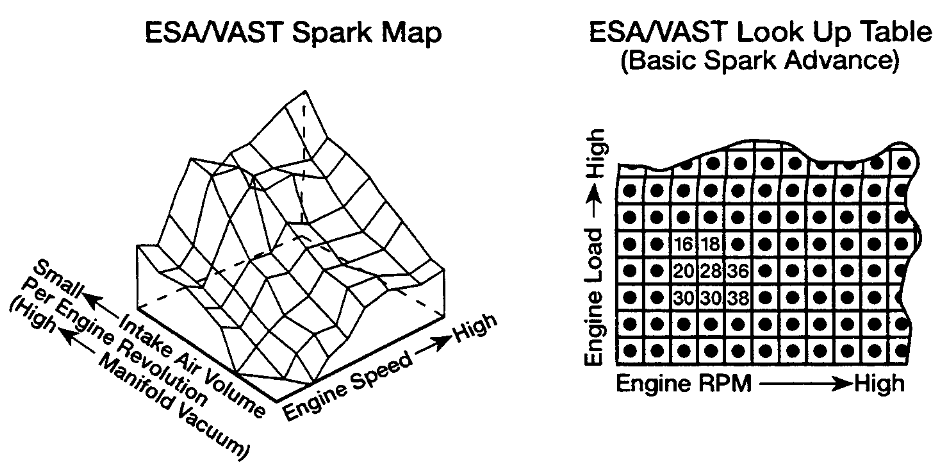
The amount of spark advance needed by the engine varies depending on a number of different operating conditions. Generally, spark advance follows the following strategy:

- spark advance **increases** with higher engine speeds for performance and fuel economy.
- spark advance needs to **decrease** under heavy load conditions to avoid detonation.

They are many variables the system must consider when determining the proper spark lead time. Coolant temperature, fuel quality, and engine load are just a few of the many factors that can significantly impact ideal ignition time. The ECM determines proper spark timing by applying various input signals against a preprogrammed spark advance strategy or ”map”.

Spark Control ”Map”

Sprrk timing is determined by plotting input signals against a preprogrammed spark advance strategy stored in ECM memory.



Fuel injected Toyota vehicles use either a mechanical or electronic spark advance control system. They are referred to as either conventional EFI ignition system (mechanical), Variable Advance Spark Timing (VAST) or Electronic Spark Advance (ESA). Refer to course 850 handbook for more information on the operation and program strategy of spark advance control systems.

Effects of Spark Advance on Emissions and Driveability

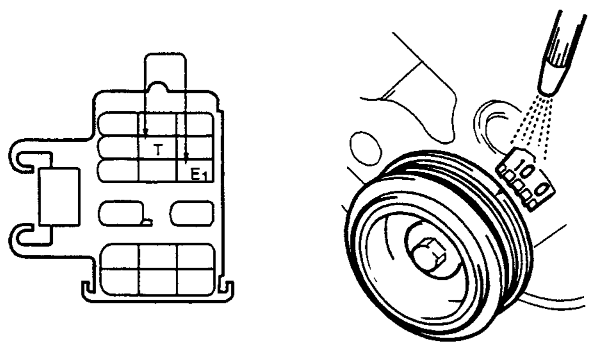
- **Too much spark advance**, particularly during high engine load conditions, increases the likelihood of engine detonation and increases combustion temperature and pressure. This results in an increase in HC and NOx output, decreased engine performance, and possible permanent damage the engine.
- **Too little spark advance** causes only partial combustion of the air/ fuel charge, resulting in very poor engine performance and fuel economy. Partial combustion will also result in an increase in CO levels.

Functional Testing

Spark advance problems can result from an incorrect initial timing setting or a problem with spark advance during operation. Before attempting to check spark advance during operating conditions, the *initial or "base" ignition timing* setting should checked and adjusted.

Initial Timing Check

This procedure requires jumping terminals in a diagnostic connector and then inspecting/adjusting the initial timing setting.

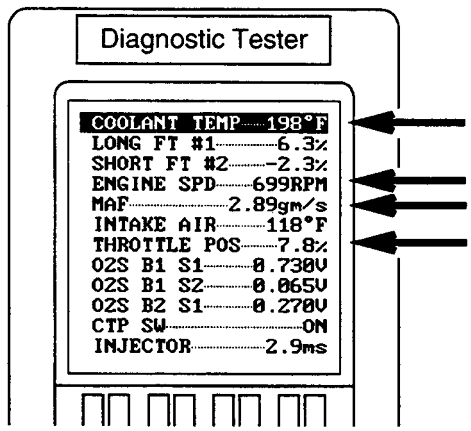


This procedure varies between systems, but on TCCS equipped vehicles, it generally requires jumping terminals at an underhood check connector (DLCl) to default the TCCS system to initial timing. After checking or adjusting initial timing, remove the test wire to inform the ECM to reestablish corrective control over timing. Refer to the Repair Manual for details on performing this procedure.

Even with initial timing correct, it is still possible that the system is miscalculating ignition timing as a result **of incorrect sensor inputs.** For example, if an airflow meter indicates light engine load, when in fact, the engine is experiencing high engine load, the ECM may incorrectly respond by over advancing ignition timing to the point of causing detonation. Refer to course 850 and 873 handbook for additional information on spark advance control strategy.

Critical Sensor Inputs

Incorrect spark timing may result from inaccurate sensor information. Check for incorrect sensor data including; coolant temp., engine speed, load, throttle angle, etc.



If inaccurate sensor inputs are suspected on earlier EFI and TCCS vehicles, it is recommended that you perform standard voltage checks of all major sensor inputs to the ECM. Compare these readings to those listed on the standard voltage chart on the Repair Manual or readings obtained from other known good vehicles. On OBD-II vehicles, you may observe ignition timing and identify incorrect signal data using the Diagnostic Tester. Some of the more important spark control parameters include engine speed, engine load, throttle angle, and coolant temperature.

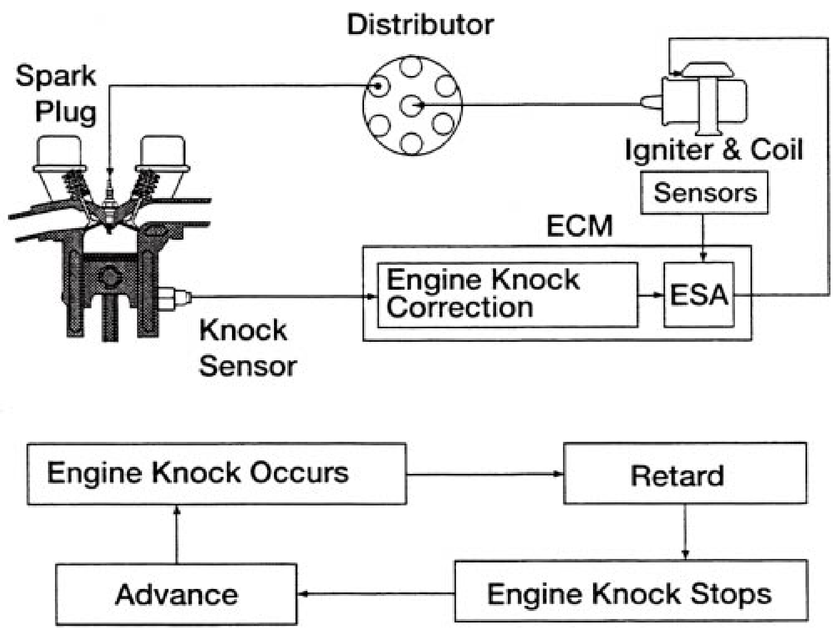
On early EFI vehicles, all spark advance is handled by mechanical means. This system uses a centrifugal advance mechanism to represent engine speed and vacuum advance mechanism to represent engine load. Resolving advance problems with this type system requires inspecting governor weights, springs, pivots, signal rotor, vacuum diaphragm, vacuum signal source, breaker plate, etc.

Knock Detection Control

The KNK (knock) input signal is critical in the prevention of engine detonation. The ECM uses the knock sensor(s) to determine when, and to what degree, engine detonation is occurring and then retards ignition timing as needed. The spark advance program is designed to provide the maximum spark advance possible, while keeping the engine from producing an audible ”ping”. If problems occur with this input signal, detonation may result, producing significant levels of HC and NOx emissions.

Knock Control Logic

Knock control allows the ECM to provide the maximum spark possible, while keeping the engine from knocking.

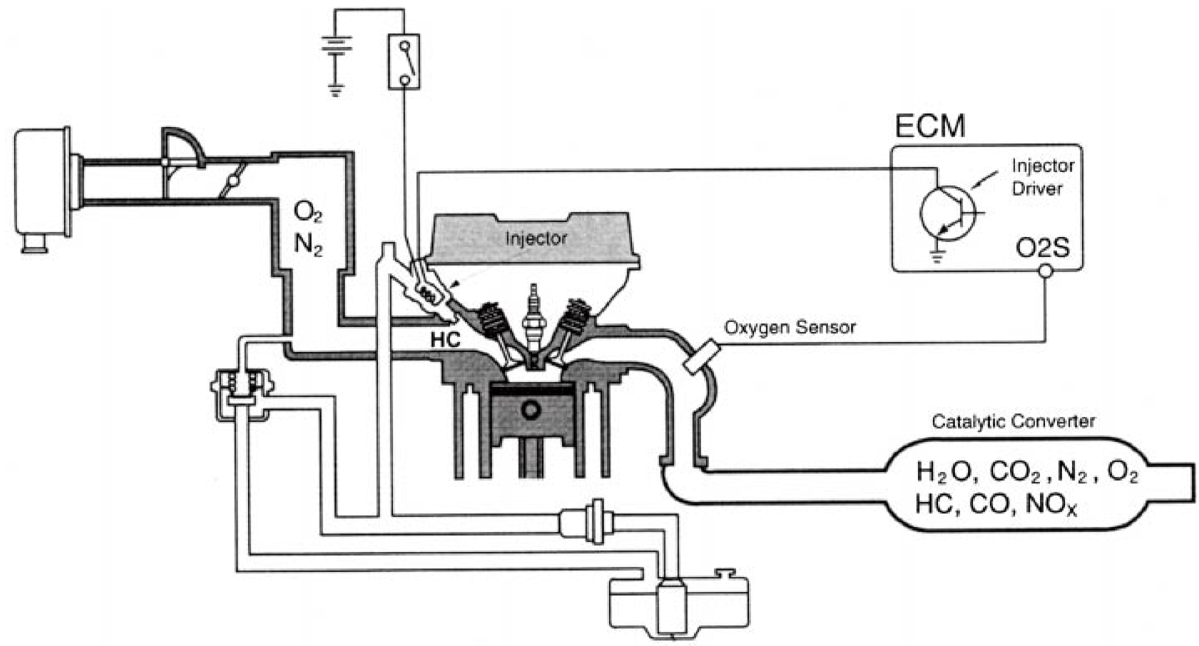


The ECM is designed to filter out KNK signal voltages that it considers are outside of the engine detonation range. Thus, a check of a knock control system by tapping on the engine close to the knock sensor may produce an output signal, but will not cause spark timing to retard. A check of the KNK signal pattern using the Diagnostic Tester Oscilloscope or lab scope may provide you the most diagnostic information.

Emission Control Sub-Systems

Closed Loop Control

The Closed Loop Control System controls converter feed-gas content by keeping the A/F mixture modulated **around the "ideal" ratio.**



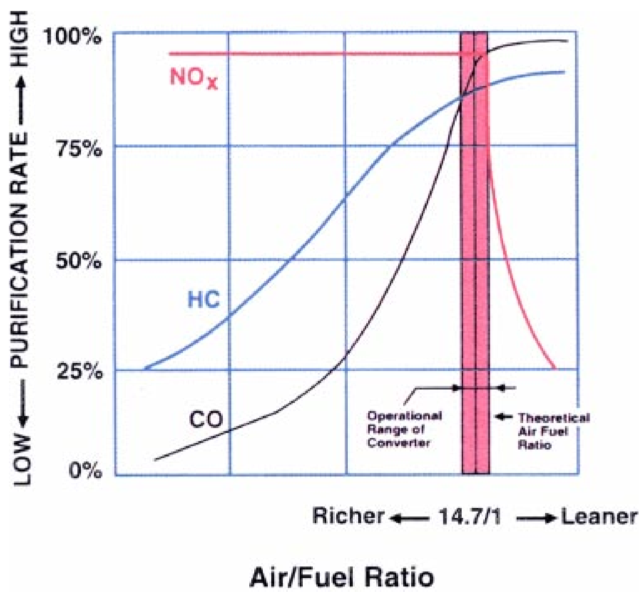
Closed Loop Feedback Control System

The heart of the emissions control system is the closed loop fuel feedback control system. It is responsible for controlling the content of the catalytic converter **feed gas** and ultimately determines how much HC, CO and NOx leaves the tailpipe. The closed loop control system works primarily during idle and cruise operations and makes adjustments to injection duration based on signals from the exhaust oxygen sensor.

During closed loop operation, the ECM keeps the air/fuel mixture modulated around the ideal 14.7 to 1 air/fuel ratio **(stoichiometry).** By precisely controlling fuel delivery, the oxygen content of the exhaust stream is held within a narrow range that supports efficient operation of the three-way catalytic converter. However, if the air/fuel ratio begins to deviate from its preprogrammed swings, catalyst efficiency falls dramatically, especially the reduction of NO_X.

Catalyst Efficiency

As you can see, Closed Loop Control is needed to keep A/F mixture modulated around the "ideal" range, where catalyst purification efficiency is high.



Closed Loop Operation

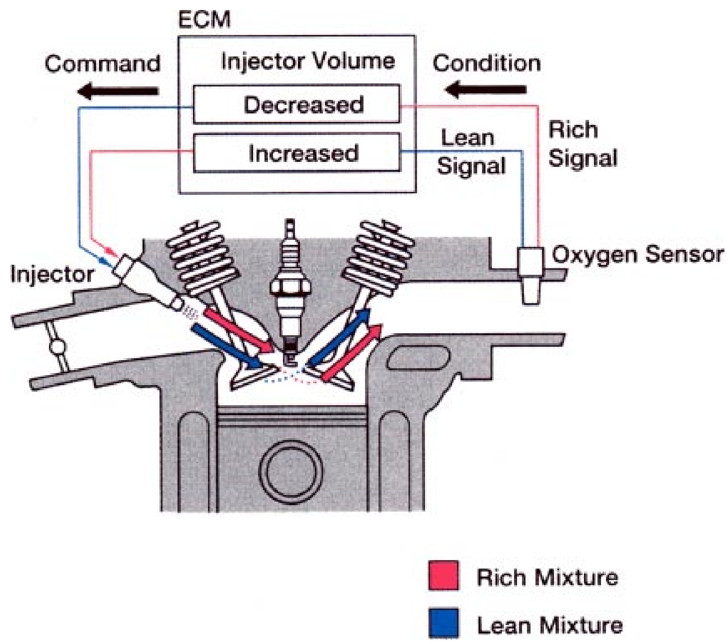
When the ECM has determined conditions suitable for entering closed loop operation (based on many sensor values), it uses the oxygen sensor signal to determine the exact concentration of oxygen in the exhaust stream. From this signal, the ECM determines whether the mixture is richer (low 62) or leaner (high 02) than the ideal 14.7 to 1 air/fuel ratio:

- If the oxygen sensor signal is **above 0.45 volt,** the ECM determines that the air/fuel mixture is **richer than ideal** and decreases the injection duration.
- If the oxygen sensor signal is **below 0.45 volt,** the ECM determines that the air/fuel mixture is **leaner than ideal** and increases the injection duration.

During normal closed loop operation, the oxygen sensor signal switches rapidly between these two conditions, at a rate of more than 8 cycles in 10 seconds at 2500 rpm. Small injection corrections take place each time the signal switches above and below the 0.45 threshold voltage.

Closed Loop Operation

The Closed Loop Control System continuously monitors the oxygen content in the exhauset and then makes minor adjustments to injection duration.



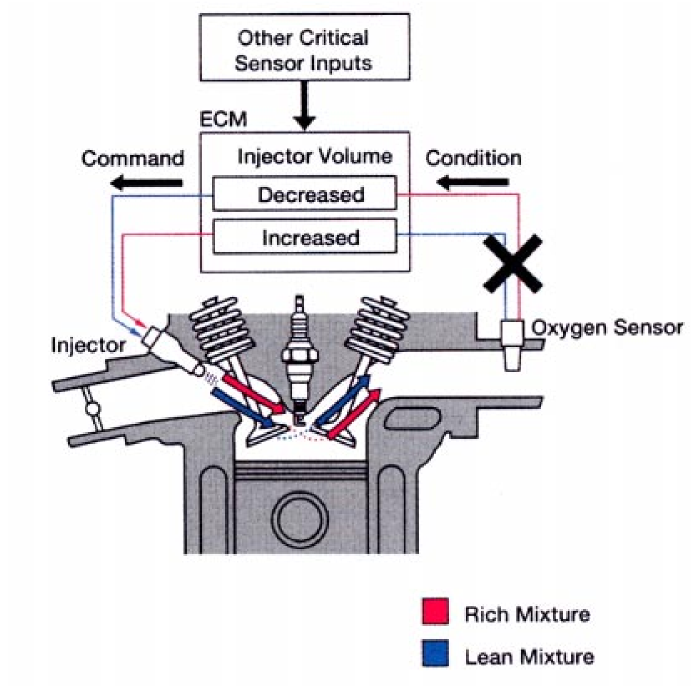
Closed loop control works on the premise **of the command changing the condition** and can be summarized as follows:

- O2S indicates **rich** = ECM commands **leaner** injection duration
- O2S indicates **lean** = ECM commands **richer** injection duration

In short, the oxygen sensor informs the ECM of needed adjustments to injector duration based on exhaust conditions. After adjustments are made, the oxygen sensor monitors the correction accuracy and informs the ECM of additional adjustments. This monitor/command cycle occurs continuously during closed loop operation in an effort to keep the air/fuel mixture modulated around the ideal ratio.

Open Loop Operation

During conditions that require A/F mixtures richer or leaner than ”ideal”, the system disregards teh O2S signal and controls injection duration based on other sensor inputs. This is referred to as Open Loop.



Open Loop Operating Conditions

There are certain operating conditions that require the mixture to be richer or leaner than ideal. During these conditions the ECM ignores the oxygen sensor signal and controls fuel duration using other sensor information. This operation, called Open Loop, typically occurs during engine start ”clock out”, cold engine operation, acceleration, deceleration, moderate to heavy load conditions, and wide open throttle (WOT).

Effects of Incorrect Closed Loop Control on Emissions and Driveability

Generally, incorrect fuel control affects emissions and driveability as follows:

- **Air/fuel ratio too rich** may result in emissions failure for CO and HC, rich misfire, engine stalling, rough idle, hesitation, overheated converter, etc.
- **Air/fuel mixture too lean** may result in failure for HC and NOX, lean misfire, engine stalling, stumble, flat spot, hesitation, rough idle, poor acceleration, etc.

Closed Loop Control System Functional Checks

If you suspect that the closed loop system is not properly controlling fuel delivery, one of the first checks you should perform is an **Oxygen (O_2) Sensor signal check.** Since the ECM relies on the O2S signal to fine tune injection duration during closed loop operation, an accurate check of the O2S signal is crucial in diagnosing problems that you suspect are the result of improper closed loop control.

Remember, the engine (and engine control system) must meet certain conditions prior to checking the O2S signal or your results may be inaccurate. This usually means that the engine and O_2 sensor must reach operating temperature, the feedback system is in closed loop, and engine speed is maintained at a specified rpm. O2S signal checks can be performed on OBD/OBD-II vehicles by using the Diagnostic Tester. Older vehicles may require you to backprobe the O2S signal wire using the Autoprobe or digital multimeter.

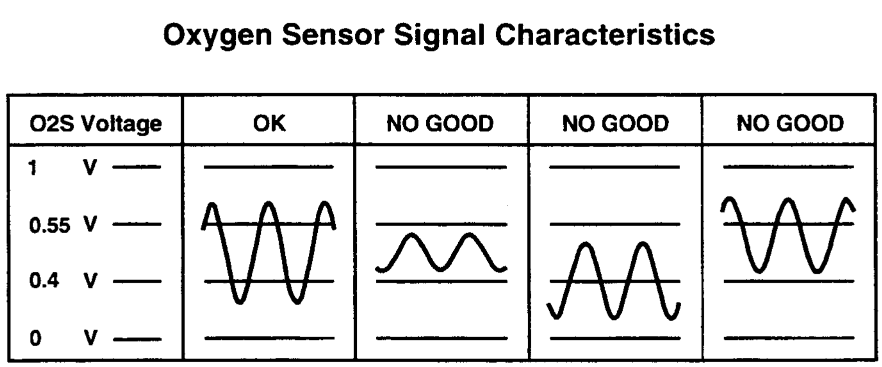
Oxygen Sensor (O2S) Signal Checks

Monitoring oxygen sensor signal **switching frequency and amplitude is** the key to a quick functional test of the entire closed loop control subsystem. The check can be performed as follows:

- Start engine and allow it reach operating temperature
- Make sure all accessories are off
- Run engine at 2500 rpm for at least two minutes to ensure O_2 sensor is at normal operating temperature
- O2S signal frequency should be at least eight cycles in ten seconds (0.8 hz) in order to ensure efficient catalyst operation.
- Also, signal amplitude should consistently exceed 550 mv on the rich swing and fall below 400 mv on the lean swing. If the sensor is degraded, either signal frequency or amplitude or both will be effected.

O_2S Signal Patterns

Examples of acceptable and unacceptable O2S signal patterns. Note: O2S signal amplitude exceeds 550 mv on rich swing and 400 mv on lean swing.

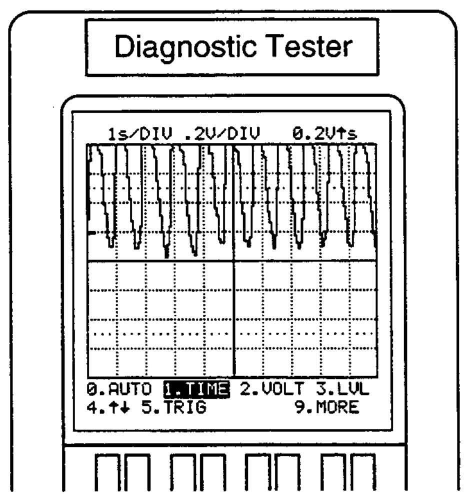


O2S Check Using Autoprobe

If the Autoprobe feature of the Diagnostic Tester is used, set up the oscilloscope to read the O2S signal. Follow these steps:

- Calibrate the Autoprobe
- Set time to 1 sec/div (use 0.2 sec/div when measuring switch time)
- Set volts to 0.2 v/div
- Set trigger to automatic
- Use the single shot trigger to capture and freeze the signal

O2S Check Using Autoprobe



O2S Check Using a Digital Multimeter

If a digital multimeter (DMM) is used, like the Fluke 80 series, set up the meter as follows:

- DC volts
- Select the MIN/MAX feature
- Press the MIN/MAX button to toggle between maximum, minimum, and average signal voltage

Tests can be performed by connecting your test instrument to the OX1/OX2 terminal of DLC1, or by back probing directly at the oxygen sensor connector.

Many factors can contribute to the degradation of the oxygen sensor including age and contamination. Since this topic relates closely with catalytic converter operation, it will be discussed in detail later.

Closed Loop Control Quick Check

If you suspect that the ECM is not responding correctly to the oxygen sensor signal, a quick check of the closed loop system can be made by ***artificially driving the system rich or lean*** and observing the corresponding change in closed loop fuel control. This check can be performed as follows:

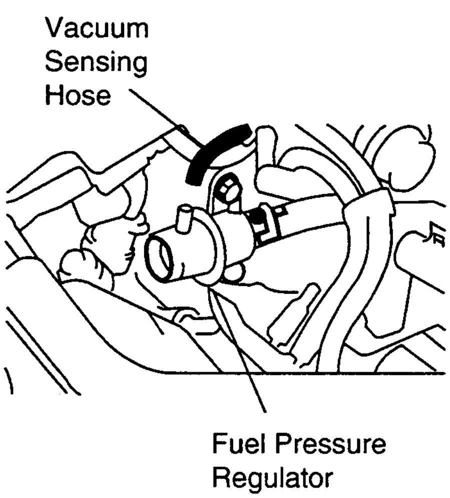
- Temporarily remove the fuel pressure regulator signal hose and plug it, to create a rich condition. The ECM should respond by commanding the injectors to lean the mixture.
- Temporarily create an intake manifold vacuum leak to make a lean condition. The ECM should respond by commanding the injectors to enrich the mixture.

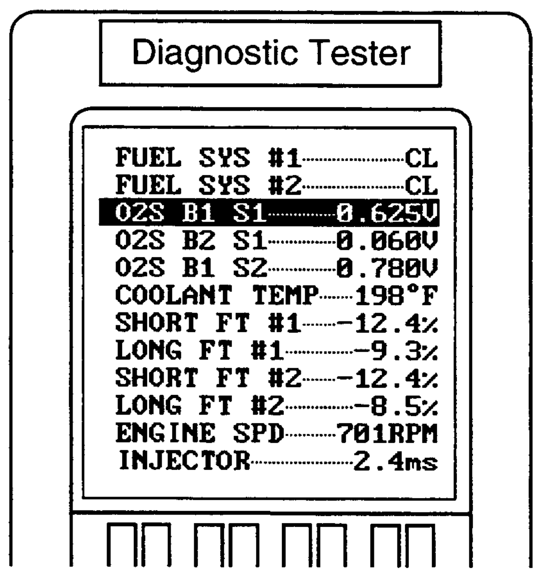
On vehicles with serial data, changes to 02S signal, fuel trim, and injection duration can be observed using the Diagnostic Tester.

CAUTION

When performing this type of check, avoid prolonged mixture imbalances (both lean or rich) for any extended length of time, as this may cause the catalyst to overheat and permanently damage the converter.

Closed Loop Control Quick Check

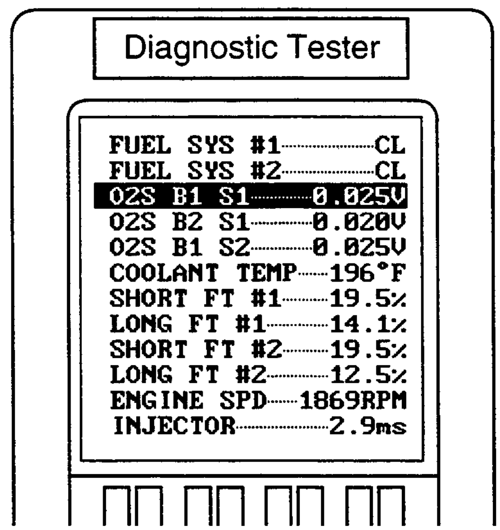




Closed loop control has the ability to provide approximately ± 20% correction range from the basic fuel calculation. This allows the system to easily compensate for small mixture imbalances; however, ***major air/fuel imbalances*** (such as large vacuum leaks, leaky fuel pressure regulator, etc.) may push its correction abilities to the limit without bringing the air/fuel mixture back to the "ideal" ratio. If this occurs, whether the mixture is driven too rich or too lean, increased emission levels and driveability problems may result from the systems inability to correct for these problems.

Major A/F Imbalances

Major A/F imbalances, like this vacuum leak, may go beyond the correccion abilities of the Closed Loop Control System. Check the adaptive fuel correction factors, O2S signal, injector, etc., for indications of a major A/F imbalance.



Check For Major Fuel Correction

A quick check of the **adaptive fuel correction** will show the ECM's intensions of correcting this condition. Depending on the model, this adaptive correction factor may be called VF Voltage, Target A/F, or Long-Term Fuel Trim, and on serial data equipped vehicles may be checked using the Diagnostic Tester. Refer to course 850 and 873 handbooks for additional information on accessing and interpreting adaptive correction factors.

Quick Check of Critical Sensor Inputs

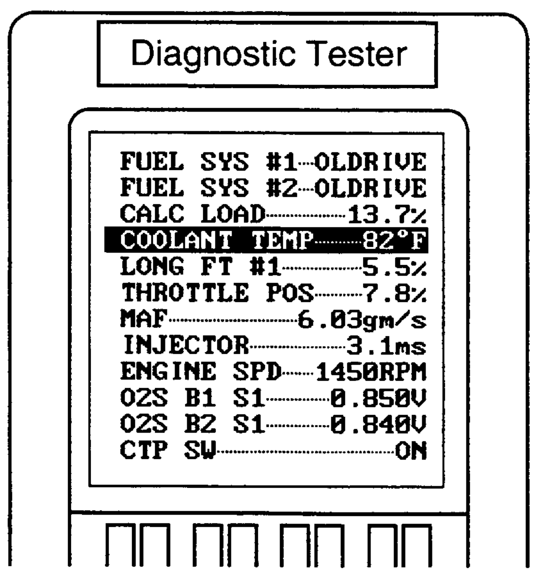
If the ECM receives **inaccurate sensor information,** it may incorrectly place the system into open loop, disregard the oxygen sensor input and drive injection richer or leaner than ideal. For example, if the coolant temperature sensor incorrectly provides a high voltage signal to the ECM (indicating cold coolant temperature) when the engine is actually at operating temperature, the ECM will incorrectly respond by placing the system into open loop and provide a richer than normal fuel ratio. If you suspect fuel control problems as a result of input sensor problems, it is imperative that you confirm closed loop operating status and sensor signal accuracy. On vehicles with serial data, this can be done by making a quick check of the **6 most critical data parameters** using the Diagnostic Tester. Remember, the critical inputs include:

- Engine speed
- Engine load
- Throttle position
- Closed throttle position
- Coolant temperature
- Oxygen sensor

Critical Sensor Inputs

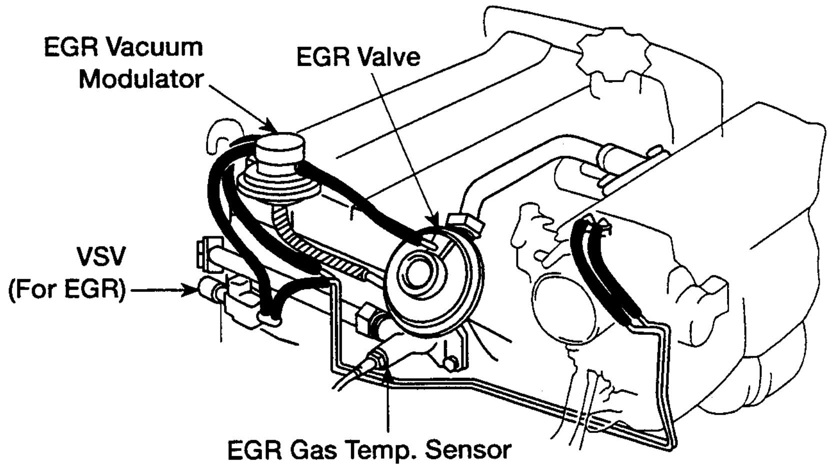
If you suspect inaccurate sensor information, always perform a quick check of the 6 most critical sensro inputs that impact fuel control.

In this example, an incorrect coolant temperature signal has improperly placed the system in open loop, while providing a richer than normal A/F mixture.



EGR System

The EGR System reduces NO_X output by recirculating exhaust gases in with the engine's normal A/F charge. By diluting the mixture, combustion temperature is lowered, and as a result, NO_X output is reduced.



Exhaust Gas Recirculation System

The Exhaust Gas Recirculation (EGR) system is designed to reduce the amount of Oxides of Nitrogen (NOx) created by the engine during operating periods that usually result in high combustion temperatures. NOx is formed in high concentrations whenever combustion temperatures exceed about 2500° F.

The EGR system reduces NOx production by recirculating small amounts of exhaust gases into the intake manifold where it mixes with the incoming air/fuel charge. By diluting the air/fuel mixture under these conditions, peak combustion temperatures and pressures are reduced, resulting in an overall reduction of NOx output. Generally speaking, EGR flow should match the following operating conditions:

- **High EGR flow** is necessary during cruising and mid-range acceleration, when combustion temperatures are typically very high
- **Low EGR flow** is needed during low speed and light load conditions
- **No EGR flow** should occur during conditions when EGR operation could adversely affect engine operating efficiency or vehicle driveability (engine warm up, idle, wide open throttle, etc.)

EGR Impact on the Engine Control System

The ECM considers the EGR system an integral part of the entire Engine Control System (ECS). Therefore, the ECM is capable of neutralizing the negative performance aspects of EGR by programming additional spark advance and decreased fuel injection duration during periods of high EGR flow. By integrating fuel and spark control with the EGR metering system, engine performance and fuel economy can actually be enhanced when the EGR system is functioning as designed.

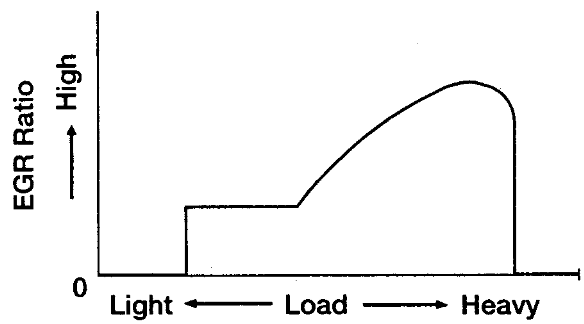
EGR Theory of Operation

The purpose of the EGR system is to precisely regulate EGR flow under different operating conditions, and to override flow under conditions which would compromise good engine performance. The precise amount of exhaust gas which must be metered into the intake manifold varies significantly as engine load changes. This results in the EGR system operating on a very fine line between good NOx control and good engine performance.

If too much exhaust gas is metered, engine performance will suffer. If too little EGR flows, the engine may knock and will not meet strict emissions standards. The theoretical volume of recirculated exhaust gas is referred to as EGR ratio. As the accompanying graph shows, the EGR ratio increases as engine load increases.

Relationship Between EGR Ratio and Load

The theoretical volume of EGR gas is referred to as EGR ratio. As shown on the graph, EGR ratio increases as engine load increases.



EGR System Components

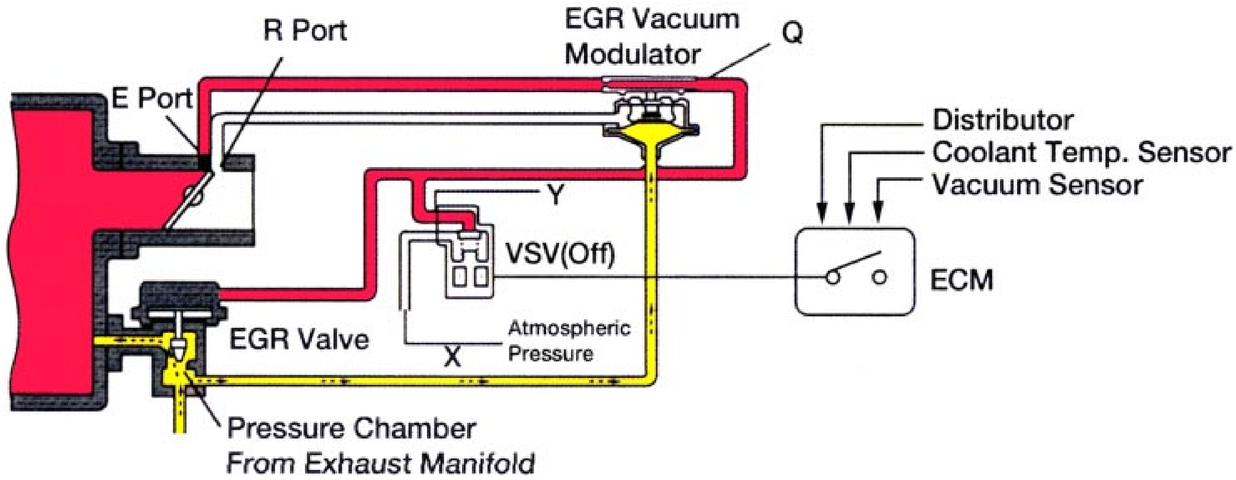
To achieve this designed control of exhaust gas recirculation, the system uses the following components:

- Vacuum Actuated EGR Control Valve
- EGR Vacuum Modulator Assembly
- ECM Controlled Vacuum Switching Valve (VSV)

EGR Control Valve

The EGR control valve is used to regulate exhaust gas flow to the intake system by means of a pintle valve attached to the valve diaphragm. A ported vacuum signal and calibrated spring on one side of the diaphragm are balanced against atmospheric pressure acting on the other side of the diaphragm. As the vacuum signal applied to the valve increases, the valve is pulled further from it’s seat. The key to accurate EGR metering is the EGR vacuum modulator assembly which precisely controls the strength of the applied vacuum signal.

Typical EGR System Configuration

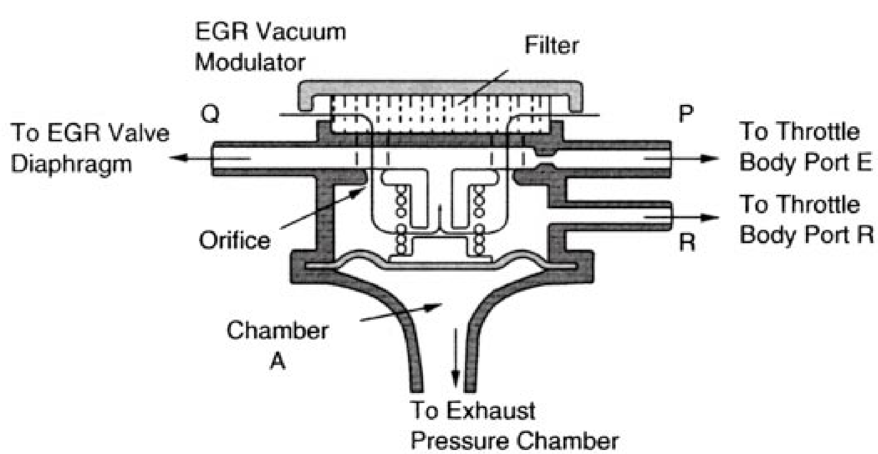


EGR Vacuum Modulator

Because exhaust backpressure increases proportionally with engine load, the EGR vacuum modulator uses this principle to precisely control the strength of the vacuum signal to the EGR valve. The typical EGR control system uses two ported vacuum signals from the throttle body. Port E is the first stage ported vacuum signal and Port R is the second stage ported vacuum signal uncovered by the opening throttle valve.

EGR Vacuum Modulator

The EGR Vacuum Modulator uses exhaust backpressure to precisely control the strength of teh vacuum signal to the EGR valve.



When vacuum is applied from port E, the strength of the vacuum signal applied to the EGR valve will be dependent on the amount of exhaust backpressure acting on chamber A of the vacuum modulator. When vacuum is applied from port R, the strength of the vacuum signal applied to the EGR valve will no longer be dependent on the strength of the exhaust backpressure signal. During this mode, the EGR signal strength is determined solely by the strength of the vacuum signal from port E of the throttle body. The EGR vacuum modulator provides the ability to precisely match EGR flow rate to amount of load applied to the engine.

EGR Vacuum Signal Logic

Port	Throttle Valve Opening	Vacuum signal
E	Position less than E port	No vacuum present
E	Position more than E port	Near manifold vacuum
R	Position less than R port	No vacuum present
R	Position more than R port	Near manifold vacuum

ECM Controlled Vacuum Switching Valve (VSV)

In addition to the EGR modulator, an ECM controlled VSV *is* used to inhibit EGR operation during conditions where it could adversely affect engine performance and vehicle driveability. The EGR VSV can be either normally open or closed and installed in series between the vacuum modulator and EGR valve or installed on a second port on the EGR valve. This VSV controls an atmospheric bleed which inhibits EGR operation any time a given set of ECM parameters are met.

ECM Override of EGR

As mentioned, the ECM is capable of inhibiting EGR flow through operation of the VSV bleed. When the ECM determines an inhibit condition, it de-energizes the VSV, blocking the vacuum signal to the EGR valve and opening the valve diaphragm to an atmospheric bleed. This causes the EGR valve to close. Typical EGR inhibit parameters are shown below.

EGR Vacuum Signal Logic

Coolant Temperature	Engine RPM	Engine Load
EGR inhibit on all engines below specified coolant temperature (based on THW), typically around 130○ F	EGR inhibit on some engines outside specified rpm range (based on Ne), typically around 4200 rpm	EGR inhibit on some engines below a given load factor (based on either Vs or PIM)

There are three basic variations of the EGR vacuum circuit depending on engine application. All three systems function similarly, the only difference being the placement of the VSV in the vacuum circuit and the logic of the VSV and ECM. Refer to course 850 handbook for details on different system configurations.

EGR Fault Detection System

An EGR malfunction detection system is incorporated into the TCCS system to warn the driver when the EGR system is not operating properly. The system uses an Exhaust Gas Temperature (THG) sensor on the intake side of the EGR valve where it is exposed to exhaust gas flow whenever the EGR valve opens.

The ECM compares the THG signal with parameters stored in memory. If EGR gas temperature is determined to be too cold when the ECM has the EGR valve enabled, the MIL will be illuminated, and a diagnostic code will be stored in ECM memory. This diagnostic configuration allows the ECM to monitor entire EGR system operation.

EGR Effect on Emissions & Driveability

- **Too little EGR flow** may cause detonation and IM240 emissions failure for excessive NOx. Because EGR tends to reduce the volatility of the air/fuel charge, loss of EGR typically causes detonation to occur. If EGR is commanded but doesn't flow (restricted passage in manifold, nonfunctional valve, etc.) severe detonation will occur.
- **Too much EGR flow** and/or excessive flow for driving conditions may cause stumble, flat spot, hesitation, and surging. Because EGR dilutes the air/fuel charge, too much EGR for a given engine demand can cause a misfire. It is not uncommon to see tip in hesitation, stumble and surging when too much EGR is metered.

EGR System Functional Tests

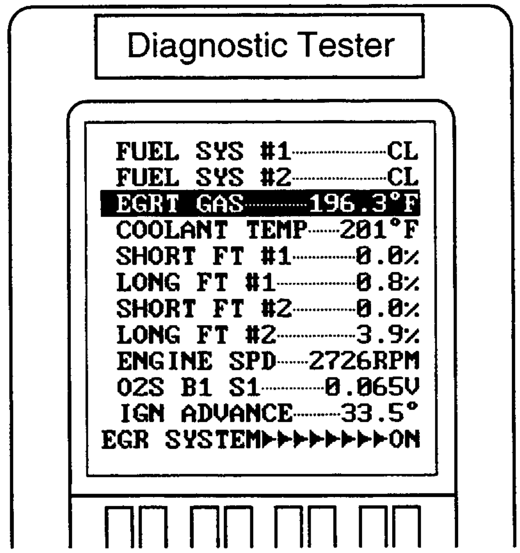
On some OBD-II vehicles, the EGR system can be controlled using the **active test** feature of the Diagnostic Tester. This is the easiest way to verify EGR system operation and can generally be performed *as* follows:

- Start the engine and allow it to reach operating temperature
- Using the Diagnostic Tester, access the Active Test menu
- Select ”EGR System” from the Active Test menu
- Raise engine speed and maintain a steady 3000 rpm
- Activate the EGR VSV (turn EGR On)
- You should notice a slight drop in engine speed and a rise in EGRT gas temperature as EGR is activated

If engine speed and EGRT gas temperature does not change, the EGR system is not functioning and the problem may be mechanical or electrical. If the rpm drop is very slight, the problem may be a partially blocked or restricted EGR passage.

EGR Check Using Active Test

On OBD-II vehicles, the Diagnostic Tester may

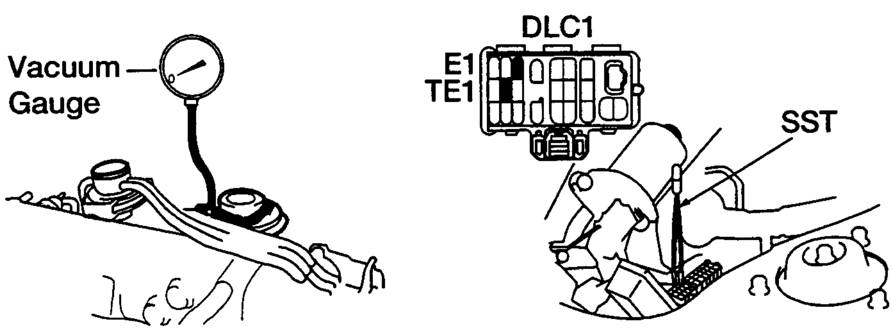


EGR System Inspection

On other vehicles, the only way to accurately check the operation of the EGR system is to perform a **systematic inspection** of the entire system. The following inspection procedures are for a '95 5S-FE Camry:

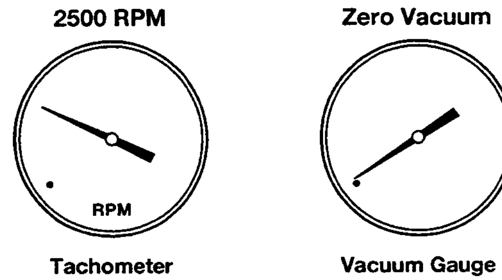
- First, inspect the EGR modulator filter and, if necessary, remove and clean the filter with compressed air.
- "Tee" a vacuum gauge into the vacuum line between the EGR valve and VSV.
- Start the engine and confirm that it does not run rough at idle. *Note: This verifies that the EGR valve is closed.*
- Next, connect terminals Tel to El at DLC 1.

EGR System Inspection



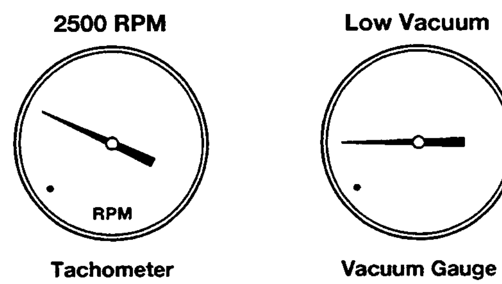
- With coolant temperature cold (A/T: below 140° F, M/T: below 131° F) and engine at 2500 rpm, the vacuum gauge should indicate zero. *Note: This verifies that the VSV is inhibiting EGR flow during cold engine operations.*

EGR System Inspection (cont.)



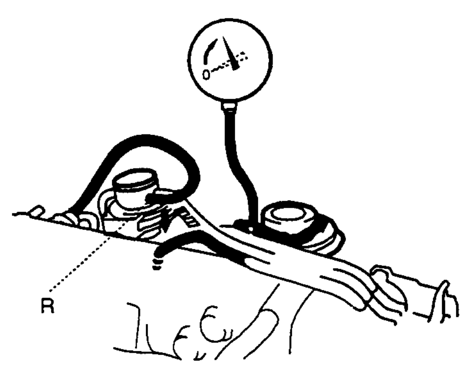
- Next, warm the engine to operating temperature and maintain 2500 rpm. The vacuum gauge should now indicate low vacuum (typically around 3”)
  Note: This verifies proper low vacuum signal to the EGR valve during light engine load conditions.

EGR System Inspection (cont.)



- Next, with engine speed at 2500 rpm, connect the R port of the EGR modulator directly to a manifold vacuum source. The vacuum gauge should now indicate high vacuum (typically around 13”) and the engine should run rough.
  Note: This verifies proper high signal vacuum to the EGR valve when R port vacuum overrides the backpressure modulator.

EGR System Inspection (cont.)

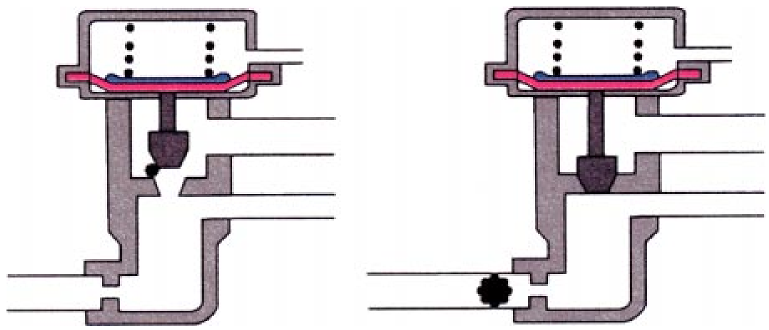


- Disconnect terminals TE1 and El at DLC1 and reattach the EGR hoses to their original location.

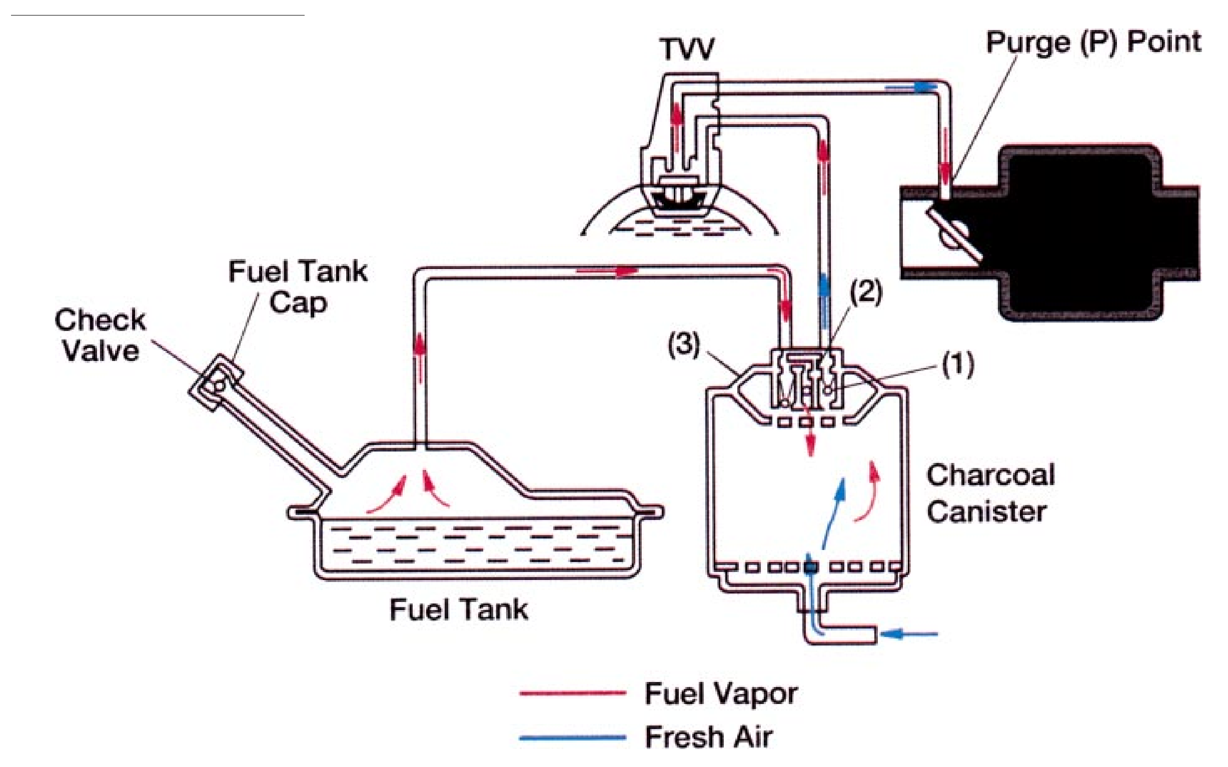
If the problem is related to the EGR valve itself, make sure heavy carbon deposits are not keeping the valve unseated or causing it to stick when opening. Also, if EGR valve control is OK, remove the valve and check the EGR exhaust and intake passages for restrictions. Heavy carbon deposits can be removed by using a special carbon scrapping tool.

EGR Valve Inspection

When inspecting the EGR valve, look for common problems such as unseated or sticky valves and plugged exhaust/intake passages.



This inspection example systematically confirms the integrity of the EGR valve, VSV, backpressure modulator, system hoses, and EGR passages. Once the suspect part/component is identified, it should be individually tested and then repaired or replaced as necessary. Because slight model to model variations exist between EGR systems, refer to the Repair Manual for specific EGR system inspection procedures.



Evaporative Emission Control System

Approximately 20% of all hydrocarbon (HC) emissions from the automobile originate from evaporative sources. The Evaporative Emission Control (EVAP) system is designed to store and dispose of fuel vapors normally created in the fuel system; thereby, preventing its escape to the atmosphere. The EVAP system delivers these vapors to the intake manifold to be burned with the normal air/fuel mixture. This fuel charge is added during periods of closed loop operation when the additional enrichment can be managed by the closed loop fuel control system. Improper operation of the EVAP system may cause rich driveability problems, as well as failure of the Two Speed Idle test or Enhanced I/M evaporative pressure or purge test.

The EVAP system is a fully closed system designed to maintain stable fuel tank pressures without allowing fuel vapors to escape to the atmosphere. Fuel vapor is normally created in the fuel tank as a result of evaporation. It is then transferred to the EVAP system charcoal canister when tank vapor pressures become excessive. When operating conditions can tolerate additional enrichment, these stored fuel vapors are purged into the intake manifold and added to the incoming air/fuel mixture.

Toyota vehicles use two different *types* of evaporative emission control systems:

- **Non-ECM controlled EVAP systems** use solely mechanical means to collect and purge stored fuel vapors. Typically, these systems use a ported vacuum purge port and a Thermo Vacuum Valve (TVV) to prohibit cold engine operation.
- **ECM controlled EVAP systems** uses a manifold vacuum purge source in conjunction with a duty cycled Vacuum Switching Valve (VSV). This type of EVAP system has the ability to provide more precise control of purge flow volume and inhibit operation.

Non-ECM Controlled EVAP System

Non-ECM controlled EVAP systems typically use the following components:

- Fuel tank
- Fuel tank cap (with vacuum check valve)
- Charcoal canister (with vacuum & pressure check valves)
- Thermo Vacuum Valve (TVV)
- Ported vacuum purge port (port P; on throttle body)

EVAP System Operation

Under some conditions, the fuel tank operates under a slight pressure to reduce the possibility of pump cavitation due to fuel vaporization. Pressure is created by unused fuel returning to the tank and is maintained by check valve #2 in the charcoal canister and the check valve in the fuel tank cap.

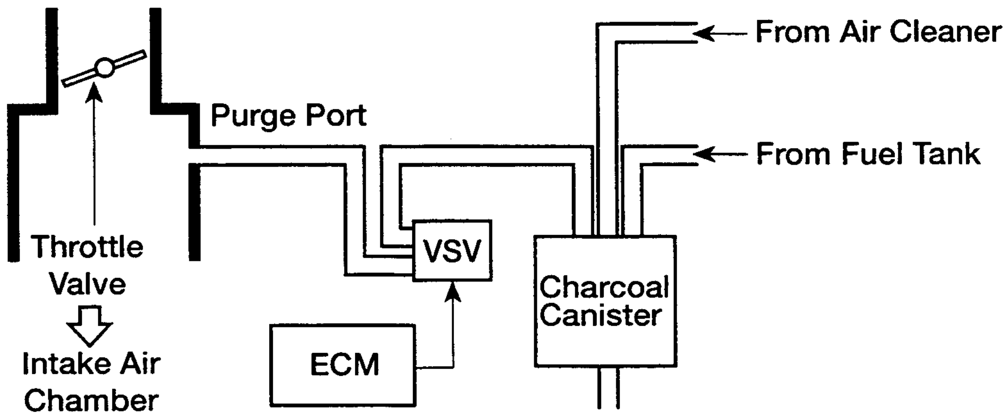
Under other conditions, as fuel is drawn from the tank, a vacuum can be created in the tank causing it to collapse. This is prevented by allowing atmospheric pressure to enter the tank through check valve #3 in the charcoal canister or the fuel tank cap check valve. The EVAP system is designed to limit maximum vacuum and pressure in the fuel tank in this manner.

When the engine is running, stored fuel vapors are purged from the canister whenever the throttle has opened past the purge port (port P) and coolant temperature is above a certain point (usually around 129° F). Fuel vapors flow from the high pressure area in the canister, past check valve #1 in the canister, through the Thermo Vacuum Valve (TVV), to the low pressure area in the throttle body. Atmospheric pressure is allowed into the canister through a filter located on the bottom of the canister. This ensures that purge flow is constantly maintained whenever purge vacuum is applied to the canister.

When coolant temperature falls below a certain point (usually around 95° F), the TVV prevents purge from taking place by blocking the vacuum signal to check valve #1.

EVAP System Using Vacuum Switching Valve (VSV)

Typical EVAP System using a duty cycle controlled VSV.



ECM Controlled EVAP System Operation

Introduced on the '95 Avalon for CA, this system is similar to the Non-ECM controlled systems, except that an ECM controlled Vacuum Switching Valve (VSV) is used in place of the Thermo Vacuum Valve (TVV). The VSV is normally closed and duty cycle controlled, which means the ECM rapidly opens and closes the VSV passage to provide precise, variable control of purge flow volume and inhibit operation.

Because this system uses a manifold vacuum purge port, it may provide slight purge flow during idle if conditions can tolerate its enrichment. The ECM uses engine speed, intake air volume, coolant temperature, and oxygen sensor information to control EVAP operation.

EVAP Purge System Monitoring

By monitoring the oxygen sensor and injection pulse width as the canister is being purged, the ECM can detect the reduction of exhaust oxygen content and corresponding decrease in injection pulse width to correct for this momentary rich condition. In this manner, the ECM can detect a failure in the EVAP purge control system and store a DTC to alert the vehicle operator of the malfunction. Purge flow monitoring is only used on '95 and later OBD-II equipped vehicles.

EVAP Effect On Emissions and Driveability

During Two Speed Idle tests, it is not uncommon for vehicles to fail off idle tailpipe tests for excessive CO emissions due to normal evaporative purge cycle operation. It is also possible for the charcoal canister to become saturated with liquid fuel to the degree that it becomes unserviceable.

To avoid emissions failures due to normal evaporative emissions purge cycle, the vehicle should not be tested after long hot soak periods, prolonged idle or after having been left in sitting in the sun on a hot day. All of these conditions will cause large amounts of fuel vapor to store in the charcoal canister. To put the EVAP system through it's normal purge cycle, the vehicle can be driven at highway speeds for five minutes. This should purge any vapor from the canister which would normally accumulate during the above mentioned conditions.

If the canister continues to cause high CO emissions after a normal purge cycle has been performed, it is possible that the canister is irrecoverably saturated. If the EVAP is suspected as potential cause of high CO emissions failure or rich driveability problems, the following checks should be made:

- Isolate the EVAP system from the engine intake by removing the purge port hose from throttle body port.
- Test vehicle with EVAP system isolated.

If the EVAP system is determined to be at fault, use procedures in the appropriate Repair Manual to inspect the charcoal canister, filter, check valves, TVV or VSV and the related vacuum plumbing.

Enhanced I/M EVAP Purge and Pressure Test Diagnosis

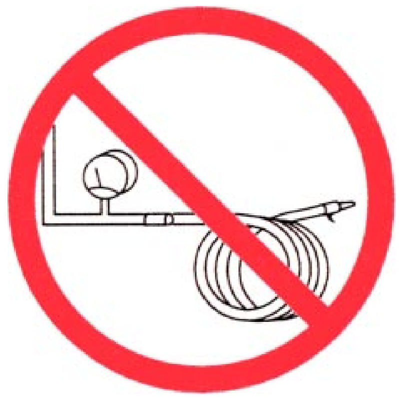
As discussed in Section 2, Evaporative System Purge and Pressure Tests will be required as a part of Enhanced I/M testing. If the vehicle fails for either purge or pressure, checks can be made to verify the operation and integrity of evaporative control system.

EVAP System Pressure Test Diagnosis

The Enhanced I/M Evaporative Pressure Test is performed by filling the EVAP vapor line and fuel tank with nitrogen to a pressure of 14 inches of water (approximately 0.5 psi). If the system maintains at least 8 inches of water pressure after 2 minutes, it passes the test.

Warning!

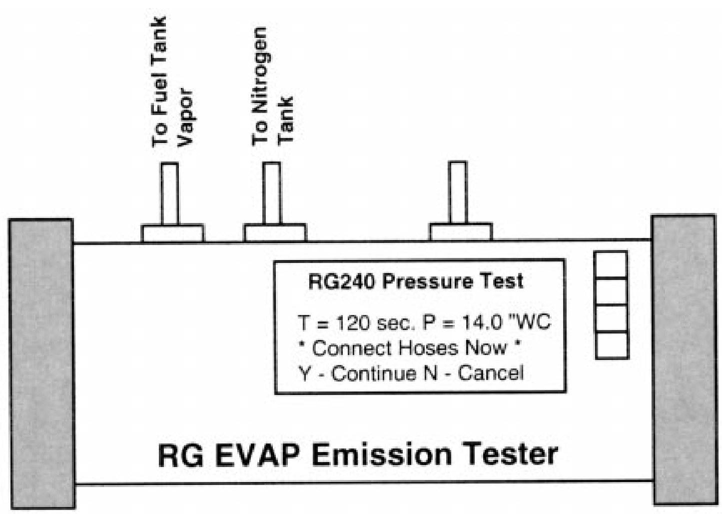
Because of difficulty regulating compresed air, and the hazardous nature of introducing oxygen to stored fuel vapors, never attempt to pressurize the EVAP system using shop air.



If the EVAP system fails the pressure test, a leak exists either in the vapor vent line between the canister and tank, the fuel tank itself, or the fuel cap. Visual checks may or may not identify the source of leak(s) in the system; however, **you should never pressurize the EVAP system with shop air!** Doing this would introduce oxygen into the EVAP system were it could combine with fuel vapors and create a very explosive condition. Secondly, the system is tested at very low pressure which would make accurate, pressure regulation difficult. If the system was accidently pressurized beyond this point, severe damage to the system may result.

EVAP Pressure Testing (Using Special Test Equipment)

Aftermarket test equipment may be used to accurately pressure test the EVAP system similar to the method used in IM240



EVAP Pressure Testing Using Special Test Equipment

The best way to test and identify leak(s) that cause a pressure test failure is to use special EVAP pressure testing equipment available from aftermarket suppliers. This equipment allows you to perform an actual pressure test, in addition to having features that help you locate the leak. There are many variations and differences between test equipment and procedures, but for the sake of example, here is the test procedure for an EVAP pressure tester that uses pressurized nitrogen gas:

1. Disconnect the fuel tank vapor line from the canister and attach the pressure tester to this line.

   Note: The tester may have an adapter that allows you to connect the pressure line between the tank filler neck and the fuel cap.

2. Activate the tester and pressurize the line until 14 inches of water pressure is maintained.
3. Observe the pressure gauge and note if the pressure begins to drop.

   Note: It is normal for pressure to initially rise or fall slightly then stabilize after a few seconds. This is caused by the initial temperature variation between the nitrogen and EVAP fuel vapors. Once temperatures stabilize, the pressure will equalize if no leak exist.

4. If the pressure drops dramatically, listen for leaks from the fuel cap, tank seams, and hoses.
5. Check for frayed or cracked hoses, poor connections, damaged fuel tank seams, faulty fuel cap gasket or check valve.
6. The leak may be found by spraying the suspected area with soapy water and looking for bubbles.
7. Special ultrasonic leak detectors are now available that can ”listen” for the exact frequencies caused by these low pressure leaks. Another method uses the exhaust analyzer to check for the escape of fuel vapors (HC) from the leaky part/component.

   Note: The drawback to using the exhaust analyzer is the limited amount of fuel vapors that exist in EVAP system (fuel tank). If the leak is not quickly identified, all HC vapors will escape leaving only a nitrogen (inert gas) leak to locate.

8. If the leak cannot be identified by the completion of the test, select the manual mode that provides a constant pressure on the system.
9. Once the leaky part/component is identified, perform the needed repair or replacement.

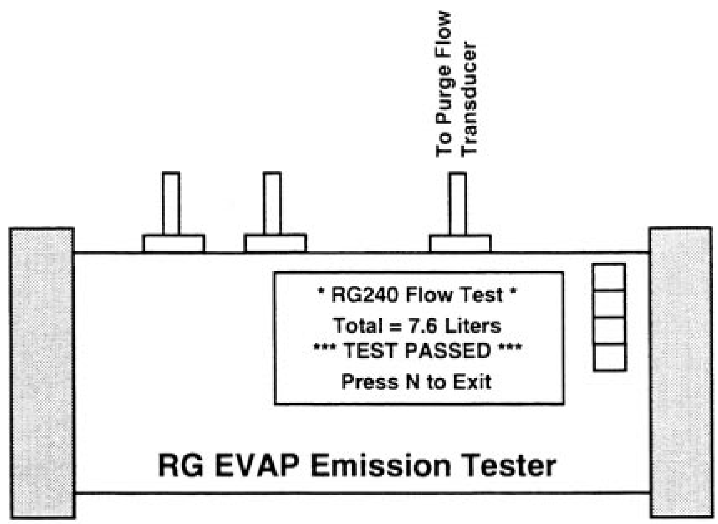
EVAP Purge Test Diagnosis

The evaporative purge test is performed during the IM240 transient (drive cycle) test. A flow transducer is placed in series with the purge line between the canister and engine. In order to pass, the system must purge **at least 1 liter of flow** by the end of the IM240 drive cycle. Toyota vehicles with properly operating EVAP systems normally purge 25 liters or more by the completion of drive cycle.

If the EVAP system fails the purge test, a problem exists with the purge port, the purge hose to the canister, or the charcoal canister itself. Since 1 liter of flow is such a nominal amount, the test really only verifies whether the system is purging or not. There are checks that you can make to confirm vacuum to the canister or the effects of purge flow on the air/fuel mixture; however, the only real way of measure actual flow volume is to use a flow transducer, similar to the one used in the actual purge test.

EVAP Purge Test (Using Special Test Equipment)

Aftermarket test equipment may also be used to perform an EVAP purge test in a similar manner to IM240



EVAP Purge Test Using Special Equipment

The most accurate method of checking EVAP purge flow is to check the system in the same manner in which it was tested. EVAP purge flow testers (sometimes combined with pressure testers) are currently available from aftermarket sources and typically operates as follows:

1. Precondition the vehicle by running the engine until it reaches operating temperature.
2. Connect the tester's flow transducer into the EVAP purge line between the engine and evaporative canister.
3. With the engine off, zero the tester to calibrate the purge flow reading.
4. Next, with the engine idling, start the timer and observe the purge flow rate and accumulated purge volume on the tester display.

   Note: On TVV equipped systems that use a ported vacuum purge source, no purge should take place during idle; however, on systems using a VSV, the ECM may command a very slight amount of flow during idle.

5. Slowly raise engine speed and maintain a steady 2500 rpm. During this period purge flow should increase dramatically and, on a properly functioning EVAP system, 1 liter of flow should be surpassed in a matter of seconds.
6. If the system does not flow at least 1 liter within the 240 second test period or it marginally passes the test, perform the following functional checks to help identify the suspect parts or components.

   Note: Since most vehicles flow 25 liters or more during the same period, marginal passes should also be checked and repaired since these systems are not functioning properly and will probably fail in future tests.
7. Once the problem has been identified and repaired, perform this test again to confirm sufficient improvements in purge volume.

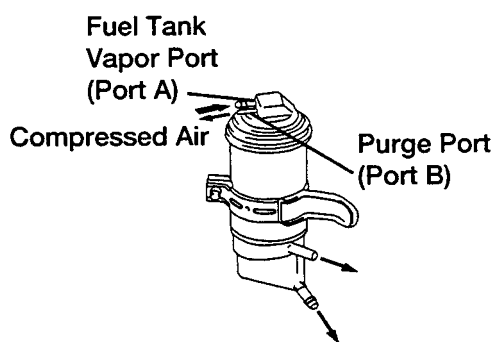
EVAP System Check

If the system fails the purge flow test or flows very little, the following **Evaporative Emission System Check** may help identify problems causing no or low purge flow. The following inspection procedures are for a '95 5S-FE Canary:

1. First, visually inspect the fuel tank, fuel cap, canister, lines and connections for any damage, cracks, fuel leakage, or deterioration and repair or replace as necessary.
2. Check the canister for a clogged filter or stuck check valve by performing the following:
   - Apply low pressure compressed air (0.68 psi) into the fuel tank vapor port (port A) of the canister and confirm that air flows out from all other canister ports.

   Note: Airflow from canister ports is difficult to detect.

EVAP System Check



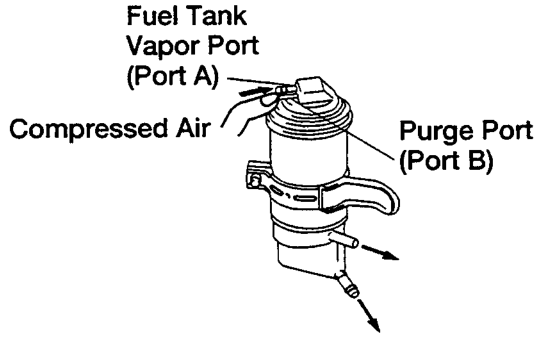
   - Next, apply low pressure compressed air to the purge port (port B) of the canister and confirm that air does not flow out from any of the other ports.

   Note: Replace the canister if a problem is detected with either of the checks above.

   - Clean the canister filter by applying air pressure (43 psi) to the tank vapor port (port A) while holding the purge port (port B) closed with your finger.

   Note: If carbon blows out during this test replace the canister.

EVAP System Check



3. Check the operation of the TVV by performing the following:
   - Disconnect the hoses from the TVV and then attach a hand operated vacuum pump to the lower port of the TVV.
   - With coolant temperature cold (below 95° F), operate the vacuum pump and confirm that air does not flow (vacuum is held) from the upper port to the lower port.

     Note: It is normal for some TVVs to allow a slight amount of airflow when cold.
   - Next, allow coolant temperature to rise above 129° F. Operate the vacuum pump and confirm that air now flows (vacuum bleeds off) between the top port and the lower port.

     Note: If the TVV fails any of the checks above, replace it.

This EVAP check example systematically confirms the integrity of the evaporative canister and TVV. Once repair or replacement is made, retest the system to confirm sufficient purge improvement needed to pass a retest. Because slight variations exist between evaporative system tests, refer to the Repair Manual for specific EVAP test procedures and specifications.

Positive Crankcase Ventilation System

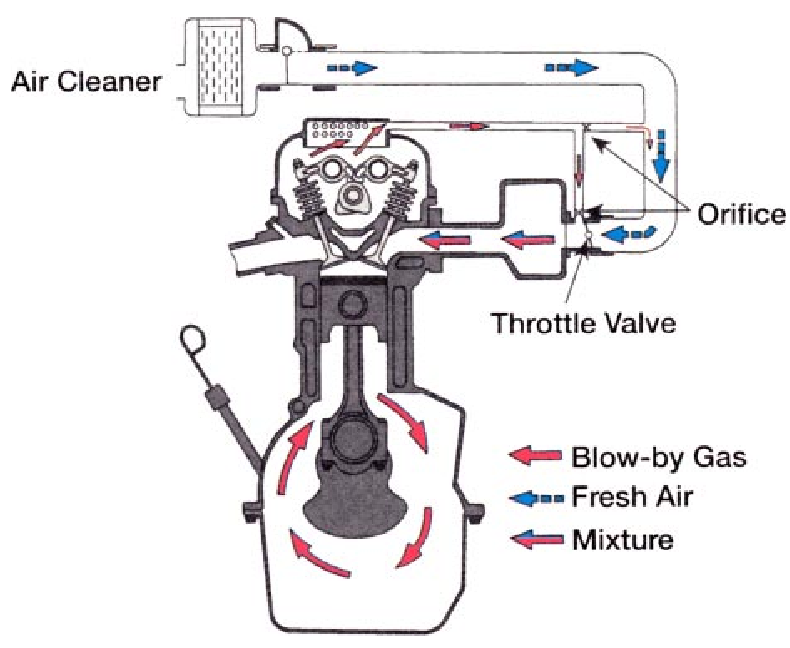
During normal compression stroke, a small amount of gases in the combustion chamber escapes past the piston. Approximately 70% of these ”blowby” gases are unburned fuel (HC) that can dilute and contaminate the engine oil, cause corrosion to critical parts, and contribute to sludge build up. At higher engine speeds, blowby gases increase Crankcase pressure that can cause oil leakage from sealed engine surfaces.

The purpose of the Positive Crankcase Ventilation (PCV) system is to **remove these harmful gases from the Crankcase** before damage occurs and combine them with the engine's normal incoming air/fuel charge. Fuel injected Toyota vehicles use two different types of closed PCV systems to prevent the escape of Crankcase vapors into the atmosphere:

- Fixed Orifice PCV System
- PCV System Using Variable Flow PCV Valve

Fixed Orifice PCV System

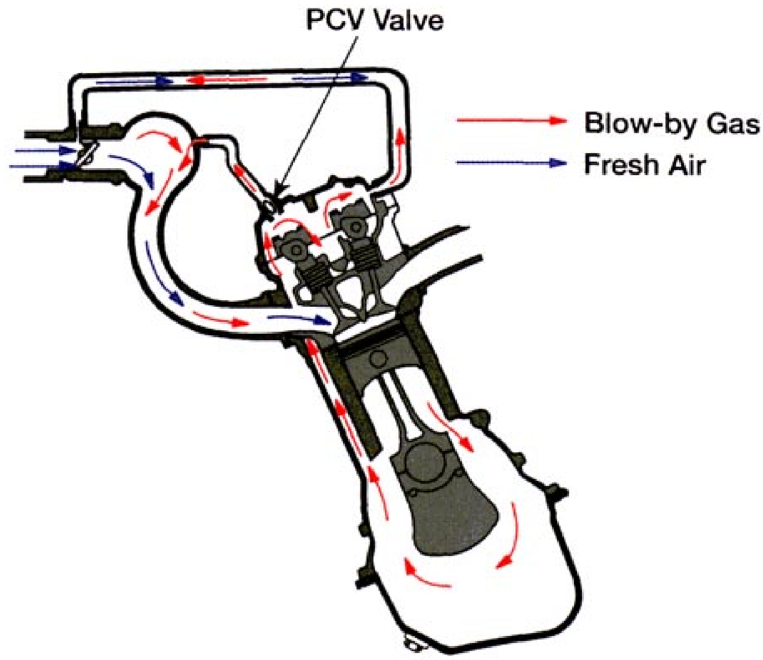
Used on some early Toyota EFI vehicles. Two fixed orifice valves were used to balbance the strength of vacuum applied to ventilate the crankcase.



Fixed Orifice PCV System

On some early Toyota EFI vehicles, a fixed orifice PCV system is used to meter blowby from the Crankcase into the intake manifold, where they would be consumed during normal engine operation. This system is simple in design and construction, and provides Crankcase ventilation based on the size of the fixed orifice valves and the normal operating characteristics of intake manifold vacuum. The two fixed orifice valves are used to balance the strength of vacuum applied to the Crankcase as engine operating conditions change. The biggest drawback of this type system is that blowby production does not always match intake manifold vacuum characteristics.

PCV System (With PCV Valve)

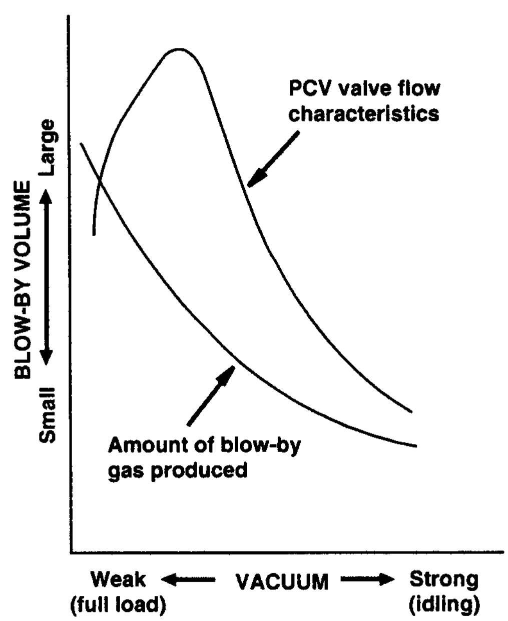


PCV System Using Variable-Flow PCV Valve

Unlike fixed orifice type systems, PCV systems that use a variable-flow PCV valve more accurately match ventilation flow with blowby production characteristics. By accurately matching theses two factors, Crankcase ventilation performance is optimized, while engine performance and driveability remains unaffected.

PCV Valve Flow Characteristics

As shown, the PCV Valve flow characteristics closely match blowby production characteristics.



PCV System Components

The variable-flow type PCV systems are also very simple in design and consists of the following components:

- PCV Valve
- PCV purge hose
- Breather hose

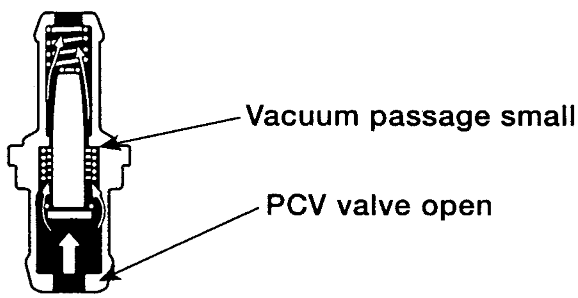
PCV System Operation

Like the previous system, this system also uses manifold vacuum to draw Crankcase vapors back into the intake manifold. Typically, blowby production is the greatest during high load operations and very light during idle and light load operations. Since the characteristics of manifold vacuum do not match the flow requirements needed for proper Crankcase ventilation, a PCV valve is used to regulate blowby flow back into the intake manifold.

- ***During idle and deceleration,*** blowby production is very low, but intake manifold vacuum is very high. This causes the pintle inside the PCV valve to fully retract against spring tension. The positioning of the pintle provides a small vacuum passage and allows for low blowby flow to the combustion chamber.

PCV Valve (Idle, Deceleration)

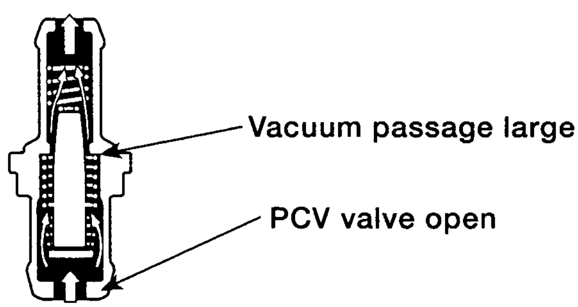
Pintle fully retracted; provides low blowby flow.



- ***During low load cruising,*** the pintle inside the PCV valve is positioned somewhat in the center of its travel. This positioning allows a moderate volume of blowby flow into the combustion chamber.

PCV Valve (Low Load Cruising)

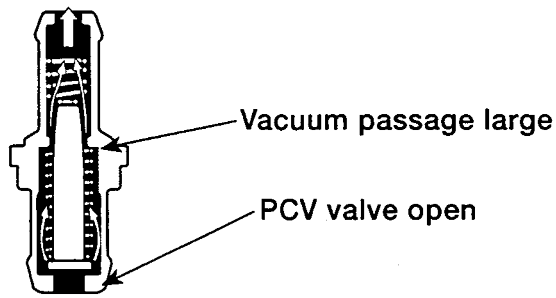
Pintle centered; provides moderate blowby flow.



- **During acceleration and high load operations,** blowby production is very high. The pintle extends out further from the restriction allowing the maximum flow of blowby into the combustion chamber. During extremely high engine loads, if blowby volume exceeds the ability of the PCV valve to draw in the vapors, the excess blowby flows through the breather hose to the air cleaner housing where it can enter the combustion chamber.

PCV Valve (Acceleration, High Load)

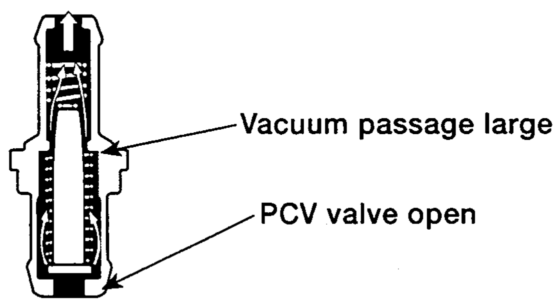
Pintle extended; provides maximum blowby flow.



- **When the engine is off or it backfires,** spring tension closes the valve completely preventing the release of blowby into the intake manifold. The valve closes during a backfire to prevent the flame from travelling into the Crankcase where it could ignite the enclosed fuel vapors.

PCV Valve (Engine Off, Backfire)

Pintle fully extended; valve closed.



PCV System Effects on Emissions and Driveability

Because PCV operation is factored into the proper operation of the feedback control system, problems with the PCV system may disrupt the normal air/ fuel ratio balance. A plugged PCV valve will prevent the normal flow of Crankcase vapors into the engine and can result in a richer than normal air/fuel mixture. A plugged Crankcase breather hose may cause the engine to consume oil because of the increased level of Crankcase vacuum.

In addition, depending on the location of the fresh air breather hose, a nonfunctional valve or restricted vacuum hose can cause oil contamination in the air cleaner housing or throttle bore coking. Always suspect and check the PCV system if you find traces of oil in the air intake system.

If the Crankcase becomes diluted with fuel, carbon monoxide (CO) levels will likely increase because the PCV system will meter extra fuel vapor into the intake system. Always replace fuel diluted engine oil and identify and resolve the problem causing the fuel contaminated.

Although there are no mandatory maintenance intervals for the PCV system, periodically check the system for a plugged or gummed PCV valve and damaged hoses. Replace suspect components as necessary. Since PCV flow rates differ between vehicle models, it is important to use the correct replacement PCV valve to ensure proper operation. The installation of an incorrect valve may cause engine stalling, rough idle and other driveability complaints. Thus, never install universal type PCV valves!

PCV System Functional Tests

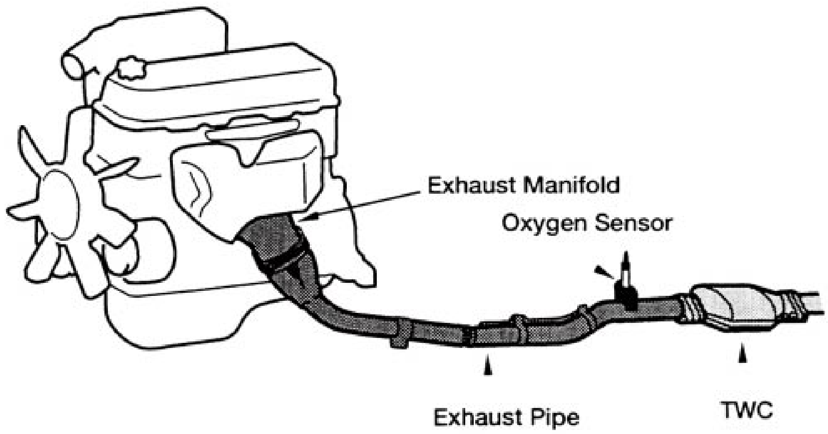
The following **RPM Drop Test** may be used as a basic quick check to confirm that the PCV system is functioning:

- Start the engine and allow it to reach operating temperature
- On TCCS equipped vehicles, connect Te to El at the diagnostic connector
- Allow the engine to stabilize at idle
- Pinch or block the hose between the PCV valve and vacuum source
- Typically, engine rpm should drop around 50 rpm

If engine rpm does not change, check the PCV valve and system hoses for blockage. Replace components as necessary and then retest the system.

Catalytic Converter

A Three-Way Catalytic Converter is used to cause a desirable chemical reaction to take place in the exhaust flow



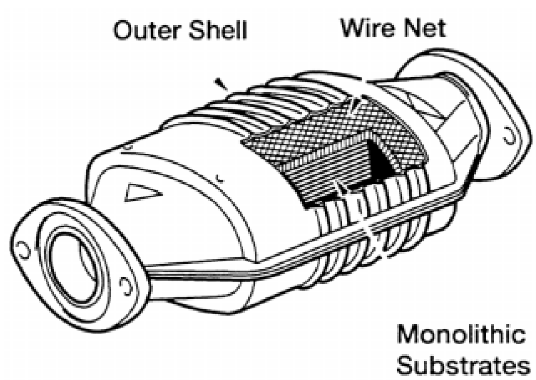
Catalytic Converter

Regardless of how perfect the engine is operating, there will always be some harmful by-products of combustion. This is what necessitates the use of a Three-Way Catalytic (TWO Converter. This device is located in-line with the exhaust system and is used to cause a desirable chemical reaction to take place in the exhaust flow.

Essentially, the catalytic converter is used to complete the oxidation process for hydrocarbon (HC) and carbon monoxide (CO), in addition to reducing oxides of nitrogen (NOx) back to simple nitrogen and carbon dioxide.

Monolithic TWC

Late model Toyota vehicles are equipped with monotlith TWC that use a honeycomb shaped catalyst element.



Two different types of Three-Way Catalytic Converters have been used on fuel injected Toyota vehicles. Some early EFI vehicles used a **pelletized** TWC that was constructed of catalyst coated pellets tightly packed in a sealed shell, while later model vehicles are equipped with a **monolith** type TWC that uses a honeycomb shaped catalyst element. While both types operate similarly, the monolith design creates less exhaust backpressure, while providing ample surface area to efficiently convert feed gases.

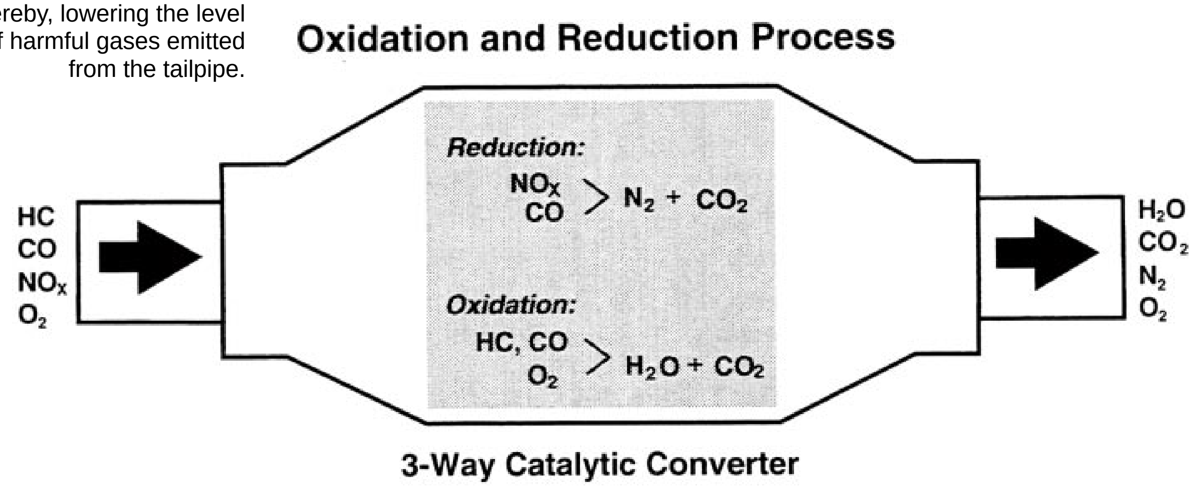
The Three-Way Catalyst, which is responsible for performing the actual feed gas conversion, is created by coating the internal converter substrate with the following key materials:

- **Platinum/Palladium;** Oxidizing catalysts for HC and CO
- **Rhodium;** Reducing catalyst for NOx
- **Cerium;** Promotes oxygen storage to improve oxidation efficiency

The diagram below shows the chemical reaction that takes place inside the converter.

TWC Operation

As shown, the TWC reduces and oxidizes harmful engine-out gases; thereby, lowering the level of harmful gases emitted from the tailpipe.



TWC Operation

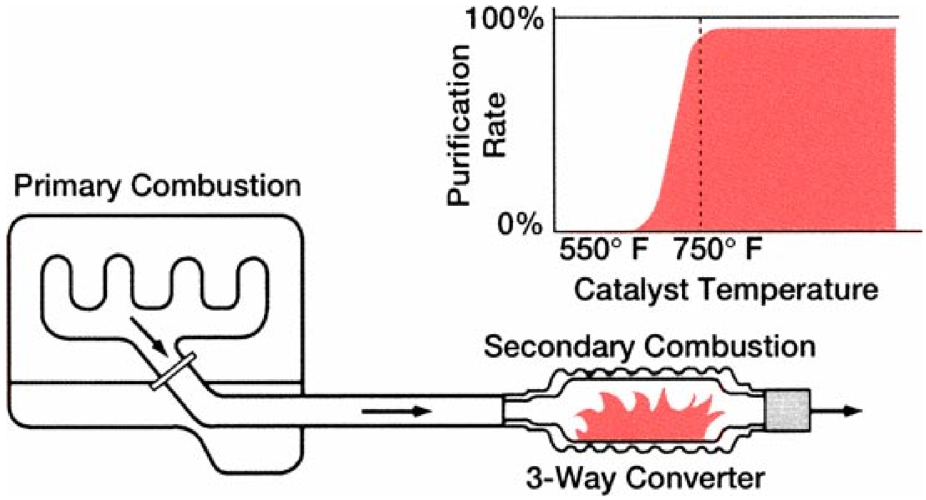
As engine exhaust gases flow through the converter passageways, they contact the coated surface which initiate the catalytic process. As exhaust and catalyst temperatures rise, the following reaction occurs:

- Oxides of nitrogen (NOx) are ***reduced*** into simple nitrogen (N2) and carbon dioxide (CO2)
- Hydrocarbons (HC) and carbon monoxide (CO) are ***oxidized*** to create water (H2O) and carbon dioxide (CO2)

Catalyst operating efficiency is greatly affected by two factors; *operating temperature and feed gas composition.* The catalyst begins to operate at around 550° F.; however, efficient purification does not take place until the catalyst reaches at least 750° F. Also, the converter feed gasses (engine-out exhaust gases) must alternate rapidly between high CO content, to reduce NOx emissions, and high O2 content, to oxidize HC and CO emissions.

Catalyst Operating Temperature

The TWC begins to operate around 550○F, but must be at least 750○F, before efficient purification takes place.



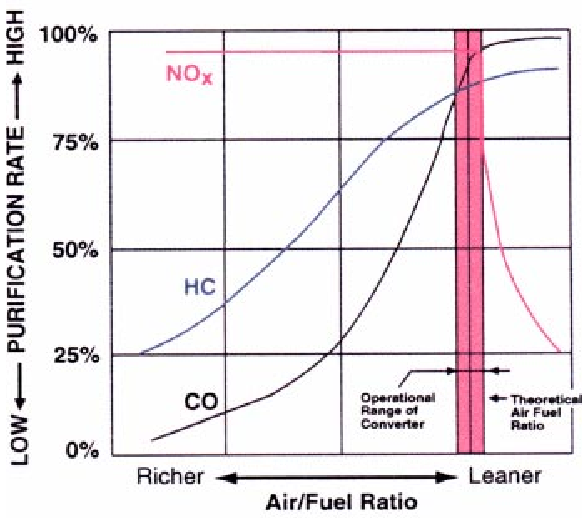
Effects of Closed Loop Control on TWC Operation

To ensure that the catalytic converter has the feed gas composition it needs, the closed loop control system is designed to rapidly alternate the air/fuel ratio slightly rich, then slightly lean of stoichiometry. By doing this, the carbon monoxide and oxygen content of the exhaust gas also alternates with the air/fuel ratio. In short, the converter works as follows:

- **When the A/F ratio is leaner than stoichiometry,** the oxygen content of the exhaust stream rises and the carbon monoxide content falls. This provides a high efficiency operating environment for the oxidizing catalysts (platinum and palladium). During this lean cycle, the catalyst (by using cerium) also stores excess oxygen which will be released to promote better oxidation during the rich cycle.
- **When the A/F ratio is richer than stoichiometry,** the carbon monoxide content of the exhaust rises and the oxygen content falls. This provides a high efficiency operating environment for the reducing catalyst (rhodium). The oxidizing catalyst maintains its efficiency as stored oxygen is released.

Catalyst Efficiency

Efficient catalyst purification relies on the Closed Loop Control system to maintain a very narrow A/F mixtrure range around the "ideal" 14.7/1 ratio.



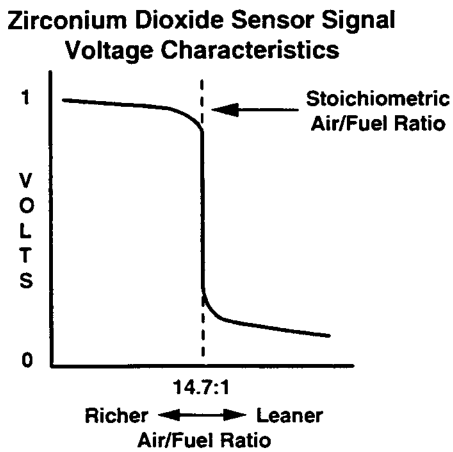
Air/Fuel Ratio

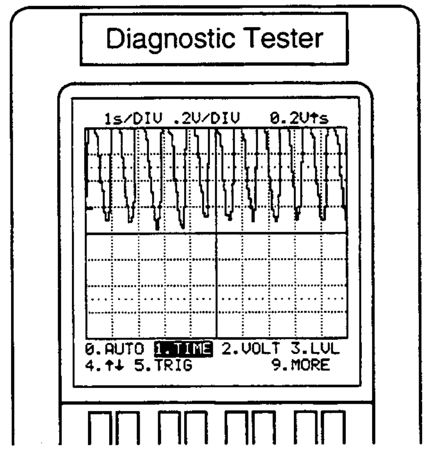
As mentioned in the beginning of this section, precise closed loop control relies on accurate feedback information provided from the exhaust oxygen sensor. The sensor acts like a switch as the air/fuel ratio passes through stoichiometry.

Closed loop fuel control effectively satisfies the three way catalyst's requirement for ample supplies of both carbon monoxide and oxygen. Generally speaking, if the closed loop control system is functioning normally, and fuel trim is relatively neutral (see course 873), you can be assured that the air induction and fuel delivery sub-systems are also operating normally. If the closed loop control system is not working properly, the impact on catalytic converter efficiency, and ultimately emissions, can be significant.

O2S Signal Charcteristics

O2S signal accuracy is crucial to the proper operation of the Closed Loop Control system. As shown, the O2S signal acts as a "switch" to indicate mixtures richer or leaner than "ideal".





Effects of Oxygen Sensor Degradation

Since the oxygen sensor is the heart of the closed loop control system, proper operation is critical to efficient emission control. There are several factors which can cause the oxygen sensor signal to degrade and they include the following:

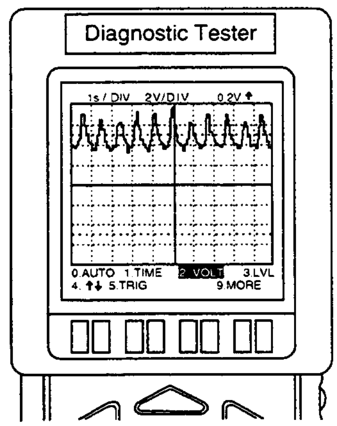
- **Silicon contamination** from chemical additives, some RTV sealers, and contaminated fuel.
- **Lead contamination** can be found in certain additives and leaded motor fuels.
- **Carbon contamination** is caused by excessive short trip driving and/or malfunctions resulting in an excessively rich mixture.

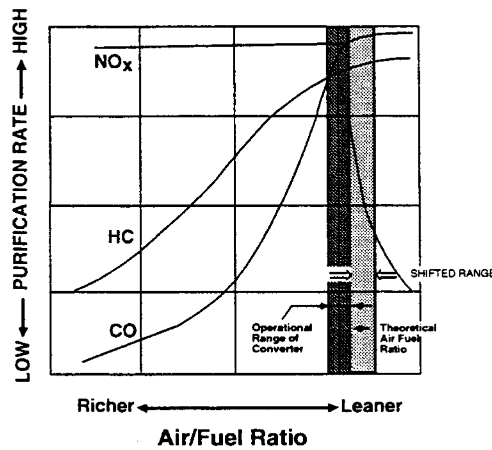
The effects of sensor degradation can range from a subtle shift in air/fuel ratio to a totally inoperative closed loop system. With respect to driveability and emissions diagnosis, a silicon contaminated sensor will cause the most trouble.

When silicon burns in the combustion chamber, it causes a silicon dioxide glaze to form on the oxygen sensor. This glaze causes the sensor to become sluggish when switching from rich to lean, and in some cases, increases the sensor minimum voltage on the lean switch. This causes the fuel system to spend excessive time delivering a lean mixture.

Rich Biased O2S Signal

The O2S signal displayed is considered rich biased (does not fall below 400 mv on the lean swing). This causes the Closed Loop Control system to shift A/F mixture lean, resulting in a decreas to TWC reduction efficiency.



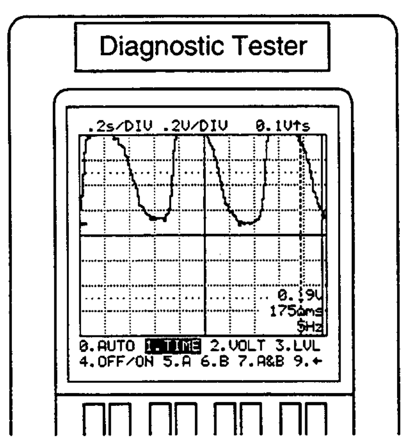


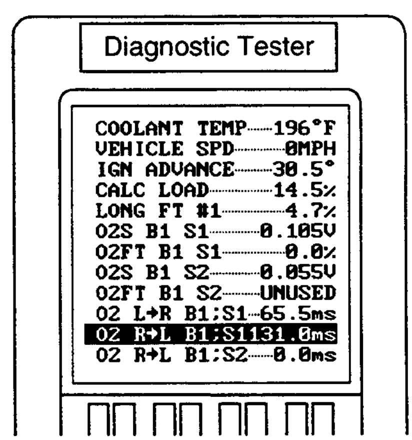
It is often difficult to identify a sensor which is marginally degraded, and in many cases, vehicle driveability may not be effected significantly. With the advent of IM240 emissions testing, however, *marginal sensor degradation may cause some vehicles to fail the NOx portion of the loaded mode test.*

The impact of a slightly lean mixture has a dual effect on emissions. A leaner mixture means higher combustion temperatures so more NOx is produced during combustion. Additionally, because less carbon monoxide is available in catalyst feed gas, the reducing catalyst efficiency falls off dramatically. The end result is a vehicle which may fail an IM240 test for excessive NOx.

Rich > Lean Switch Time

When rich to lean switch time becomes excessive, the air/fuel mixture gets leaner. There is no standard for R> L switch time; however, good sensors (like the one displayed) will typically switch from 700 mv to 200 mv in less than 350 milliseconds.





As previously mentioned, the O2S signal voltage must fluctuate above and below 0.45 volts at least 8 times in 10 seconds at 2500 rpm with the engine at operating temperature. During the rich swing, voltage should exceed 550 mv and during the lean swing should fall below 400 mv. O2S signal checks can be made using the Autoprobe feature of the Diagnostic Tester, digital multimeter, or 02S/RPM check using the Diagnostic Tester. Refer back to the oxygen sensor tests in the closed loop control section for specific test procedures.

Effects of TWC Degradation

Now that we understand the effects of O2S degradation on catalyst efficiency, let's look at the effects of a catalytic converter failure. Keep in mind, there are many different factors that can cause its demise.

- **Poor engine performance** as a result of a restricted converter. Symptoms of a restricted converter include; loss of power at higher engine speeds, hard to start, poor acceleration and fuel economy.
- **A red hot converter** indicates exposure to raw fuel causing the substrate to overheat. This symptom is usually caused by an excessive rich air/fuel mixture or engine misfire. If the problem is not corrected, the substrate may melt, resulting in a restricted converter.
- **Rotten egg odor** results from excessive hydrogen sulfide production and is typically caused by high fuel sulfur content or air/fuel mixture imbalance. If the problem is severe and not corrected, converter meltdown and/or restriction may result.
- **I/M emission test failure** may occur if catalyst performance falls below its designed efficiency level. Perform additional tests to confirm that the problem is in fact converter efficiency and not the result of engine or emission sub-system failure. ***Never use an emission test failure as the only factor in replacing a catalytic converter!*** If you do, you may not be fixing the actual cause of the emission failure.

Like the oxygen sensor, the most common cause of catalytic converter failure is contamination. Examples of converter contaminants include:

- **Overly rich air/fuel mixtures** will cause the converter to overheat causing substrate meltdown.
- **Leaded fuels**, even as little as one tank full, may coat the catalyst element and render the converter useless.
- **Silicone** from sealants (RTV, etc.) or engine coolant that has leaked into the exhaust, may also coat the catalyst and render it useless.

There are other external factors that can cause the converter to degrade and require replacement. **Thermal shock** occurs when a hot converter is quickly exposed to cold temperature (snow, cold fuel, etc.), causing it to physically distort and eventually disintegrate. Converters that have sustained **physical damage** (seam cracks, shell puncture, etc.) should also be replaced as necessary.

TWC Functional Checks

Before a converter is condemned and replaced, it is crucial that any problem(s) that may have contributed to the damage and failure of the converter is identified and repaired. If not, the replacement converter will soon fail!

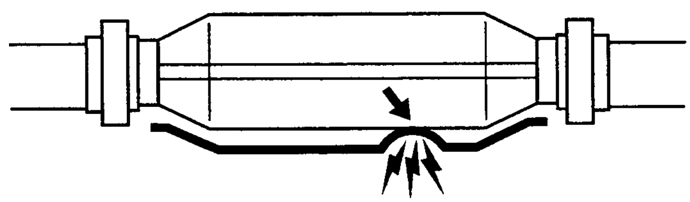
Also, in order to accurately check catalytic converters, all engine mechanical, engine control systems, and emission sub-systems must be in proper working order or your results will be inaccurate. Remember, the converter relies on a narrow feed gas margin or efficiency suffers.

There are a number of tests that can be performed on catalytic converters; however, no one test should be used to verify the complete integrity and conversion efficiency of the converter. The following are examples of typical TWC checks.

Visual Inspection

The first check, and the easiest, is to perform a thorough visual inspection of the converter and related hardware. Many converter problems have obvious symptoms that are easily identified during a visual inspection. Look for the following; pinched exhaust pipe, physical damage to the insulator or converter shell, cracked or broken seams, excessive rust damage, mud or ice in the tailpipe, etc.

Physical Damage

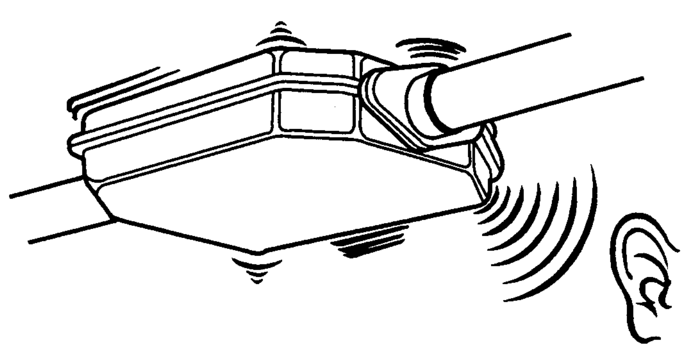


Rattle Test

Perform a rattle test by firmly hitting the converter shell with the center of your palm (avoid hitting it too hard or you may damage it!) If the substrate is OK, it should sound solid. If it rattles, the substrate has disintegrated and the converter should be replaced.

Rattle Test

The TWC will rattle if the internal substrate is damaged. Replace the converter if noise is heard.



Restricted Exhaust System Check

Driveability comments like ”lacks power under load” or ”difficult to start, acts flooded and also lacks power” may indicate a restricted exhaust. In extreme cases the exhaust may be so restrictive that the engine will not start. Generally speaking, here’s how to test for a restricted exhaust system:

- Attach a vacuum gauge to an intake manifold vacuum source.
- Allow the engine to reach operating temperature.
- From idle, raise engine speed to approximately 2000 rpm.

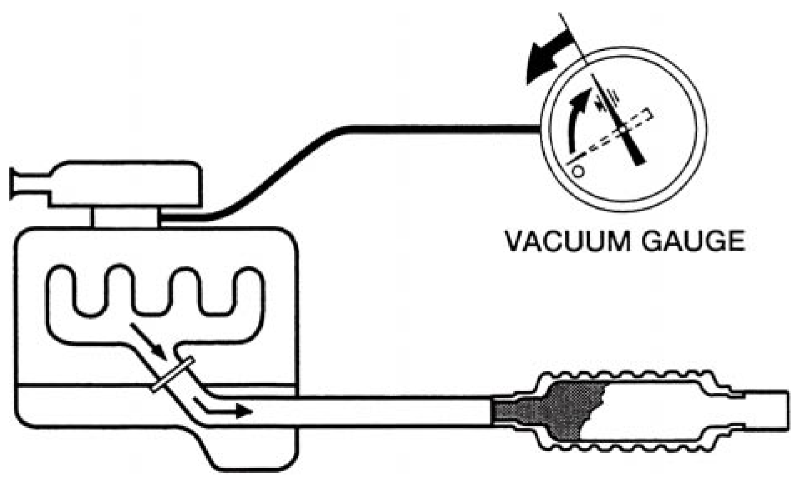
  Note: The vacuum reading should be close to normal idle reading.
- Next, quickly release the throttle.

  Note: The vacuum reading should momentarily rise then smoothly drop back to a normal idle reading. If the vacuum rises slowly or does not quickly return to normal level, the exhaust system may be restricted.

If the catalyst has disintegrated, it is likely that contamination has also restricted the muffler. Don’t overlook that possibility. If the engine will not start, try disconnecting the exhaust system at the manifold and see if the engine will start.

Restricted Exhaust Check

A check for a restricted exhaust system can be made by observing intake manifold vacuum levels at specific engine operating conditions.



Lead Contamination Check

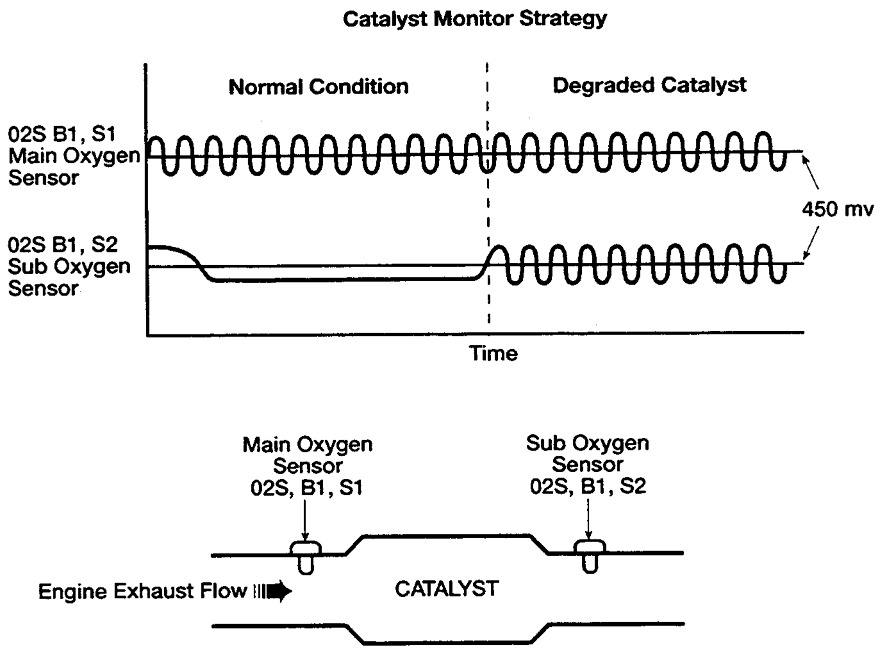
A common cause of converter contamination is lead poisoning. As mentioned, lead reduces converter efficiency by coating the catalyst element. Special lead detecting test paper (or paste) is available from aftermarket suppliers that checks for the presence of lead in the tailpipe. Follow the specific instructions provided by the test paper manufacturer.

TWC Efficiency Quick Check (CA Vehicles)

On CA vehicles equipped with sub-O2 sensors, a quick check of TWC operation can be made by comparing the signal activity of the main oxygen sensor with the sub-oxygen sensor. Since the main O2S in located upstream of the converter and the sub-O2S is located downstream, a signal comparison would indicate whether a catalytic reaction is taking place inside the converter. If the catalyst is operating, the main O2S signal should normally toggle rich/lean, while the sub-O2 sensor should react very slowly (similar to a bad main O2S signal.) Main and sub O2S signals can be observed using the graphing display of the Diagnostic Tester (OBD-II) or V-BoB on other models.

TWC Efficiency Check

A quick check of TWC efficiency can be made by comparing main and sub oxygen sensor activity. Note the sluggish sub-O2S signal activity during normal operation.

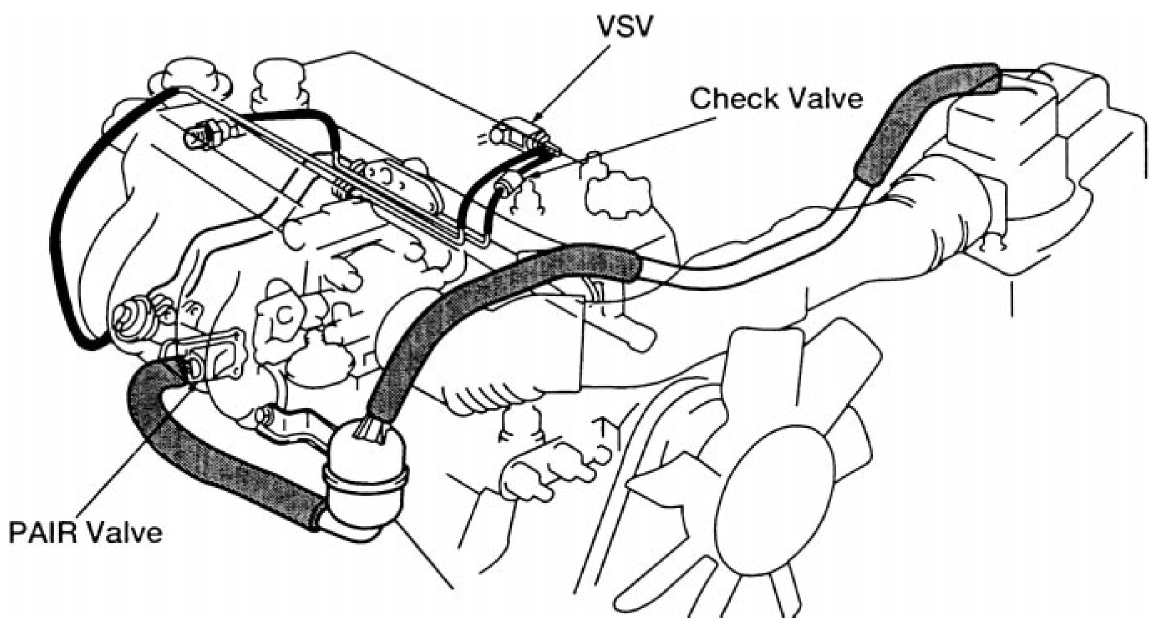


NOTE

Before any catalyst efficiency tests are performed, it is important that both the engine and converter are properly preconditioned. Remember, proper feed gas conversion cannot take place until the closed loop control system is actively maintaining ideal mixture and the catalyst has reached operating temperature. To ensure these conditions are met, particularly during cold ambient conditions, operate the engine off-idle until the TWC is sufficiently heated. This will ensure optimal catalyst conversion efficiency.

Secondary Air Injection

Secondary Air Injection



Pulsed Secondary Air Injection System (PAIR)

Combustion gases that enter the exhaust manifold are not completely burned and would continue to burn if not limited by the amount of oxygen in the exhaust system. To decrease the level of emissions emitted from the tailpipe, the Pulsed Secondary Air Injection (or Air Suction) system is used to introduce air into the exhaust flow, thereby allowing combustion to continue well into the exhaust system. This prolonged combustion (oxidation) period helps to lower the levels of HC and CO emissions that are forwarded to the catalytic converter. Additional air in the exhaust system also ensures that an adequate supply of oxygen is provided to the converter for catalyst oxidation.

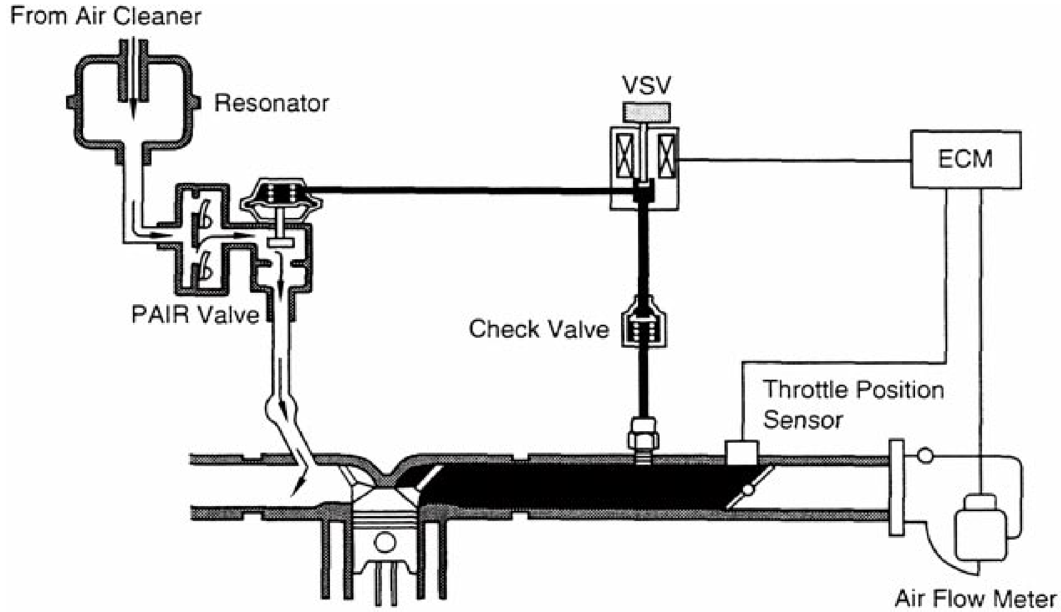
Pulsed Secondary Air Injection (PAIR) systems do not use an air pump, but rely solely on the pressure differential that exists between atmospheric pressure and exhaust vacuum pulsation to draw air into the exhaust manifold.

System Components

Toyota PAIR system uses the following components:

- PAIR valve (with reed valves)
- Vacuum Switching Valve (VSV)
- Check valve
- Resonator
- Air passage hoses

PAIR System



PAIR System Operation

Exhaust pressure is high when the exhaust valve opens to allow combustion gases into the exhaust manifold. However, once the valve closes, exhaust pressure drops below atmospheric pressure to create a vacuum in the exhaust manifold. This explains why exhaust pressure rapidly pulsates above and below atmospheric pressure.

The PAIR system promotes HC and CO oxidation by adding additional oxygen into the exhaust manifold during cold engine operation and deceleration (when very specific parameters are met). These operating conditions typically produce higher levels of HC and CO emissions.

This system simply provides a controlled air passage between atmosphere and the exhaust manifold. Whenever exhaust manifold pressure drops below atmospheric pressure, fresh air from the high pressure zone (atmosphere) flows through the system and enters the exhaust manifold where it promotes emission oxidation.

PAIR Valve

The PAIR system should only operate when needed; thus, a PAIR valve is used to control system air flow. It is simply a vacuum control diaphragm valve, similar to an EGR valve, that is opened to allow secondary air flow and closed to prohibit flow. The PAIR valve assembly also contains reed valves that prevent exhaust gases from entering system and possibly damaging it, when exhaust pressure exceeds atmospheric pressure.

ECM Controlled VSV

An ECM controlled VSV is located in-line with the vacuum signal to the PAIR valve. It is a normally closed VSV that is switched on by the ECM during conditions when emission production is high and fresh air is needed to promote emission oxidation. A resonator is located at the air intake and is used to baffle air pulsation that normally occurs during system operation.

PAIR System Operating Strategy

PAIR operating strategy varies between different engine applications; therefore, refer to the Repair Manual for exact system operating parameters. An example of a typical program strategy (Truck with 22R-E engine) allows secondary air flow during the following conditions:

- **Cold engine operation;** when coolant temperature is below 86° F and engine speed is below 3600 rpm
- **Deceleration;** when either of the following conditions are met:
  - coolant temperature above 140° F, IDL on, and vehicle speed above 2 mph
  - coolant temperature above 140° F, IDL on, vehicle speed below 2 mph, and engine speed above 2,500 rpm

Effects of PAIR System on Emissions and Driveability

In most cases, an inoperative PAIR system will have little effect on vehicle driveability; however, higher levels of emissions may result during periods when secondary air should be supplied (cold engine operation and deceleration). This is due to the lack of oxygen needed to prolong combustion in the exhaust manifold and assist the in catalyst oxidation.

PAIR System Tests

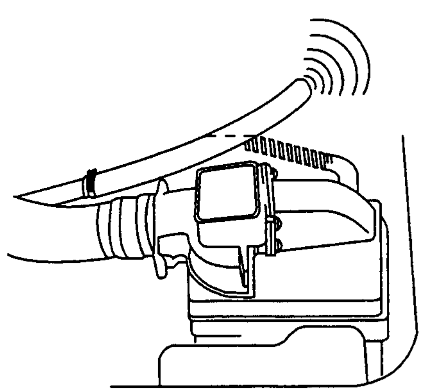
A **visual check** of the PAIR system hoses and components may quickly identify problems that prevent secondary air flow. Check the air control and passage hoses for leaks, kinks, cracks, or damage and replace as necessary. Exhaust residue in the air induction system would indicate damaged reed valves.

A functional check of the PAIR system can be performed as follows:

- Disconnect the PAIR system air intake hose from the air cleaner
- Start the engine cold and allow it to idle. Confirm that a pulsating noise is heard from the PAIR air intake hose

  Note: This confirms secondary air flow during cold engine idle

PAIR System Functional Check



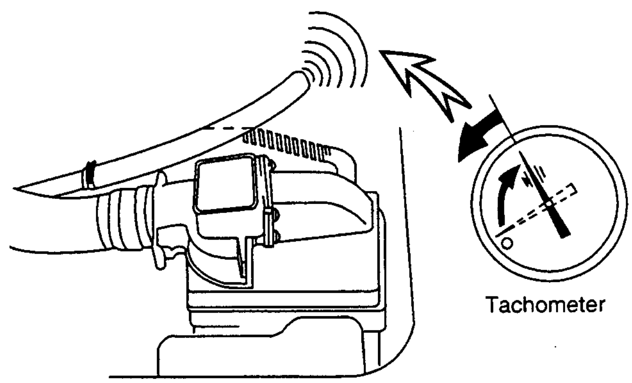
- Allow the engine to reach operating temp, and let it idle. Confirm that no pulsating noise is heard from the PAIR air intake hose

  Note: This confirms no secondary airflow during hot engine idle

* Next, race the engine and then snap the throttle closed. Confirm that a pulsating noise is initially heard from the PAIR air intake hose, then stops after a few seconds.

  Note: This confirms secondary air flow during deceleration until engine speed falls below a certain level.

PAIR System Functional Check



Idle Air Control System

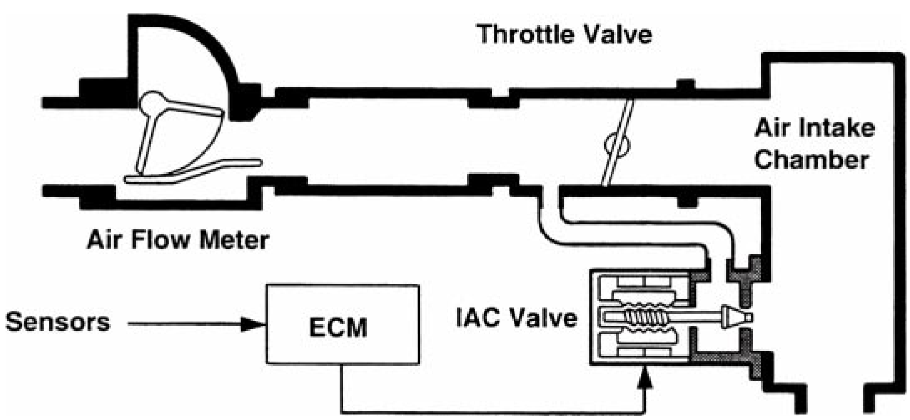
The Idle Air Control (IAC) system is used to stabilize idle speed during cold engine and after warm-up operations. Idle speed stabilization is needed due to the effect engine load changes has on emission output, idle quality and vehicle driveability. The IAC system uses an ECM controlled idle air control valve (IACV) that regulates the volume of air bypassed around the closed throttle. The ECM controls the IACV by applying various input signals against an IAC program stored in memory.

There are four different types of lACVs used on Toyota models. These systems are referred to as:

- Step-Motor
- Duty-Control Rotary Solenoid
- Duty-Control Air Control Valve (ACV)
- On/Off Vacuum Switching Valve (VSV)

Step-Motor Type IACV

The step-motor IACV has 125 possible ”steps” to vary the amount of air bypassed around the closed throttle



Step-Motor IAC System

This system uses a step-motor type IACV to control bypass airflow. The IACV consists of a step-motor with four coils, magnetic rotor, valve and seat, and can vary bypass airflow by positioning it’s valve into one of 125 possible ”steps”. Basically, the higher the IACV step number, the larger the airflow opening and the greater the volume of air bypassed around the closed throttle.

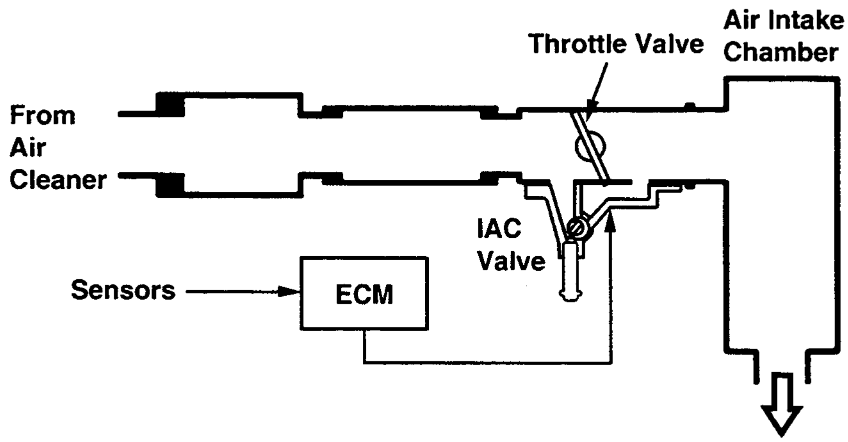
The ECM controls IACV positioning by sequentially energizing its four motor coils. For each coil that is pulsed, the LACVs magnetic rotor moves one step, which in turn changes the valve and seat positioning slightly. The ECM commands larger IACV position changes by repeating the sequential pulses to each of the four coils, until the desired position is reached. If the IACV is disconnected or inoperative, it will remain fixed at it’s last position.

Duty-Control Rotary Solenoid IAC System

This system uses a rotary solenoid IACV to perform idle speed stabilization. Bypass air control is accomplished by means of a movable rotary valve which blocks or exposes a bypass port based on command signals from the ECM. The IACV consists of two electrical coils, permanent magnet, valve, bypass port, and bi-metallic coil.

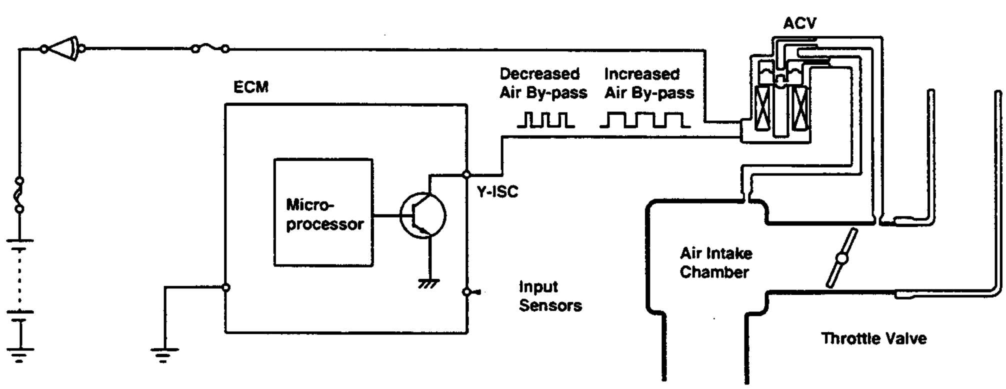
Rotary Solenoid IACV

The ECM controls this type of IACV by applying a duty cycled signal to the electrical coils inside the IACV.



The ECM controls IACV positioning by applying a duty cycled signal to the two electrical coils in the IACV. By changing the duty ratio (on time versus off time), a change in magnetic field causes the valve to rotate. Basically, as duty ratio exceeds 50%, the valve opens the bypass passage and as duty ratio drops below 50%, the valve closes the passage. If the IACV is disconnect or inoperative, the valve will move to a default position and idle rpm will be around 1000 to 1200 rpm at operating temperature.

Duty-Control ACV



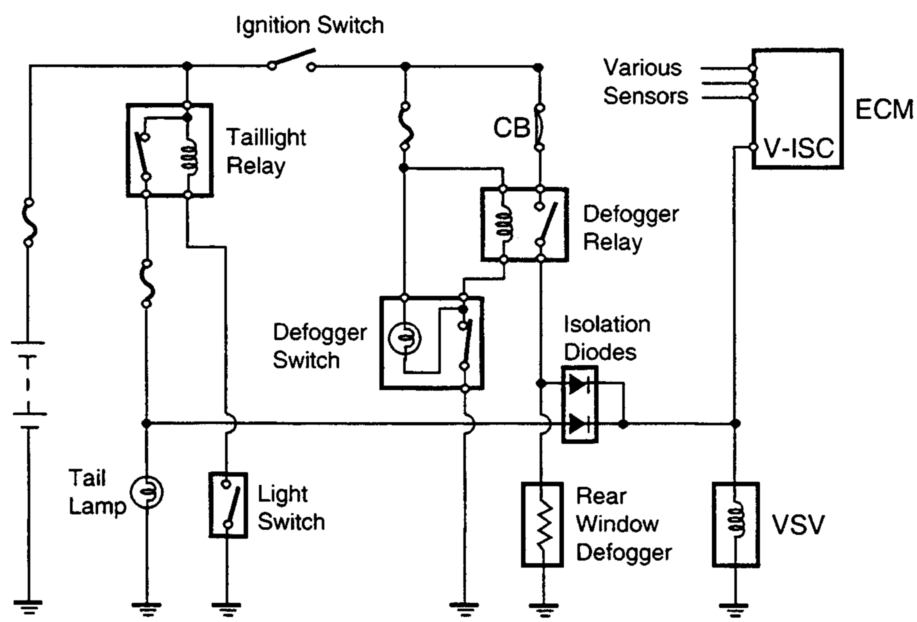
Duty-Control ACV System

This system regulates air bypass volume by using an ECM duty-cycle controlled Air Control Valve (ACV). The ACV uses an electric solenoid to control a normally closed air valve which blocks passage of air from the air cleaner to the intake manifold. Since the ACV is incapable of flowing high air volume, a separate mechanical air valve is used to perform cold fast-idle on vehicles equipped with this system.

With this type system, the ECM varies bypass airflow by changing the duty ratio of the command signal to the ACV. By increasing the duty ratio, the ECM holds the air bypass open longer, causing an increase to idle speed. The ACV does not have any effect on cold fast idle or warm-up fast idle speed, and is only used during starting and warm curb-idle.

On/Off VSV Type IAC System

This VSV used in this type IAC system can be activated by either the ECM, tail lamp or rear window defogger circuit.



On/Off VSV Type IAC System

This type of IAC system uses a normally closed Vacuum Switching Valve (VSV) to control a fixed air bleed into the intake manifold. This on/off type VSV is controlled by signals from the ECM or directly through the tail lamp or rear window defogger circuits.

The ECM controls the VSV by supplying current to the solenoid coil when preprogrammed conditions are met. Also, current can be supplied to the solenoid from the tail lamp or rear window defogger circuits by passing through isolation diodes. Engines using this IAC system must also use a mechanical air valve for cold fast-idle.

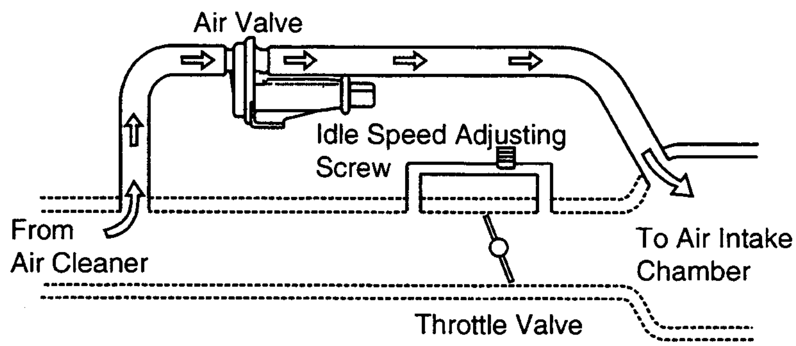
IAC System Control Parameters

Depending on system type and application, the IAC system may perform a combination of the following control functions; initial set-up, engine startup, warm-up control, feedback idle control, engine speed estimate control, electric load idle-up, learned idle speed control, and A/T idle-up control. Refer to course 850 handbook for specific details concerning the operating parameters for each of the IAC systems.

Air Valves

There are two types of non-ECM controlled air valves that are used on some engines to perform cold fast-idle control. The first type simply uses a thermo-wax element to vary the amount of bypass air based on the coolant temperature. Once the engine reaches operating temperature, the air valve should be fully closed.

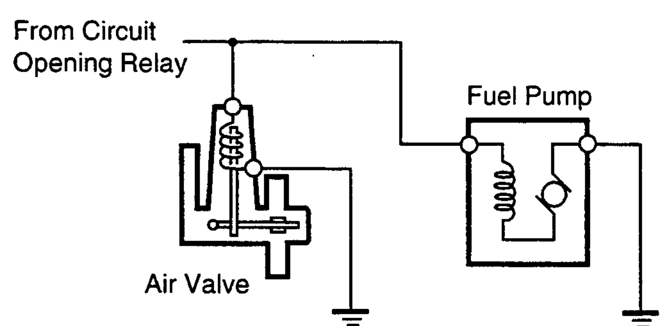
Bi-Metal Air Valve



The second type uses a spring loaded gate balanced against a bi-metal element. As engine temperature rises, the bi-metal element deflects to close the gate valve, thereby reducing the amount of bypass air. A heater coil surrounds the bi-metal element and is used to heat the element whenever the engine is running (fuel pump operates). An air valve quick check can be performed by pinching off the supply hose and observing rpm drop. The drop should be less than 50 rpm when the engine is warm, and should be significantly higher when the engine is cold.

Air Valve Construction

This type of air valve uses a bi-metal strip to control a gate valve. A heater coil is used to heat the strip whenever the engine is running.



Effects of IAC Operation on Emissions & Driveability

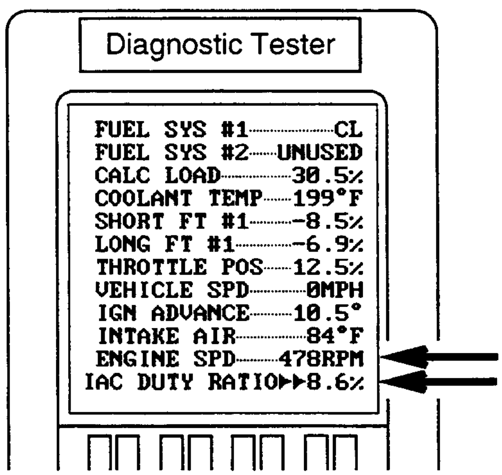
Improper operation of the IAC system can have significant impact on idle quality and driveability. If idle speed is too low, the engine may stall or idle very rough. If idle speed is too high, harsh A/T gear engagement may result.

On some IAC systems, the IACV step count or ECM duty ratio may provide hints as to whether a major correction is being made to offset a idle speed problem. For instance, if false air entry causes idle speed to be much higher than normal, the LAC system may correct for this condition by decreasing bypass air volume in an effort to bring idle speed back to the ”target” idle speed.

The IACV step count or duty ratio may also identify a restricted air passage, mis-adjusted throttle, or IAC valve problem. Observe IAC signal data at idle, while applying various ”loads” to the engine. Look for a corresponding change to IACV step count or duty ratio, as loads are placed on the engine. Also, a signal comparison to other known good vehicles may be helpful.

IAC Check Using Active Test

Some late model OBD-II vehicles are equipped with an active test feature that allows you to commmand changes to IACV positioning.



IAC System Functional Tests

Because functional checks vary between the four major types of IAC systems, refer to the Repair Manual for specific procedures on performing an on-vehicle IAC inspection. On some late model OBD-II vehicles, an active test feature will allow you to manually command IACV positioning from fully open to fully closed. A quick check can be made by commanding a change to IACV positioning while watching for expected changes to idle rpm.

Notes

WORKSHEET 3 (ON-CAR)

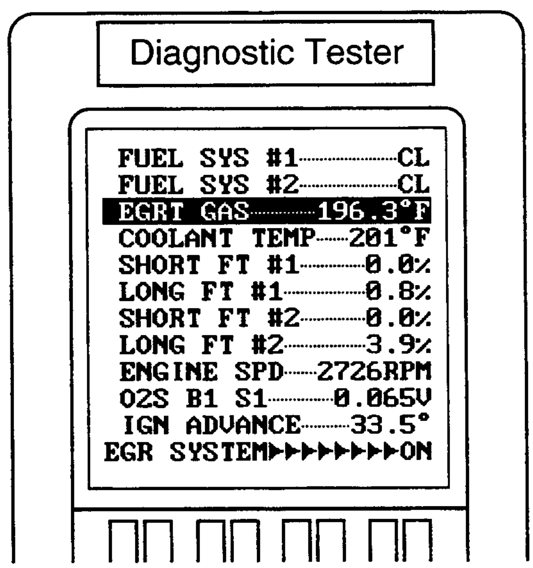
Emission Sub-System Functional Tests

Vehicle	Year/Prod. Date	Engine	Transmission

In this worksheet, you will perform various functional tests (and quick checks) to confirm the integrity and operation of major engine and emission sub-systems. Proper sub-system operation is key to catalyst efficiency, good vehicle driveability, and low emission output levels. Carefully perform the following procedures and record your results when prompted.

Worksheet Key Points:

- For some procedures, the Diagnostic Tester will be used to access data parameters that are useful in functional checks. Make sure the OBD/OBD-II program card is properly installed and the correct data link cables are used for the vehicle application.
- Since sub-system functional checks vary between models, always refer to the Repair Manuals for specific procedures on testing sub-system (and component) operation.



EGR System Active Test (OBD-II Only)

1. Start the engine and allow it to reach operating temperature.
2. Access **Active Test** menu on the Diagnostic Tester.
3. Select **EGR Test** from the Active Test menu.
4. With engine speed at 3000 rpm, record the current engine speed and EGRT Gas temperature below.

Condition:	Engine Speed	EGRT Gas
EGR Off		

5. Next, with engine speed at 3000 rpm, activate the EGR VSV (turn EGR On)

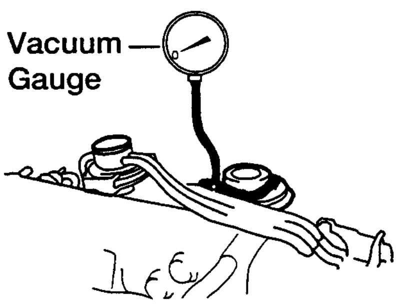
6. Wait for approximately 30 seconds, then record the new engine speed and EGRT gas temperature below.

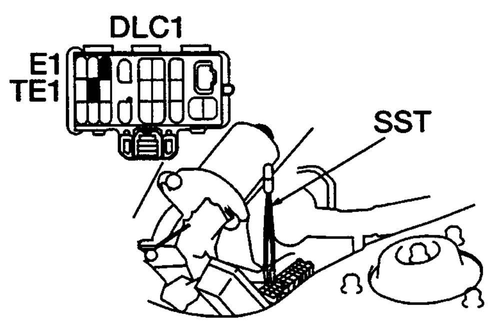
Condition:	Engine Speed	EGRT Gas
EGR Off		

7. Why did the readings change between step 4 and step 6?

8. If the readings did not change at all, what could the problem be?

9. If the rpm drop and temperature rise was very slight, what are some likely causes?





EGR System Functional Check

1. Locate the ***EGR System Inspection*** procedure in the Emission Control System section of the appropriate Repair Manual.

2. Using these procedures, perform the EGR System Inspection (do not perform component inspections).

3. When you reach the operational check of the EGR modulator (engine hot), answer the following questions.

4. At what rpm does the Repair Manual have you check for ”low vacuum” to the EGR signal line? Also, perform the check and record the actual vacuum reading below.

”Low Vacuum” RPM	EGR Vacuum Signal

5. If you obtained 0 inches of vacuum in step 4, what could this indicate?

6. Next, at what rpm does the Repair Manual have you check for "high vacuum" to the EGR signal line? Also, perform the check and record the actual vacuum reading below.

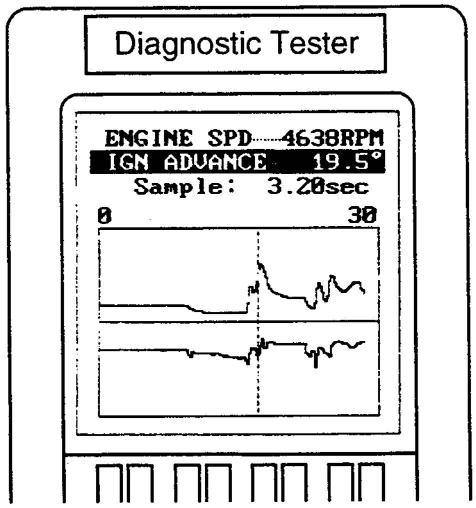
"High Vacuum" RPM	EGR Vacuum Signal

7. What immediately happened to engine operation when you made this "high vacuum" check? What do you think caused this to occur?

8. Is this an appropriate amount of EGR flow for the given operating condition? Explain.

9. At this point, exactly which EGR components have been checked and verified?

10. Remove the vacuum gauge and reattach all hoses back to their original locations.



Spark Advance System Check

1. Connect the Diagnostic Tester to DLC 3.

2. Start the engine and allow it to reach operating temperature.

3. Access ***Ignition*** **or** ***Ign Advance*** data on the Diagnostic Tester data list. While idling, record the ignition advance reading in the space below.

Condition:	Ign. Advance:
Normal Idle	

4. Next, connect terminals TE1 to E1 at DLC 1. Record the new ignition advance reading below.

Condition:	Ign. Advance:
TE1 to E1	

5. Did ignition advance increase or decrease? What is the purpose of this?

6. Remove the test wire between TE1 and E1. Once again, record ignition timing reading below.

Condition:	Ign. Advance:
Normal Idle	

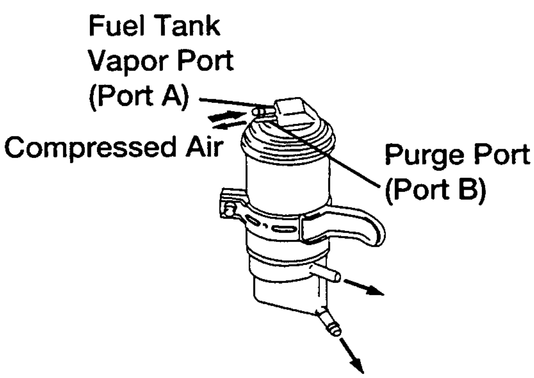
7. Did ignition advance increase or decrease? What is the significance of this?

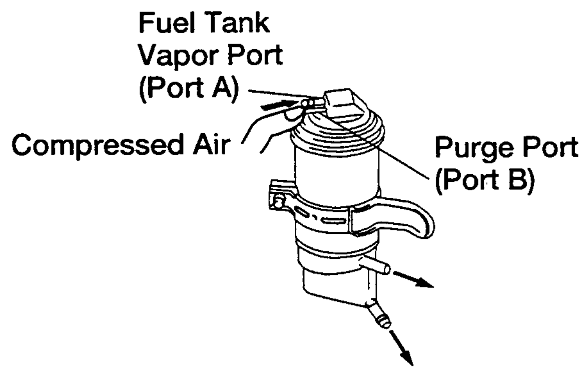
8. Next, using the Diagnostic Tester manual snap shot function, create a line graph of ***Engine*** Spdand ***Ignition*** or ***Ign Advance*** at the following engine conditions. After completing the snap shot, scroll the cursor through the graph's lines and record ignition advance at the conditions listed below:

Condition:	Ign. Advance:
Normal Idle	
2500 rpm	
Acceleration	
Deceleration	

9. Does the spark advance curve reflect the changes you made to engine speed? What important correction factor is not represented in this spark curve?

10. What is the advantage of performing step 8 while driving the vehicle?





Evaporative System Functional Check

1. Locate the ***EVAP System Inspection*** procedure in the appropriate Repair Manual.

2. Using these procedures, perform the EVAP visual and canister inspection (do not perform other component inspections).

3. When you reach the canister inspection procedure, answer the following questions.

4. According to the Repair Manual, what exact level of air pressure must be maintained when blowing air into selected ports of the evaporative canister?

Canister Air Pressure

5. Perform the air checks exactly as outlined in the Repair Manual. *Note: Airflow from the canister ports is difficult to detect, listen for hints of airflow!*

6. Specifically, what do the air checks test for?

____

____

7. At this point in the inspection, what components have been checked?

____

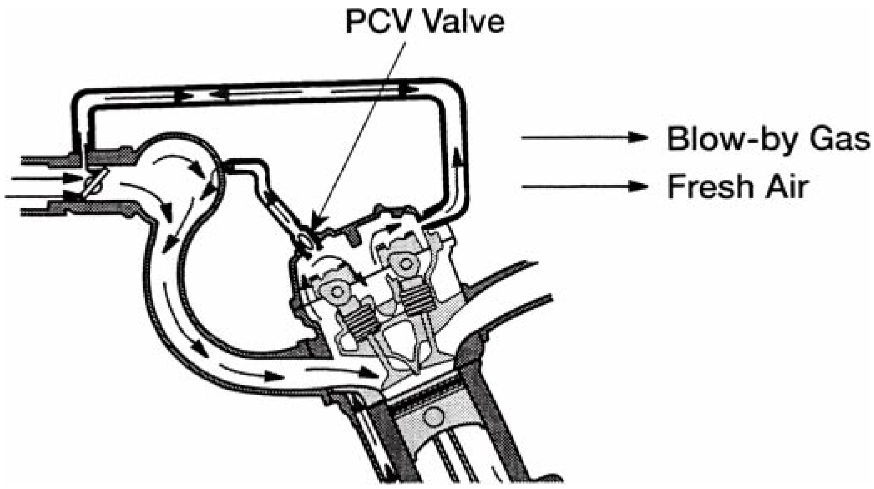
____

8. What suggestions do you have for an EVAP TVV ”quick check”?

____

____

9. Reattach all EVAP system hoses.



PCV System Quick Check

1. Connect terminals TE1 to E1 at DLC 1.
2. Start the engine and make sure it reaches operating temperature.
3. Allow the engine to stabilize and record the idle rpm below.

Normal Idle rpm

4. Pinch the hose between the PCV valve and manifold vacuum source.
5. Record the new idle rpm below.

Idle rpm (PCV hose pinched)

6. Did idle rpm increase or decrease? Is this normal? Explain.

7. If idle rpm did not change in step 5, what do you think has happened?

8. What would traces of oil in the intake air system possibly indicate?

Notes

WORKSHEET 4 (ON-CAR)

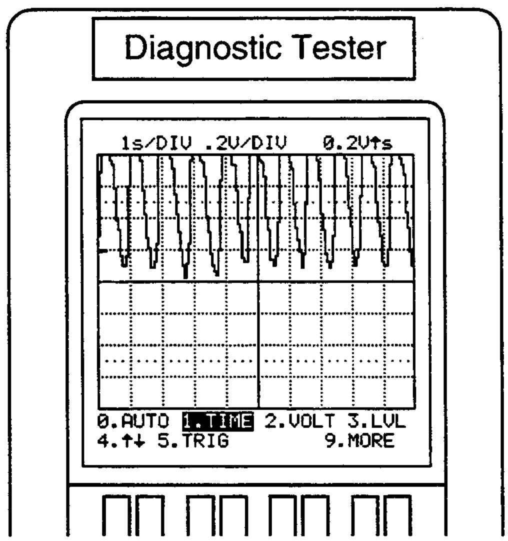
Closed-Loop Control Testing

Vehicle	Year/Prod. Date	Engine	Transmission

Closed Loop Control Testing (Using Test Instruments)

Closed loop fuel control effectively satisfies the three-way catalyst's requirement for ample supplies of both carbon monoxide and oxygen. If the closed loop system is not working properly, the impact on catalytic converter efficiency, and ultimately emissions, can be significant.

The following worksheet will allow you to practice several methods of testing the closed loop control system to quickly and accurately confirm that the fuel delivery, air induction, and closed loop control systems are functioning normally.



Test Procedure (Part 1, Multimeter):

Maximum, Minimum, Average Sensor Voltage, and Signal Frequency

1. Using a suitable jumper lead, connect the multimeter to the OX1 or OX2 terminal of DLC1.
2. If the vehicle is not equipped with an OX terminal in DLC1, use the EWD to identify the OX terminals of the oxygen sensor connector. Use a suitable tool to backprobe the oxygen sensor signal wire.
3. Next, select DC volts and then press the MIN/MAX button to put the meter in Record mode.
4. With the engine cold, start the engine and raise speed to 2500 rpm. After 10 seconds, record the following O2S signal voltages (Hint: Press MIN/MAX button to toggle between Max, Min, Avg).

Mode:	Reading:
Max.	
Min.	
Avg.	

5. Reset the MIN/MAX values on the meter (hold the MIN/MAX button for 2 sees, and then press the button one additional time).

6. Maintain engine speed at **2500 rpm.** Be sure the engine and oxygen sensor are fully warmed up by running the engine at **2500 rpm** for at least two minutes. Again, record sensor signal voltages:

Mode:	**Reading:**
Max.	
Min.	
Avg.	

7. Compare your readings from steps 4 and 6. Do they differ significantly? If so, why?

---

8. Return the multimeter to normal DC volts. Using the bar graph display, observe the switching activity of the sensor.

9. With the engine running at **2500 rpm,** measure the sensor signal switching frequency by counting the bar graph switching activity in a ten second period. Note and record the number of cycles in 10 seconds and then calculate the frequency (Hz) by dividing the total number of cycles by the total number of seconds.

Cycles in 10 secs.	**Hz**

10. Select AC volts and set up the meter to display frequency using the following procedure:

- Press the Hz button and then manually range meter to 4 VAC by pressing the range button

11. Return engine speed to **2500 rpm.** Note and record the displayed frequency.

Hz

12. Does this frequency agree with that which you recorded in the step 9?

---

13. Return the engine to **idle.** Change back to DC Volts. Note and record the sensor signal voltage below.

Mode:	**Reading:**
Max.	
Min.	
Avg.	
Hz	

14. Compare the data from your 2500 rpm readings (steps 6 and 9) with the readings at idle (step 13).

15. What is the difference between the O2S signal characteristic at 2500 rpm compared to idle speed?

16. How do you explain the difference in signal characteristics from idle to **2500 rpm?**

17. Based on the data you have gathered, is the closed loop control sub-system functioning normally?

Procedure (Part 2: Oscilloscope):

Analyzing the Closed Loop Control System With an Oscilloscope

1. Access the Autoprobe feature on your Diagnostic Tester. Note: make sure that the Diagnostic Tester has a good power supply and ground for this test.
   - Calibrate the Autoprobe by selecting ”calibrate” from the Autoprobe Menu. Follow screen prompts.
   - Choose ”oscilloscope” from the Autoprobe Menu.
   - Press F1 and then set time to **1 s/div.**
   - Press F2 and then set volts to **.2 v/div.**
   - Press F5 and then set trigger to automatic.
3. Using the same test point as used in Part 1 of this worksheet, connect the Autoprobe to the main O2S.
4. Make sure the engine and oxygen sensor are fully warmed up. Raise engine speed to **2500 rpm** and maintain speed. Observe the scope trace and answer the following questions:
5. What is the approximate minimum signal voltage on the lean switch? and for the rich switch?
6. What is the approximate average signal voltage between the rich and lean switch?
7. Change the scope trigger to single shot (”s”) by toggling F5 button. What does this do to your signal trace?
8. Next, press the ENTER key and describe what happens.

9. Press the Autoprobe button and describe what happens.

____

____

10. Print the signal trace and paste it in the space below:

Paste Screen Print Here

11. What is the approximate frequency that this sensor is switching at?

Hz

12. Does this meet the minimum frequency requirement specified in the Repair Manual and course book?

____

13. Change the time setting to **.2 s/div.**

14. With the engine still running at **2500 rpm,** use the single shot trigger to snapshot the oxygen sensor signal.

15. Measure rich to lean (R-L) switch time using the following procedure:

- Select the cursor menu by pressing the F9 button and then turn cursors on by pressing F4 burton twice.
- Next, move cursor A to any point where the R-L switch (downward slope) crosses 700 mv.
- Select cursor B only (press F6 button).
- Move cursor B to the point where the R-L switch (downward slope) crosses 200 mv using the grid lines as a voltage reference.
- Read the R-L switch time in milliseconds in the display at lower right hand corner of display.

16. Note and record the R-L switch time.

R-L Switch Time

17. Print the oscilloscope pattern and paste it in the space below:

Paste Screen Print Here

18. Based on data acquired with the oscilloscope, is the Closed Loop Control system functioning normally?

Effect of Engine Misfire on Oxygen Sensor Signal

1. Set up the oscilloscope to monitor the oxygen sensor signal using the following settings:

- Set time to **.5 s/div.,** set volts to **.2 v/div.,** set trigger to **single shot** ("s").

2. Run the engine at a steady **2500 rpm.** Disconnect an injector electrical connector and observe the oxygen sensor signal.

3. Use the single shot trigger to store this pattern, then print the pattern and paste it in the space below.

Paste Screen Print Here

4. How did this pattern differ from the one taken on a normally running engine? Explain.

____

____

5. Reconnect the injector connector.

6. Next, disconnect a secondary ignition wire (from bank 1) and ground it. What happened to the signal pattern? Explain.

____

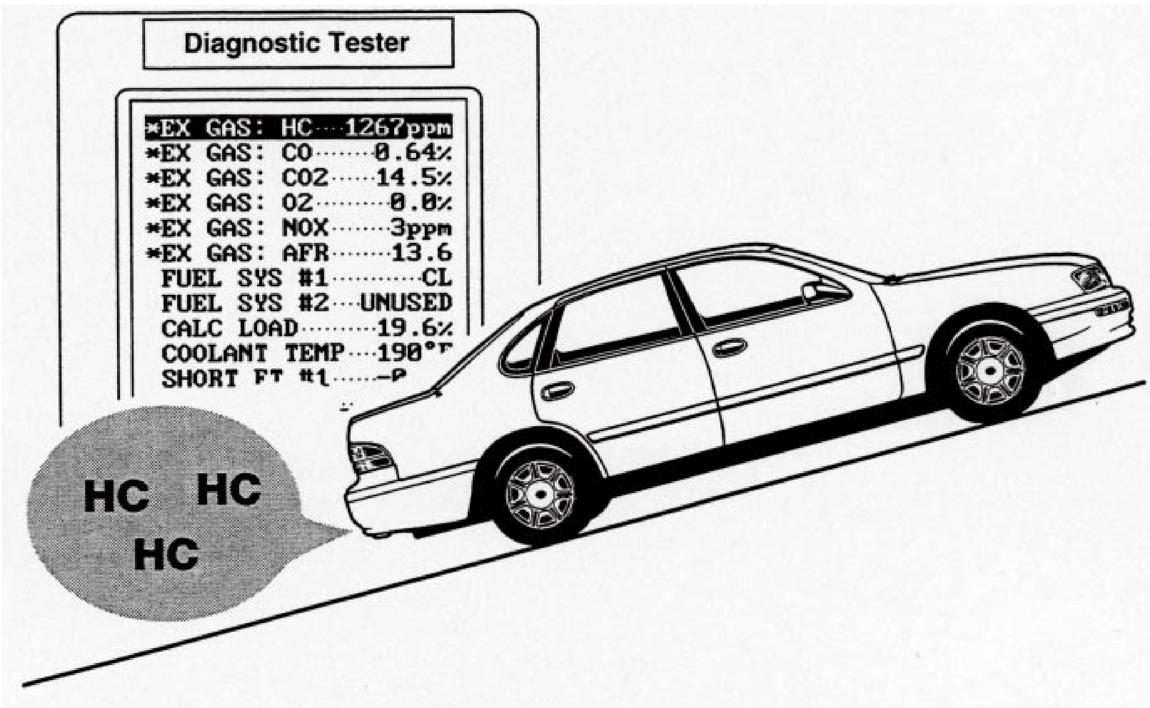
____

7. Reconnect the secondary ignition wire.

Return the vehicle to normal condition. Clear any stored diagnostic trouble codes.

Section 5

TROUBLESHOOTING

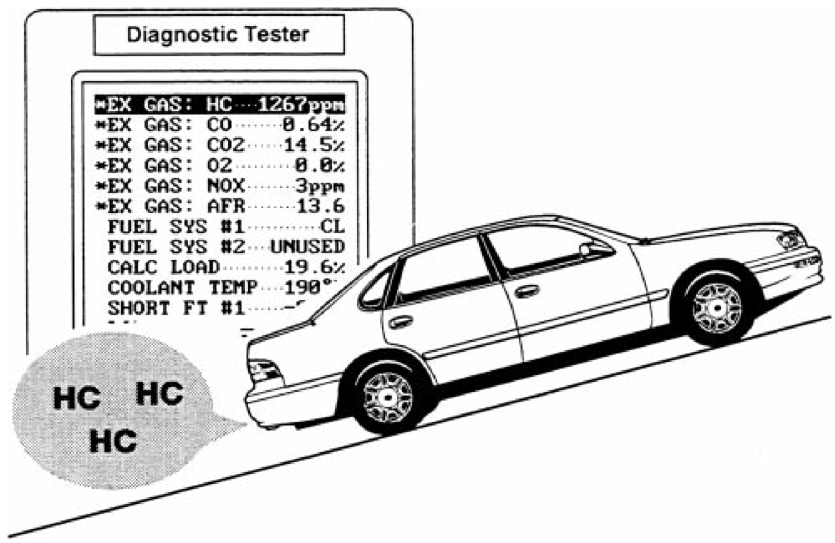


Lesson Objectives

1. Identify the key steps of a logical, systematic approach to emission & driveability diagnosis
2. Demonstrate the ability to perform a detailed basic inspection of engine mechanical & electrical systems, air induction system, fuel delivery system, and spark advance system.
3. Explain how air/fuel mixture imbalances can result in driveability symptom such as; hesitation, stumble, flat spot, surge, etc.
4. Define knocking, backfire, and afterfire and describe how the causes of these driveability symptoms differ from one another.
5. Understand the theory behind comparative analysis and its usefulness in monitoring the effectiveness of your repairs.
6. Identify the various driving modes of a ”baseline” drive cycle.

Notes

Emission and Driveability Diagnosis



Emission and Driveability Diagnosis

When troubleshooting any emission or driveability related concern, it only makes sense that you follow a logical, systematic approach to quickly identify and accurately resolve concerns you are investigating. A complete systematic process should include a general troubleshooting sequence, followed by individual sub-system quick checks, technical references, and suggested applications for diagnostic tool and equipment usage.

Following a logical diagnostic flow helps you ”zero” in on the most likely cause of a customer’s concern in the shortest time possible. It also increases your effectiveness in locating and permanently fixing the cause of the concern, the first time out.

General Diagnostic Approach

Simply put, the approach we will use for emission and driveability diagnosis includes the following keys steps:

- Verify and accurately define the customer’s concern
- Evaluate service information related to the suspected system
- Determine what tests to perform and use the appropriate test instrument to gather data.
- Perform the recommended tests using a multimeter, scan tool, oscilloscope, or some combination of these test instruments
- Analyze the collected test data and results
- Make a diagnostic decision based on driveability symptoms, test data and results
- Prioritize the diagnosis of suspected sub-systems
- Perform necessary adjustments and/or repairs
- Verify the repair

Combining Emission & Driveability Diagnosis

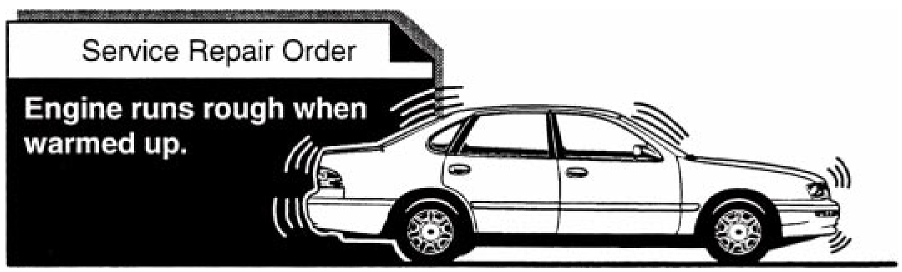
When troubleshooting any customer concern, it's always important to use every bit of diagnostic information available. This is especially true for emission and driveability diagnosis. Many times the cause of an emission failure will also cause an accompanying driveability symptom (and vice versa). By combining your driveability symptom diagnosis *along with* a thorough analysis of tailpipe emissions, you will greatly increase your troubleshooting accuracy by essentially doubling your diagnostic input. This approach will be discussed in detail later.

Routine Quick Checks

In any diagnostic process, routine quick checks should be made to eliminate basic causes of a customer's concern. These preliminary checks should start with a confirmation of the customer's concern, a check of the battery's cranking and engine running voltage, and if necessary, routine visual, mechanical, and electrical connection checks. Additional basic inspection items should be checked prior to troubleshooting by symptoms.

Verify Customer Concern

Always verify the customer's concern prior to attempting repairs. This will give you a better idea of the exact nature of the customer's concern



Customer Analysis Check Sheet

Before diving "head-first" into diagnosis, it's important to know everything about the concern you are attempting to resolve. Always gather and analyze as much information as the customer can supply. Also, have the ASM fill out a Customer Problem Analysis Check Sheet (see opposite page). This check sheet will help you obtain detailed information from the customer concerning the exact symptoms they've experienced, when they occur, how frequently they occur, as well as other details that may provide diagnostic "clues" as to the cause of the concern. With this information, you will be better informed in making an accurate diagnosis based on all exhibited driveability symptoms. If necessary, take a test drive with the customer to ensure that the concern is not a customer perception issue or the result of unrealistic customer driving habits.

Diagnostic Circuit Inspection

If the vehicle supports a serial data stream, use the Diagnostic Tester to perform a diagnostic circuit inspection. This inspection confirms:

- Operation of the vehicle's On-Board Diagnostic (OBD) system
- Communication between the Diagnostic Tester and OBD system
- If Diagnostic Trouble Codes (DTC) are stored in ECM memory

Customer Analysis Check Sheet

Document the time, and operating conditions in which the problem occurs.

Request very detailed information concerning the symptoms experienced by the customer.

CUSTOMER PROBLEM ANALYSIS CHECK SHEET

ENGINE CONTROL System Check Sheet

Inspector's Name ____

Customer's name		**Model and model year**	
Driver's name		**Frame no.**	
Date vehicle brought in		**Engine model**	
License no.		**Odometer reading**	km miles

EG

Problem Symptoms	☐ **Engine does not Start**	☐ Engine does not crank ☐ No initial combustion ☐ No complete combustion
	☐ **Difficult to Start**	☐ Engine cranks slowly ☐ Other ____
	☐ **Poor Idling**	☐ Incorrect first idle ☐ Idling rpm is abnormal [☐ High ☐ Low (rpm)] ☐ Rough idling ☐ Other ____
	☐ **Poor Driveability**	☐ Hesitation ☐ Back fire ☐ Muffler explosion (after-fire) ☐ Surging ☐ Knocking ☐ Other ____
	☐ **Engine Stall**	☐ Soon after starting ☐ After accelerator pedal depressed ☐ After accelerator pedal released ☐ During A/C operation ☐ Shifting from N to D ☐ Other ____
	☐ **Others**	

Dates Problem Occurred		
Problem Frequency		☐ Constant ☐ Sometimes (times per day/month) ☐ Once only ☐ Other ____
Conditions When Problem Occurs	**Weather**	☐ Fine ☐ Cloudy ☐ Rainy ☐ Snowy ☐ Various/Other ____
	Outdoor Temperature	☐ Hot ☐ Warm ☐ Cool ☐ Cold (approx. ___ °F/ ___ °C)
	Place	☐ Highway ☐ Suburbs ☐ Inner City ☐ Uphill ☐ Downhill ☐ Rough road ☐ Other ____
	Engine Temp.	☐ Cold ☐ Warming up ☐ After warming up ☐ Any temp. ☐ Other ____
	Engine Operation	☐ Starting ☐ Just after starting [min.] ☐ Idling ☐ Racing ☐ Driving ☐ Constant speed ☐ Acceleration ☐ Deceleration ☐ A/C switch ON/OFF ☐ Other ____

Condition of Malfunction Indicator Lamp		☐ Remains on ☐ Sometimes lights up ☐ Does not light up	
Diagnostic Trouble Code Inspection	**Normal Mode (Precheck)**	☐ Normal	☐ Malfunction code(s) [code] ☐ Freezed frame data [ ]
	Check Mode	☐ Normal	☐ Malfunction code(s) [code] ☐ Freezed frame data [ ]

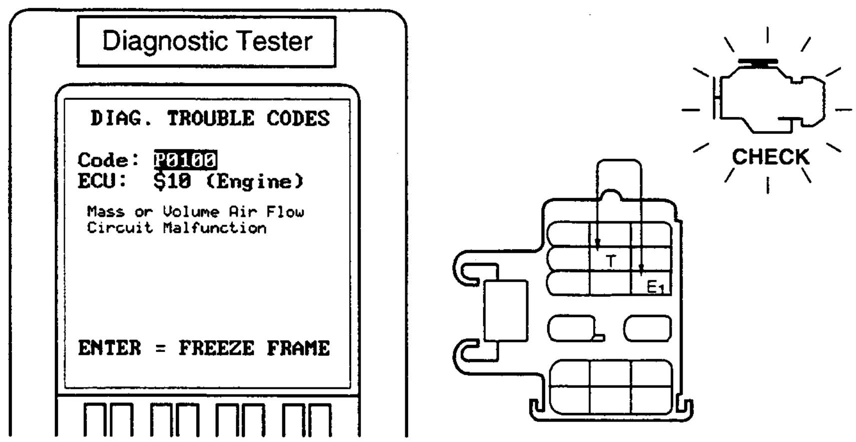
Perform a diagnostic trouble code check and note the code number(s), if any.

Diagnostic Trouble Code (DTC) Check

Due to the ease of access, especially on OBD/OBD-II vehicles using the Diagnostic Tester, a quick check for stored Diagnostic Trouble Codes (DTC) should be made after routine visual checks. If the vehicle is not equipped with an On-Board Diagnostic (OBD) system which supports serial data, a manual check for DTCs must be made. Refer to course 850 for details on how to perform this.

DTC Check

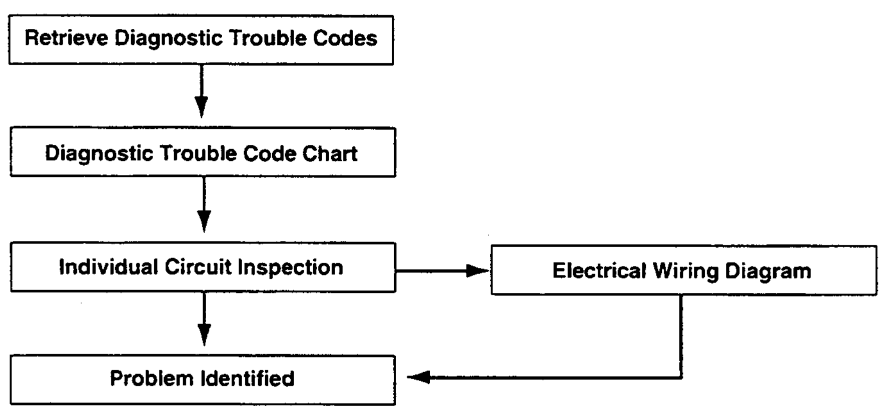
If a code is stored, follow the circuit inspection procedure as outlined in the Repair Manual. On OBD vehicles without serial data, a manual check is performed to



If DTCs are recorded by the ECM, troubleshooting should be relatively straightforward. Proceed by using the appropriate circuit inspection procedure as outlined in the Repair Manual. In addition to the DTC interpretation and respective circuit inspection procedures, the Repair Manual also provides procedures on diagnosing problems related to the operation of the OBD system. These procedures include; no communication between Diagnostic Tester and OBD system, no check engine light procedure, etc.

Troubleshooting Stored DTC's

Use the following logic when diagnosing stored DTC's. These procedures can be found in the engine trouble-shooting section of the Repair Manual.



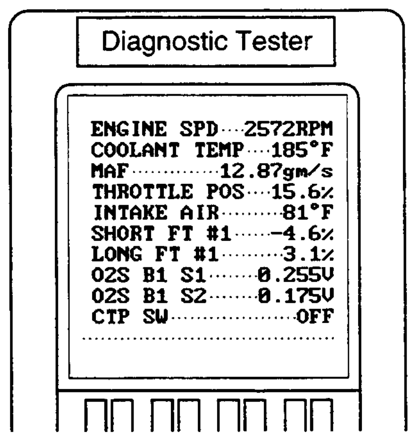
Serial Data Quick Check

Invariably, when the engine isn't running properly, there will be telltale clues in the sensor and actuator values. On vehicles equipped with serial data, most of these items can easily be checked using the Diagnostic Tester. Ask yourself the following questions:

- **Are all sensor input values in the normal range?** Of particular importance are the 6 most critical sensor signals that impact fuel delivery and spark control. They are; *engine speed, coolant temperature, load, throttle position (includes CTP (IDL) switch), intake air temperature, and oxygen sensor signal(s).* Any discrepancies here would cause the ECM to inaccurately control the closed loop control system and spark advance system.

Critical Sensor Inputs

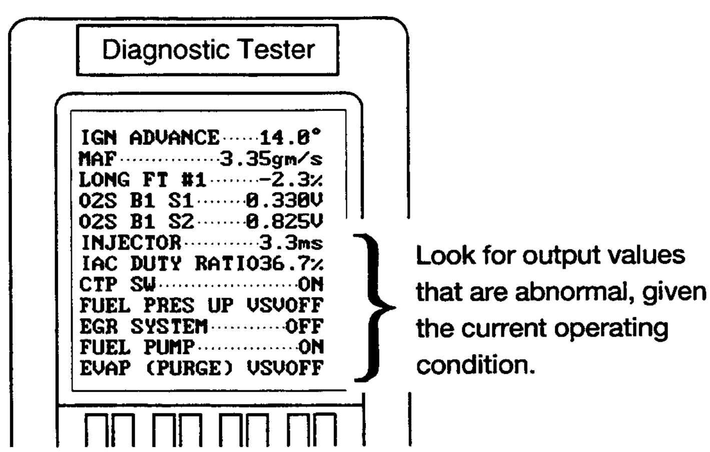
Make a quick check of the most critical sensor signals, while concentrating on the signals that could cause the condition experienced.



- **Are all of the output values in the normal range?** Some of the more important outputs include; injection duration, spark advance, idle air control, as well as available sub-system VSVs. Compare these readings with Repair Manual specifications or those obtained from good known vehicles. Remember, the ECM assumes that input signals are correct when controlling output devices; thus, problems with sensor signals can also show up as output control problems.

Output Values

Check for output values that are outside of the normal range. A comparison to values obtained from a know good vehicle under the same operating conditions may be helpful.



- **Is feedback system maintaining normal closed loop control?** Or is it responding to an abnormal condition or operating in ”open loop”? As previously mentioned, check for closed loop operating status, accurate O2S signal, and confirm that the ECM is not making any major corrections for air/fuel imbalances (adaptive strategy). See Closed Loop Control diagnosis in the previous section for details on how to perform these checks.

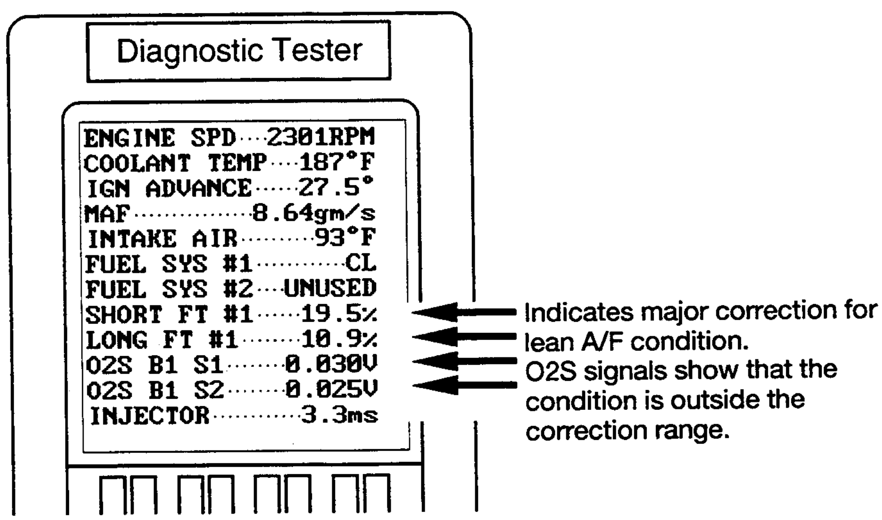
Examples of Abnormal Closed Loop Control Conditions

If an abnormal condition is detected in Closed Loop Control, functional checks of engine or emission sub-system may be required to help identify the specific cause of the condition. The following are examples of conditions that require further investigation:

1. *The O2S signal switches but voltage never goes below 400 mv.* This usually means the O2S is rich biased or, a less likely cause is that a rich air/fuel condition exists that is beyond the correction ability of the Closed Loop Control system.
2. *The O2S signal is locked rich but responds to an air leak. Also, the injection duration is abnormally long.* This could mean that the ECM is not responding to the O2S and is operating in an open loop strategy (cold engine, WOT, etc.)
3. *The O2S signal is lean most of the time and a surge and stumble is felt when the vehicle is operated, especially when cold. Also, fuel trim is abnormally high.* This excessively lean air/fuel mixture condition could result from a number of different causes including; restricted fuel filter, leaky fuel pressure regulator, intake valve deposits, etc.

Example #3:

As shown, the excessively lean A/F condition is outside the correction abilities of the Closed Loop Control system.



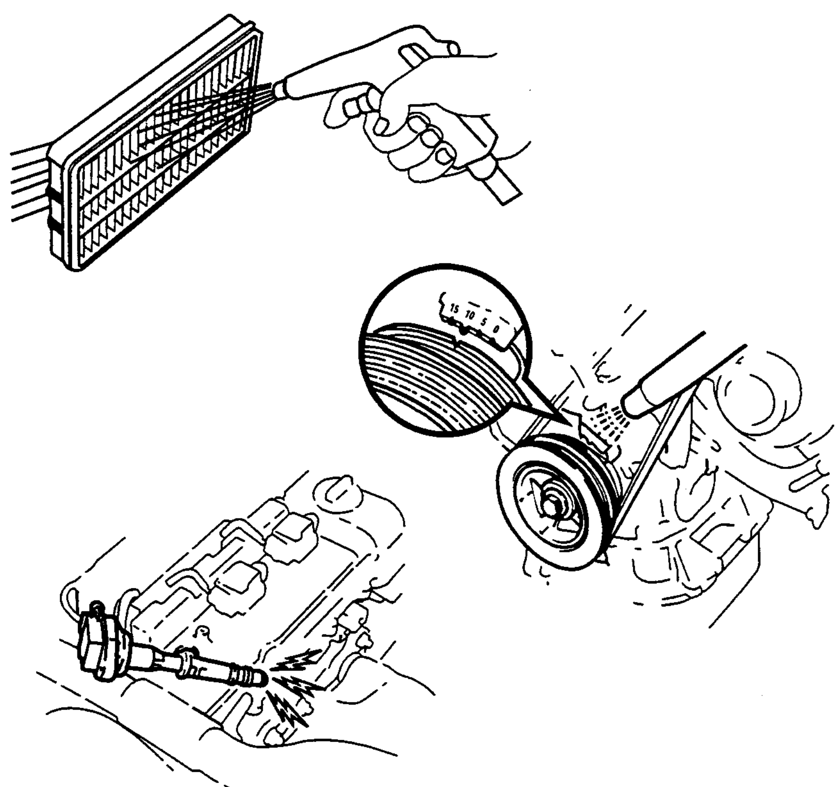
Basic Inspections

Before using the troubleshooting matrix in the Repair Manual, a detailed basic inspection should be performed to identify fundamental engine or mechanical problems that may be the cause of the concern. Depending on the driveability symptom experienced, one or several of the following checks should be conducted under the hood to help you isolate the cause:

- Confirm adequate cranking and engine running battery voltage
- Inspect/clean the air filter for excessive dirt or contamination
- Check/adjust idle speed
- Confirm base timing is properly set to specifications
- Confirm that fuel pressure is within specified range
- Perform inspection of engine's mechanical condition (audible cranking rhythm, visual secondary ignition system check, etc.)
- Perform visual inspection of accessible electrical connections, vacuum and air induction ducting.
- Locate and inspect the condition of the ECM main grounds.
- Inspect for leakage in the EGR and PCV valves.
- Inspect for unwanted fuel entering the intake manifold from the EVAP system, fuel pressure regulator diaphragm, or Crankcase ventilation system

Basic Inspection Procedure

A quick basic inspection should be performed prior to moving on to more complex engine or emission sub-system checks.



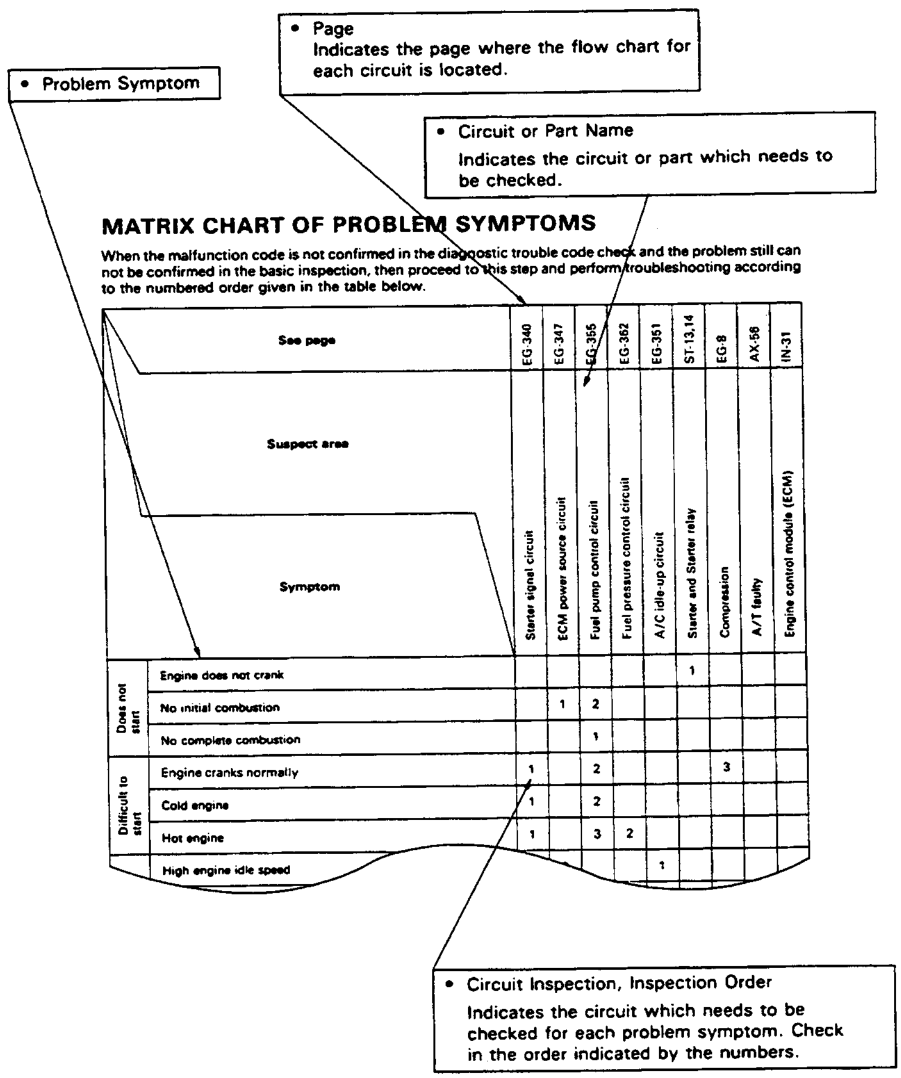
Troubleshooting by Symptom

If the driveability concern or emissions failure is not accompanied by a DTC, an accurate description of the symptom is critical. Troubleshooting by symptom relies on the use of a diagnostic matrix chart to lead you to the most likely cause of the problem. The matrix is organized to take you to the most likely cause and easiest tests to perform first. Getting to the right test first will reduce diagnostic time.

Matrix Chart of Problem Symptoms

The Matrix Chart of Problem Symptoms, in the Repair Manual, can help prioritize and direct your diagnosis towards the most likely system or component, based on the symptom experienced. Once possible systems are identified, the chart will then direct you to the individual circuit inspection flowcharts for each of the suspected systems.

Matrix Chart of Problem Symptoms



Driveability Symptoms

The key to successful driveability troubleshooting is to first accurately identify the symptom the customer is experiencing. Because driveability descriptions and terminology are inconsistently used by customers, and even service technicians, problems arise when determining the exact nature of the concern you are attempting to fix.

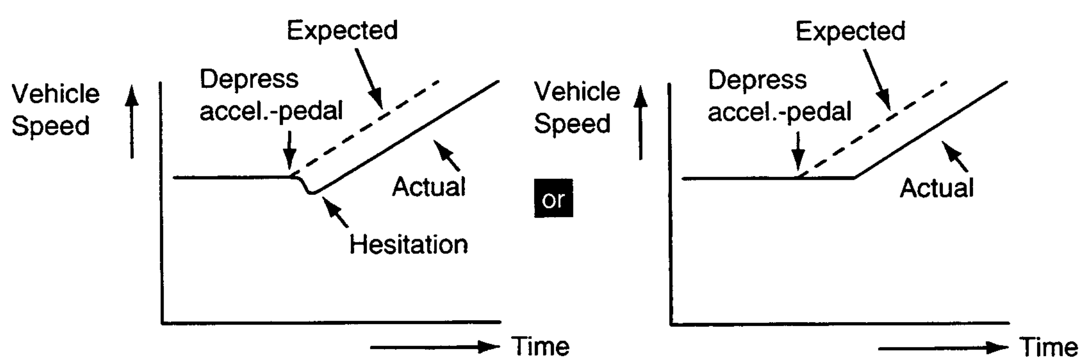
Symptom Terminology

The following descriptions will help you interpret driveability symptoms as described by the customer or as experienced during a test drive. Without this standardization, confusion may result when attempting to interpret customer concerns, which may ultimately result in misdiagnosis and wasted time. For example, when accelerating, a vehicle does not respond proportionately to the amount of throttle opening. Which term most accurately describes the condition; Stumble, Flatspot or Hesitation?

NOTE

As with any quick reference, the following list includes the *most common causes* of a described driveability symptom. Every possible cause is not and could not be included in a general reference, such as this. Use the following descriptions and symptom graphs only as a guide in assisting you in identifying likely causes of common driveability concerns.

"Hesitation" Characteristics

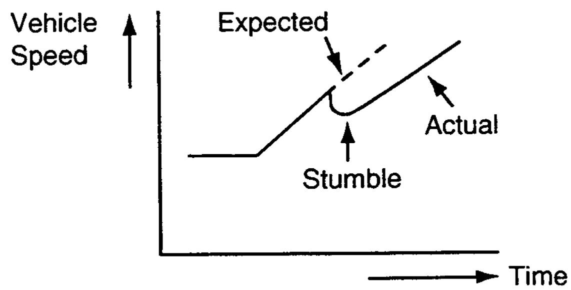


Hesitation

This symptom is defined as a momentary delay in the vehicle's response for approximately 1 second after the accelerator pedal is depressed. Vehicle response resumes after this momentary delay. This condition usually results from a momentary drop or delay in engine torque. Hesitation can be caused by many factors; however, some of the more common causes include:

- Excessively rich or lean air/fuel mixture
- Poor fuel quality
- Improper ignition system operation

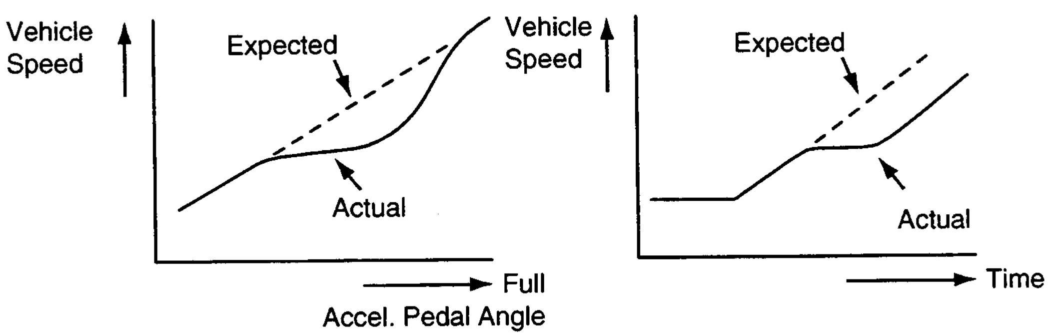
"Stumble" Characteristics



Stumble Stumble is defined as a severe momentary drop in engine power that occurs during acceleration. It differs from hesitation, in that the unexpected power loss occurs sometime during the acceleration "curve", rather than during the initial "tip in" acceleration. Common causes of stumble include:

- Excessively lean air/fuel mixture
- Improper EGR system operation
- Improper ignition system operation

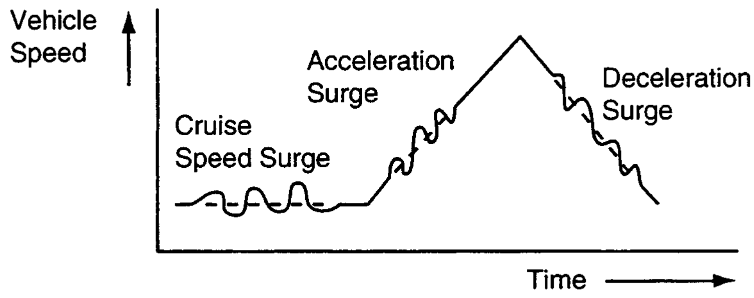
"Flat Spot" Characteristics



This symptom is used to describe acceleration that begins slower than expected and then continues through the acceleration curve at a very slow rate. Like stumble, the power loss occurs during the acceleration curve. The acceleration rate may or may not return to a normal level after a short period of time. Flat spots usually result from a drop in engine torque. It should be noted that the term flat spot is no longer used in Toyota publications and this symptom is now called stumble. Common causes include:

- Excessively lean air/fuel mixture
- Improper EGR system operation

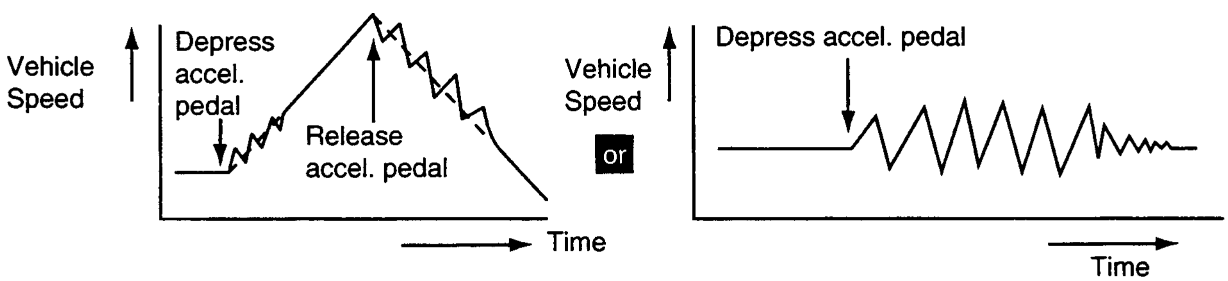
"Surge" Characteristics



Surge Surge refers to a condition where engine or vehicle speed slowly modulates up and down. It can occur at idle, steady cruise, acceleration or deceleration. This symptom is usually the result of a fluctuation in engine torque. Common causes of surging include:

- Rapid changes to air/fuel mixture or excessively lean mixture
- Improper EGR system operation
- Improper ignition system operation

"Bucking" Characteristics

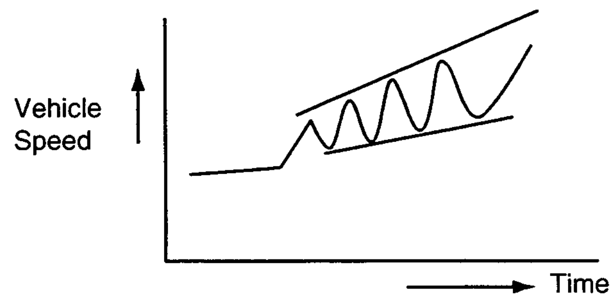


Bucking This term describes a severe, back and forth jerking motion of the vehicle shortly after acceleration or deceleration. The severity of this symptom is much greater than that of a "surge", to the point of which it physically jerks the vehicle back and forth.

If the "bucking" condition is extremely severe, the movement of the vehicle may cause the driver's foot to jerk up and down on the accelerator pedal, thereby, further exaggerating the condition. Common causes of "bucking" include:

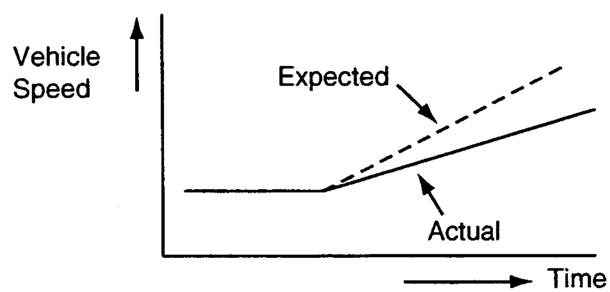
- Fluctuating air/fuel mixture
- Improper ignition/spark advance system operation
- Excessively sensitive accelerator pedal linkage

"Rabbit Hopping" Characteristics



Rabbit Hopping This driveability symptom is very similar to "bucking" condition, however, if the jerking motion is very severe and the problem is exaggerated when the accelerator pedal is depressed, this condition is referred to as "rabbit hopping". The common causes of rabbit hopping are the same as bucking.

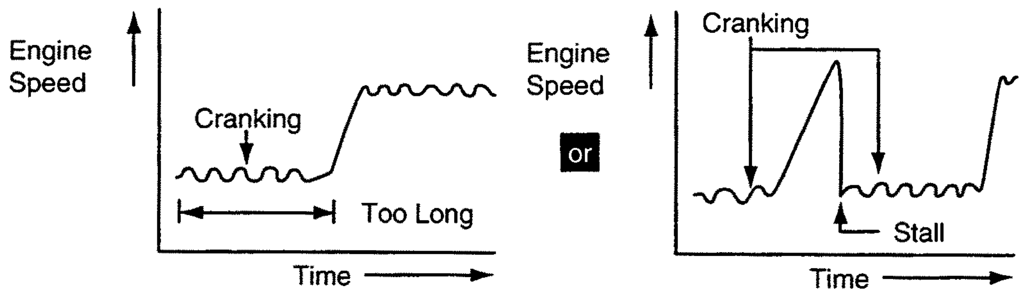
"Poor Acceleration" Characteristics



Poor Acceleration Poor acceleration is a somewhat general term used to describe any acceleration condition that is slower than expected. This symptom can originate from many different causes; however, the majority of causes of poor acceleration result from either mechanical or engine related concerns. Common causes of poor acceleration include:

- Excessively lean or rich air/fuel mixture
- Restricted intake air system
- Incorrect ignition timing advance
- Restricted exhaust system
- Improper torque converter operation
- Dragging brakes
- Stretched throttle linkage

"Hard Starting" Characteristics

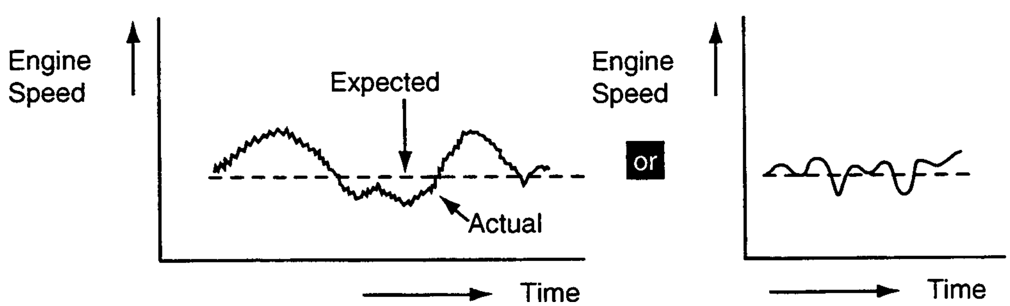


Hard Starting

Hard starting is a term used to describe an engine that requires an excessive amount of time to start (longer than 3 seconds), repeated cranking attempts, or starts but stalls shortly thereafter. Like many of the symptoms described so far, hard starting can also originate from many different possibilities. Some of the more common causes include:

- Excessively lean air/fuel mixture (during cold start-up)
- Low battery voltage (poor starter performance)
- Ignition system problems
- Restricted intake air system
- Excessively high engine oil viscosity
- Excessively rich air/fuel mixture (during warm start-up)

"Rough Idle" Characteristics



Rough Idle

This symptom describes an engine idle characteristic that is unexpectedly harsh or unstable. An excessively rough idle can even cause the engine to stall. As with most of these driveability symptoms, rough idle can originate from many different causes including mechanical engine problems or A/F mixture imbalances.

Common causes of rough idle include:

- Low engine idle speed
- Excessively lean or rich air/fuel mixture
- Improper ignition system operation
- Improper EGR system operation

NOTE

It is important to differentiate between an engine that actually idles rough and an engine that idles acceptably but is not completely isolated in the engine compartment. This may allow engine vibrations to transmit to the vehicle's passenger compartment and be perceived as rough engine idle condition.

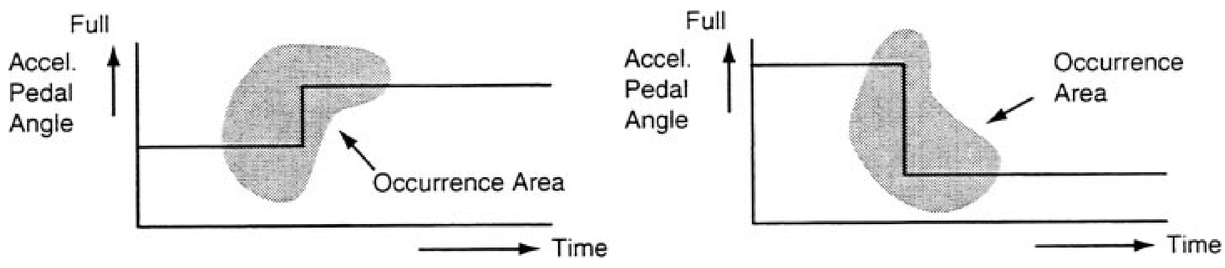
Knocking (Pinging)

Knocking, or pinging, is a term used to describe a sharp metallic noise that is heard from the engine that is caused by spontaneous combustion in the engine's combustion chamber. It is a condition where the air/fuel charge burns spontaneously (explodes) rather than burning smoothly along a flame front from the spark plug to combustion chamber walls.

High combustion heat and fuel quality are the main contributors to a detonation condition. Pressures and temperatures of the air/fuel charge increase excessively as the charge burns. This induces the unburned portion of the charge to ignite spontaneously before the flame front arrives, resulting in the metallic knocking noise. Common causes of engine knocking include:

- Fuel quality
- Over advanced ignition timing
- Improper knock control operation
- Excessively lean air/fuel mixture
- Insufficient EGR flow
- Excessively high intake air temperatures
- Heavy combustion chamber deposits
- Overheated engine

"Backfire" and "Afterfire" Characteristics



Backfire and Afterfire

Backfire is commonly used term that describes a loud, "gun shot" like explosion that results when air/fuel combustion improperly occurs in the intake air system, usually during rapid throttle opening. Similarly, after-fire is a term used to describe improper air/fuel combustion in the exhaust system and it typically occurs during rapid throttle closure. Sometimes afterfires are referred to as an "exhaust backfire". It is important to note that even though the symptoms are similar, the causes of a backfire and afterfire are quite different.

Common causes of backfire include:

- Excessively lean air/fuel mixture
- Advanced ignition timing
- Improper ignition system operation
- Excessive intake valve deposits

Common causes of afterfire (exhaust backfire) include:

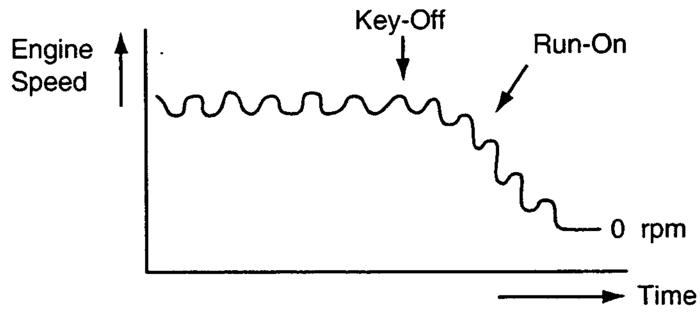
- Excessively rich air/fuel mixture
- Improper ignition system operation
- Combustion chamber misfire

Engine Stall

Engine stall describes a condition where the engine unexpectedly stops while running. Engine stall can occur at any time; however, it is most commonly described as a condition where the engine dies just after startup, completion of fast idle, decelerating to idle, or shifting A/T from P>D range or D>P range. Causes of engine stall are many; but, some of the more common possibilities include:

- Excessively low idle speed adjustment
- Excessively lean or rich air/fuel mixture
- Intermittent ignition system operation
- Improper IAC, idle-up, air bypass operation
- Intermittent ECS system operation

"Run-On" Characteristics



Run-On (Dieseling)

This term is defined as a condition where the engine continues to run after the ignition key is switched off. It most often occurs after the engine has reached operating temperature and has been running at high speeds. Common causes of run-on include:

- Leaky injectors

Rotten Egg Odor

Under certain operating conditions, the sulfur content in fuel reacts with hydrogen to form hydrogen sulfide gas, results in the offending rotten egg odor. This usually occurs when decelerating after heavy load or high speed engine operation. During these conditions the engine usually runs rich, and the extra fuel caries additional sulfur which is burned during combustion.

When troubleshooting customer concerns with rotten egg odor, it is important to consider two factors. First, the smell may not be coming from your customer's vehicle, but rather from a vehicle followed on the highway. Secondly, high sulfur content in gasoline will cause this symptom regardless of any attempts to control the odor. Usually, a name-brand fuel will have lower sulfur content than off-brand regular fuels. Common causes of rotten egg odor include:

- Excessively rich air/fuel mixture
- Excessively high sulfur content in fuel
- Ineffective catalytic converter

Additional Driveability Terminology

In addition to the driveability symptoms mentioned, there are a few additional terms used in Toyota publications that require clarification. They are:

- **Cold Soak;** Describes an engine that has not operated (engine off) for at least 8 hours.
- **Hot Soak;** Describes an engine that has been shut off, after it had been running and had reached operating temperature.
- **WOT;** Defined as Wide Open Throttle (full throttle)
- **PT;** Defined as Partial Throttle (ex: 1/2 PT is defined as 50% throttle opening)
- **Quick Acceleration;** Idle to WOT throttle acceleration that takes 0.2 - 0.3 seconds to reach.
- **Normal Acceleration;** Idle to WOT throttle acceleration that takes 0.5 -1.0 seconds to reach.
- **Slow Acceleration;** Idle to WOT throttle acceleration that takes 1.0 - 2.0 seconds to reach.

Intuitive Diagnosis

Intuitive diagnosis is another resource that can help direct your troubleshooting efforts. This approach relies on your experience, working knowledge of the affected sub-system, along with an accurate symptom interpretation, in making an *educated guess* as to the suspected sub-system. It's based on the premise that if you have successfully fixed the problem with the same symptom, under the same conditions before, there is a high likelihood the cause will be the same.

It is important to stress that repairs based on intuitive skills should only *supplement* your normal diagnostic approach. It should only be used to identify systems in need of functional testing, and not as justification for replacing parts. Always verify the success of any repair that was performed in this manner. Remember, intuitive diagnosis places heavy emphasis on past experience and knowledge.

Enhanced I/M Inspection Report Analysis

When diagnosing an emissions failure, one of the best source of diagnostic information is the inspection report provided by test facility. This report will tell you which gas or gases failed by providing you with the average output level for each of the tested gases (HC, CO, NOx, CO2). In addition, the report includes a ”second-by-second” test trace of emission output levels throughout the entire driving cycle.

When analyzing the report, one of the first things you should do is note which gas or gases failed and the extent of the failure. Compare the difference between the two failure examples:

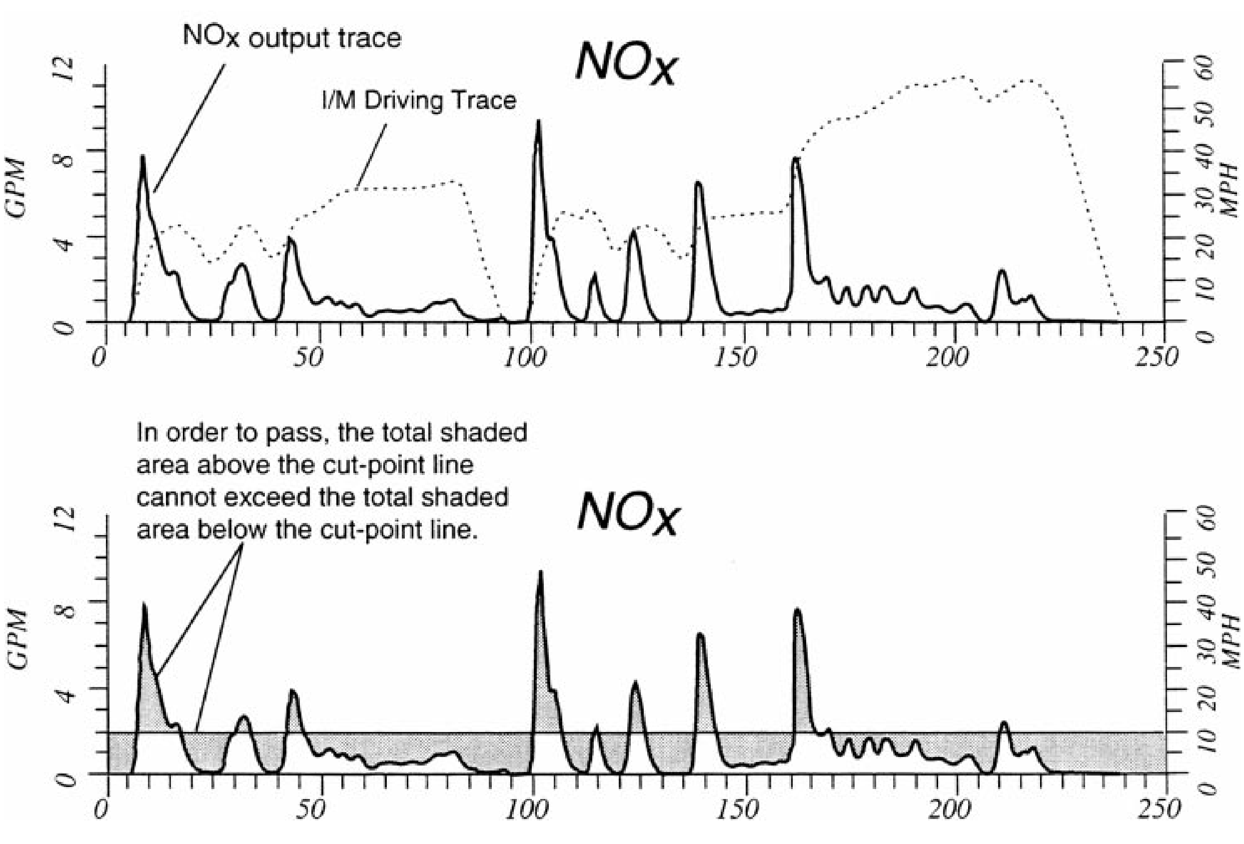
Marginal Failure

- If vehicle failed for NOx at 2.10 g/mile and the failure ”cut-point” is 2.00 g/mile, this could be considered a marginal failure that may only require a minor adjustment in order to pass a retest.

Gross Failure

- However, if the NOx failure was 4.00 g/mile with the same failure ”cut-point” of 2.00 g/mile, this problem would be considered ”gross” and more than likely the result of a major sub-system problem such as EGR, Closed Loop Control, catalyst, etc.

Test Trace Analysis

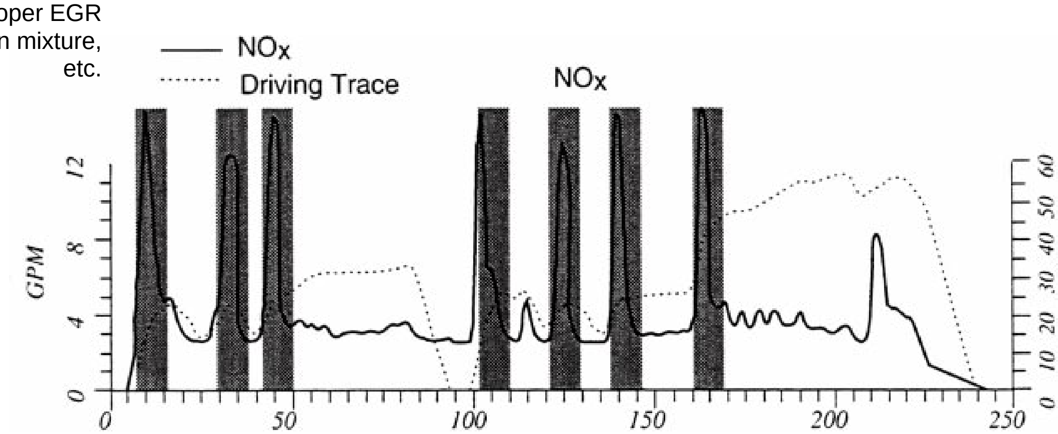


Test Trace Analysis

The inspection report also includes an output trace for each of the tested gases that is superimposed over the drive cycle. To understand the trace, first remember that mass emission output is continuously measured and plotted throughout the entire inspection drive cycle. For the sake of example, if a 2.00 g/mile NOx cut-point is used, NOx output can occasionally exceed this cut-point; however, overall NOx output cannot *average* over 2.00 g/mile by the end of the drive cycle. In short, in order to pass the test, the entire area below the NOx output trace cannot exceed the area below the 2.00 g/mile cut-point line.

NO_X Failure Example

The sample trace below shows high NO_X production during acceleration (shaded areas). This classic example of a NO_X failure trace can be caused by improper EGR operation, lean mixture, etc.



The test trace allows you to analyze emission output levels at different operating conditions including; acceleration, deceleration, low and high speed cruise, and idle. This helps you identify specific trends in the test trace such as a misfire under a load, NOx production during acceleration, etc. With this information, you can ”target” your diagnosis to include only those sub-systems or components likely to cause the pattern indicated.

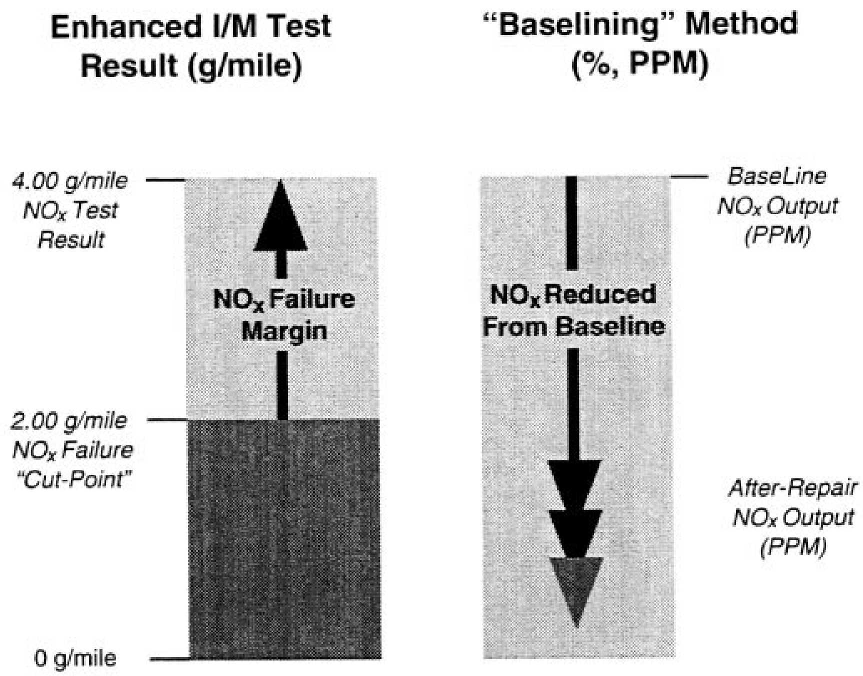
Comparative Emission Analysis

As previously mentioned, *mass* (g/mile) and *concentration (%,* ppm) based emission readings are measured and calculated in two very different ways. Therefore, the two readings can never accurately be compared to one another! If your shop is equipped with a portable emission analyzer (concentration type), you may be able perform a comparative analysis that will allow you to determine the relative emission improvement on a vehicle that has failed an emission inspection.

Using the ”gross” NOx failure example, it can be said that NOx output is twice as high as the allowable NOX ”cut-point”. Keeping this in mind, perform the following comparative analysis. The first step is to take a reference or ”baseline” emission reading while driving the vehicle, prior to making any adjustments or repairs.

Comparative Emission Analysis

This method requires establishing a ”baseline” emission reading from with ”after-repair” emission improvements are measured.

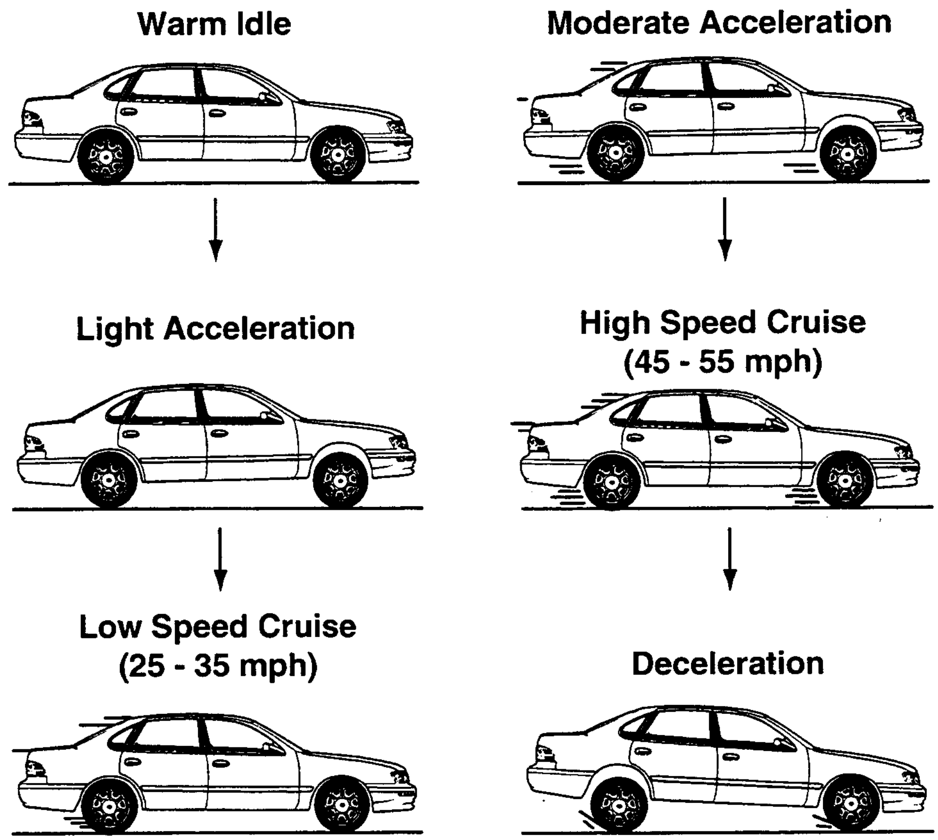


After baselining, perform your diagnosis and make all necessary adjustments and sub-system repairs required to significantly reduce overall NOx output. Then perform the drive cycle again and note the ”after-repair” emission levels. In order to feel confident the vehicle will pass an inspection retest, the after-repair NOx levels must be significantly lower than the initial baseline NOx readings.

Keep in mind, this type of comparative analysis does not guarantee the vehicle will pass the inspection retest, however, it at least provides you with a way to compare pre and post emission repair effectiveness, as well as the level of improvement made to the failed gas. Remember, the greater the margin of improvement you can make, the more likely the vehicle will pass the inspection retest.

Emission Baselining

Always establish a "baseline" from which you can determine repair effectiveness. Concentrate on the driving modes that indicate an emissions abnormality.



"Baselining"

As mentioned, baselining helps establish a "reference" point from which repair effectiveness can be measured. It first requires that a portable emission analyzer is properly installed in the vehicle with the test probe securely attached to the tailpipe. Always follow the manufacturer's instructions to ensure proper installation and hookup.

It is also important that the baseline reading is taken in a similar manner to that which the vehicle was initially inspected (loaded mode, various driving conditions.) This is particularly true when diagnosing failures that are affected by the amount of load placed on the engine (NOx failure, misfire under load, etc.) Because your ability to perform a similar drive cycle is very dependent on the location of your repair facility (metro area, etc.), at the very least your baseline drive cycle should be consistently repeatable and consist of the following modes:

- Warm idling
- Light acceleration
- Low speed cruising (25 mph - 35 mph)
- Moderate acceleration
- High speed cruising (45 mph - 55 mph)
- Rapid deceleration

Always analyze the I/M test trace and determine which of the baseline drive modes you should concentrate on. For instance, if the I/M inspection report shows high NOx levels during periods of acceleration, concentrate on the readings you obtain during the acceleration phases of the baseline drive cycle.

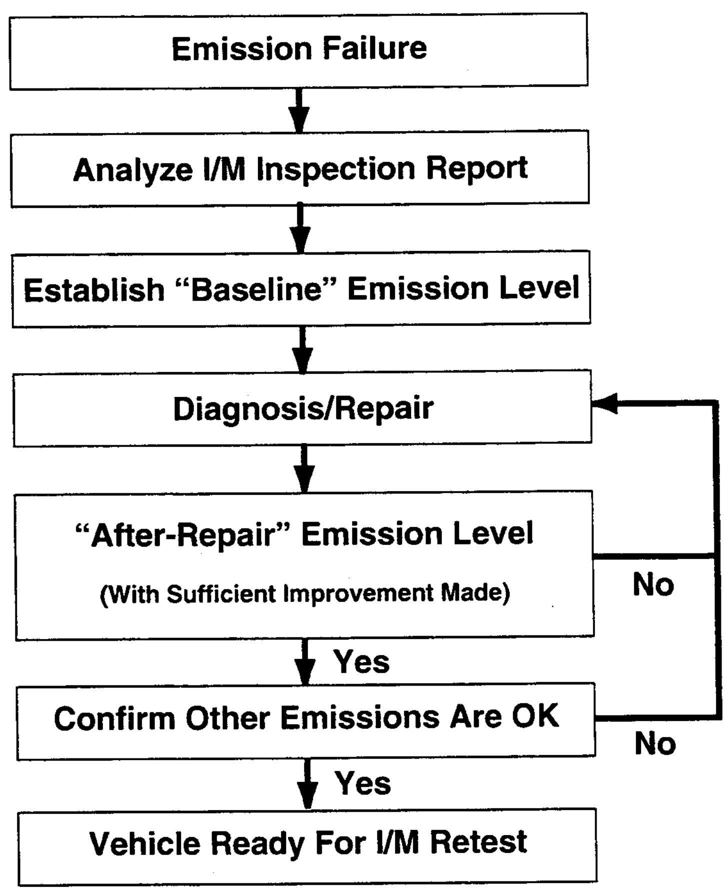
In addition to establishing baseline readings, note any abnormalities in emission output levels throughout entire drive cycle. Some analyzers have the ability to record and print individual output traces, or ”strip charts”, thereby allowing you to compare emission levels at various operating conditions. Once these ”trends” are identified, concentrate only on the subsystems whose operating strategy can result in the emission pattern indicated.

NOTE

Remember, on vehicles that have failed I/M inspection for an emission failure, always take a baseline reading *before making any adjustments or repairs*. If a baseline is not taken and repairs are performed, you will not be able to confirm the extent of improvement, if any, to the failed gas or gases.

Emission Analysis Flowchart

Use the following logic when performing repairs to a vehicle that has failed an I/M emission test.

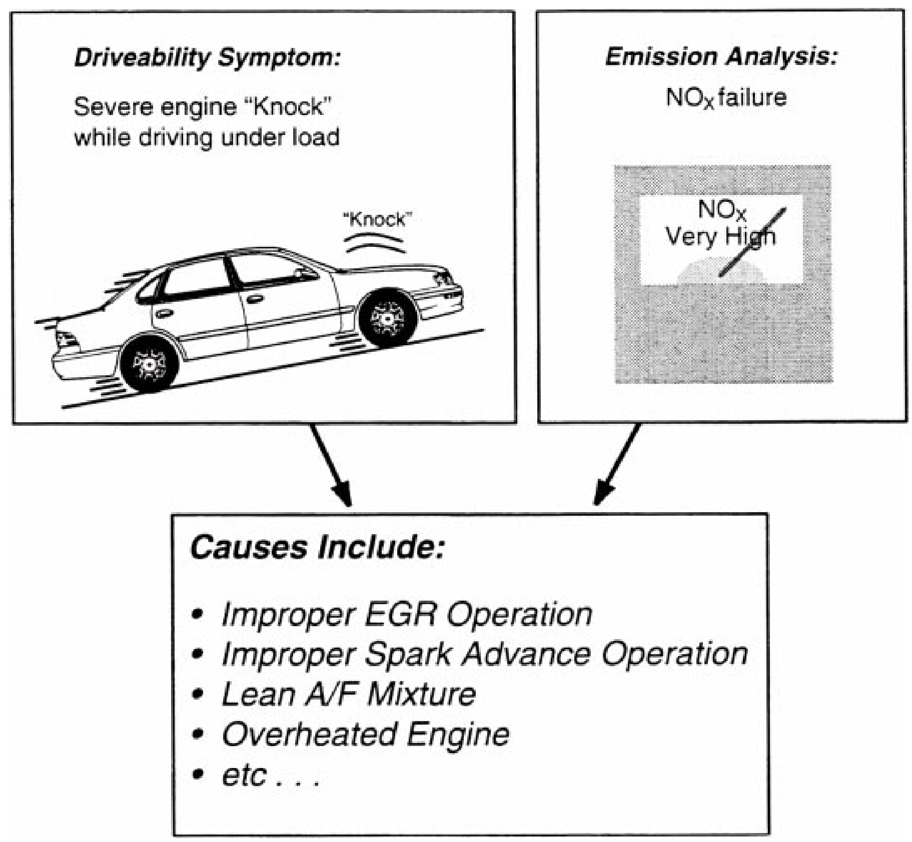


Combined Emission & Driveability Diagnosis

Whether the customer's concern is an emission failure or driveability symptom, the troubleshooting approach is essentially the same. Since emission and driveability concerns are often related and many times originate from the same cause, it only makes sense that you troubleshoot these concerns together. Concentrate only on the sub-systems that can directly or indirectly cause the emission failure or driveability symptom experienced. If necessary, refer back to section four of this handbook for the impact each sub-system has on both emissions and driveability, and prioritize your diagnosis accordingly.

Combined Diagnostic Approach

Many times emission and driveability concerns originate from the same problem. Diagnostic accuracy is improved if you consider the possibilities from both perspectives.



In general, the following points are important to remember when making your diagnosis:

- **Perform easy,** routine/preliminary checks first.
- **Eliminate** sub-systems that cannot cause the driveability symptom or emission failure indicated.
- **Prioritize** sub-system diagnosis based on most likely cause first.

Always consider the ease at which preliminary checks can be made. Performing a routine and basic inspection, retrieving stored DTC's, or evaluating serial data are examples of quick and easy checks to perform. For example, if an OBD-II vehicle has failed for NOx, quick checks can be made to identify an overheated engine, a lean shift in A/F mixture, improper O2S signal activity or spark advance operation, or even perform an EGR active test.

If the cause of the concern cannot be found during the preliminary checks, use the information gathered, along with the symptom and tailpipe emission analysis to eliminate sub-systems that could not be the cause. Since functional sub-system tests may be more complex or difficult to perform than preliminary checks, prioritize and troubleshoot the suspected subsystems in the order of the most likely cause first.

Repair Confirmation

After making repairs to a vehicle, always verify the effectiveness of the repairs by test driving the vehicle. If the vehicle failed an emissions test, always perform the ”after-repair” drive cycle while recording the new, ”improved” emission levels. Always perform the baseline and after-repair drive cycles *identically!* Without this consistency, the before and after comparison of emission levels will be inaccurate. Remember, the emission improvement must significantly exceed the failure margin or you cannot be confident the vehicle will pass an I/M retest.

Even after sufficient improvements are made to the gas that failed, it's important to confirm that other tested gases remain low. Many times when repairs are made to lower the output level of one emission, another emission level may rise. A good example of this is the relationship between CO and NOx. If repairs are made to lower CO output, NOx emissions may increase due to the decreased reduction ability of catalyst. Because of the need to decrease and ”balance” the level of all harmful emissions, always look at 5-gas emission readings as a complete ”picture”.

This logic also applies when troubleshooting driveability concerns. Always confirm improvements to driveability symptoms prior to returning the vehicle to the customer. Make sure no new driveability symptoms arise that may have been ”masked” by a previous problem. Remember, modern fuel injected automobiles use computerized engine/emission control systems designed to maximize engine performance and vehicle driveability, while maintaining extremely low tailpipe emission levels.

WORKSHEET 5 (ON-CAR)
Emission & Driveability Diagnosis

Vehicle	Year/Prod. Date	Engine	Transmission

Customer Concern:

Step 1: Analyze Customer's Concern

1. Did the vehicle fail an I/M emission inspection? If yes, answer the following questions:

   - Which gas (or gases) failed? . . . . HC CO NOX
   - Was it a multiple gas failure? . . . . Yes No
   - Was the failure marginal or gross? . . . . Marginal Gross
   - Did it fail the EVAP purge/pressure test? . . . . Yes No If yes, which test?___________

2. If the customer's concern is driveability related, verify the concern. Describe any symptoms experienced.

Step 2: Establish a Baseline 5-Gas Emission Reading:

1. If the vehicle failed an I/M emissions test, establish a "baseline" emission reading.

   - Warm idle . . . . HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______
   - Light acceleration . . . . HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______
   - Low speed cruise (25-35 mph) . . . . HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______
   - Moderate acceleration reading . . . . HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______
   - High speed cruise (45-55 mph) . . . . HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______
   - Deceleration reading . . . . HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______

2. Can you draw any conclusions from the baseline readings above? Explain.

Step 3: Check for Diagnostic Trouble Codes:

- Are any codes stored in memory? . . . . No Yes, codes indicated:____________

If codes are indicated, proceed directly to troubleshooting using Repair Manual procedures.

Step 4: Perform a Visual and Basic Inspection:

- Visually inspect electrical and vacuum circuit connections ..... OK NG
- Check the ECM main grounds (voltage drop) .... OK NG
- Check the engine's audible cranking rhythm (compression) .... OK NG
- Perform an audible check for cylinder misfire .... OK NG

If NG, perform scope check & cyl. balance test of ignition system.

- Perform all Repair Manual basic inspection procedures .... OK NG

1. Was anything found during the visual/basic inspection that could have caused the problem? Explain.

____

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Step 5: Perform a Serial Data Quick Check:

1. Based on what you know so far, what data parameters or Diagnostic Tester functions would you focus on? List them below and explain your reasoning behind these parameters or tests.

____

____

____

Step 6: Perform Sub-System Functional Checks:

Based on what you know so far, which of the following sub-systems would you check?

Of the sub-systems checked, prioritize the order of diagnosis in the boxes below (1,2, 3, etc.), and then list some possible causes within each sub-system:

- Air Induction System .... ☐ ______________________________
- Fuel Delivery System .... ☐ ______________________________
- Ignition, Spark Advance System .... ☐ ______________________________
- Closed Loop Control System .... ☐ ______________________________
- Exhaust Gas Recirculation System ...... ☐ ______________________________
- Evaporative Emission System .... ☐ ______________________________
- Positive Crankcase Ventilation System ... ☐ ______________________________
- Three-Way Catalytic Converter .... ☐ ______________________________
- Secondary Air Injection System .... ☐ ______________________________
- Idle Air Control System .... ☐ ______________________________
- Other?________________ ....

Perform all sub-system functional checks as prioritized above.

Step 7: Analyze Sub-System Test Results:

1. After performing the sub-system checks and tests, what problem(s) did you find?

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2. List the resource(s) you used to perform the sub-system checks.

____

____

3. How does this problem(s) relate to the emission failure or driveability symptoms? Explain.

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STOP! Notify your instructor of your diagnostic conclusion before proceeding with the rest of this worksheet!

Step 8: Retest For 5-Gas Emission Improvements:

1. Record the ”after repair” emission reading using the same drive cycle as the ”baseline”.

- Warm idle . . . . HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______
- Light acceleration . . . . HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______
- Low speed cruise (25-35 mph) . . . . HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______
- Moderate acceleration reading . . . . HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______
- High speed cruise (45-55 mph) . . . . HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______
- Deceleration reading . . . . HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______

2. Compare these readings with those obtained in the ”baseline”. Were significant improvements made? Explain.

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3. If the customer’s concern was driveability related, did the repairs made in step 7 resolve these driveability concerns? Explain.

____

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Return the vehicle to normal condition. Clear any stored diagnostic trouble codes.

Notes

WORKSHEET 6 (ON-CAR)
Emission & Driveability Diagnosis

Vehicle	Year/Prod. Date	Engine	Transmission

Customer Concern:

Step 1: Analyze Customer's Concern

1. Did the vehicle fail an I/M emission inspection? If yes, answer the following questions:

- Which gas (or gases) failed? . . . . HC CO NOX
- Was it a multiple gas failure? . . . . Yes No
- Was the failure marginal or gross? . . . . Marginal Gross
- Did it fail the EVAP purge/pressure test? . . . . Yes No If yes, which test?___________

2. If the customer's concern is driveability related, verify the concern. Describe any symptoms experienced.

Step 2: Establish a Baseline 5-Gas Emission Reading:

1. If the vehicle failed an I/M emissions test, establish a "baseline" emission reading.

- Warm idle . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______
- Light acceleration . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______
- Low speed cruise (25-35 mph) . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______
- Moderate acceleration reading . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______
- High speed cruise (45-55 mph) . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______
- Deceleration reading . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______

2. Can you draw any conclusions from the baseline readings above? Explain.

Step 3: Check for Diagnostic Trouble Codes:

- Are any codes stored in memory? . . . . No Yes, codes indicated:____________

If codes are indicated, proceed directly to troubleshooting using Repair Manual procedures.

Step 4: Perform a Visual and Basic Inspection:

- Visually inspect electrical and vacuum circuit connections . . . . . OK NG
- Check the ECM main grounds (voltage drop) . . . . OK NG
- Check the engine's audible cranking rhythm (compression) . . . . OK NG
- Perform an audible check for cylinder misfire . . . . OK NG

If NG, perform scope check & cyl. balance test of ignition system.

- Perform all Repair Manual basic inspection procedures . . . . OK NG

1. Was anything found during the visual/basic inspection that could have caused the problem? Explain.

____

____

Step 5: Perform a Serial Data Quick Check:

1. Based on what you know so far, what data parameters or Diagnostic Tester functions would you focus on? List them below and explain your reasoning behind these parameters or tests.

____

____

____

Step 6: Perform Sub-System Functional Checks:

Based on what you know so far, which of the following sub-systems would you check?

Of the sub-systems checked, prioritize the order of diagnosis in the boxes below (1,2, 3, etc.), and then list some possible causes within each sub-system:

- Air Induction System . . . . ☐ ______________________
- Fuel Delivery System . . . . ☐ ______________________
- Ignition, Spark Advance System . . . . ☐ ______________________
- Closed Loop Control System . . . . ☐ ______________________
- Exhaust Gas Recirculation System . . . . . . ☐ ______________________
- Evaporative Emission System . . . . ☐ ______________________
- Positive Crankcase Ventilation System . . . ☐ ______________________
- Three-Way Catalytic Converter . . . . ☐ ______________________
- Secondary Air Injection System . . . . ☐ ______________________
- Idle Air Control System . . . . ☐ ______________________
- Other?________________ . . . .

Perform all sub-system functional checks as prioritized above.

Step 7: Analyze Sub-System Test Results:

1. After performing the sub-system checks and tests, what problem(s) did you find?

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____

2. List the resource(s) you used to perform the sub-system checks.

____

____

3. How does this problem(s) relate to the emission failure or driveability symptoms? Explain.

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STOP! Notify your instructor of your diagnostic conclusion before proceeding with the rest of this worksheet!

Step 8: Retest For 5-Gas Emission Improvements:

1. Record the "after repair" emission reading using the same drive cycle as the "baseline".

- Warm idle .... HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______
- Light acceleration .... HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______
- Low speed cruise (25-35 mph) .... HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______
- Moderate acceleration reading .... HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______
- High speed cruise (45-55 mph) .... HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______
- Deceleration reading .... HC ______ CO _____ CO_2 _____ O_2 ______ NO_X ______

2. Compare these readings with those obtained in the "baseline". Were significant improvements made? Explain.

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____

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3. If the customer's concern was driveability related, did the repairs made in step 7 resolve these driveability concerns? Explain.

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____

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Return the vehicle to normal condition. Clear any stored diagnostic trouble codes.

Notes

WORKSHEET 7 (ON-CAR)
Emission & Driveability Diagnosis

Vehicle	Year/Prod. Date	Engine	Transmission

Customer Concern:

Step 1: Analyze Customer's Concern

1. Did the vehicle fail an I/M emission inspection? If yes, answer the following questions:

- Which gas (or gases) failed? . . . . HC CO NOX
- Was it a multiple gas failure? . . . . Yes No
- Was the failure marginal or gross? . . . . Marginal Gross
- Did it fail the EVAP purge/pressure test? . . . . Yes No If yes, which test?___________

2. If the customer's concern is driveability related, verify the concern. Describe any symptoms experienced.

Step 2: Establish a Baseline 5-Gas Emission Reading:

1. If the vehicle failed an I/M emissions test, establish a "baseline" emission reading.

- Warm idle . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______
- Light acceleration . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______
- Low speed cruise (25-35 mph) . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______
- Moderate acceleration reading . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______
- High speed cruise (45-55 mph) . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______
- Deceleration reading . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______

2. Can you draw any conclusions from the baseline readings above? Explain.

Step 3: Check for Diagnostic Trouble Codes:

- Are any codes stored in memory? . . . . No Yes, codes indicated:____________

If codes are indicated, proceed directly to troubleshooting using Repair Manual procedures.

Step 4: Perform a Visual and Basic Inspection:

- Visually inspect electrical and vacuum circuit connections ..... OK NG
- Check the ECM main grounds (voltage drop) .... OK NG
- Check the engine's audible cranking rhythm (compression) .... OK NG
- Perform an audible check for cylinder misfire .... OK NG

If NG, perform scope check & cyl. balance test of ignition system.

- Perform all Repair Manual basic inspection procedures .... OK NG

1. Was anything found during the visual/basic inspection that could have caused the problem? Explain.

____

____

Step 5: Perform a Serial Data Quick Check:

1. Based on what you know so far, what data parameters or Diagnostic Tester functions would you focus on? List them below and explain your reasoning behind these parameters or tests.

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____

Step 6: Perform Sub-System Functional Checks:

Based on what you know so far, which of the following sub-systems would you check?

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- Ignition, Spark Advance System .... ☐ ______________________________
- Closed Loop Control System .... ☐ ______________________________
- Exhaust Gas Recirculation System ...... ☐ ______________________________
- Evaporative Emission System .... ☐ ______________________________
- Positive Crankcase Ventilation System ... ☐ ______________________________
- Three-Way Catalytic Converter .... ☐ ______________________________
- Secondary Air Injection System .... ☐ ______________________________
- Idle Air Control System .... ☐ ______________________________
- Other?________________ ....

Perform all sub-system functional checks as prioritized above.

Step 7: Analyze Sub-System Test Results:

1. After performing the sub-system checks and tests, what problem(s) did you find?

____

____

2. List the resource(s) you used to perform the sub-system checks.

____

____

3. How does this problem(s) relate to the emission failure or driveability symptoms? Explain.

____

____

____

STOP! Notify your instructor of your diagnostic conclusion before proceeding with the rest of this worksheet!

Step 8: Retest For 5-Gas Emission Improvements:

1. Record the ”after repair” emission reading using the same drive cycle as the ”baseline”.

- Warm idle . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______
- Light acceleration . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______
- Low speed cruise (25-35 mph) . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______
- Moderate acceleration reading . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______
- High speed cruise (45-55 mph) . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______
- Deceleration reading . . . . HC ______ CO ______ CO_2 _____ O_2 ______ NO_X ______

2. Compare these readings with those obtained in the ”baseline”. Were significant improvements made? Explain.

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3. If the customer’s concern was driveability related, did the repairs made in step 7 resolve these driveability concerns? Explain.

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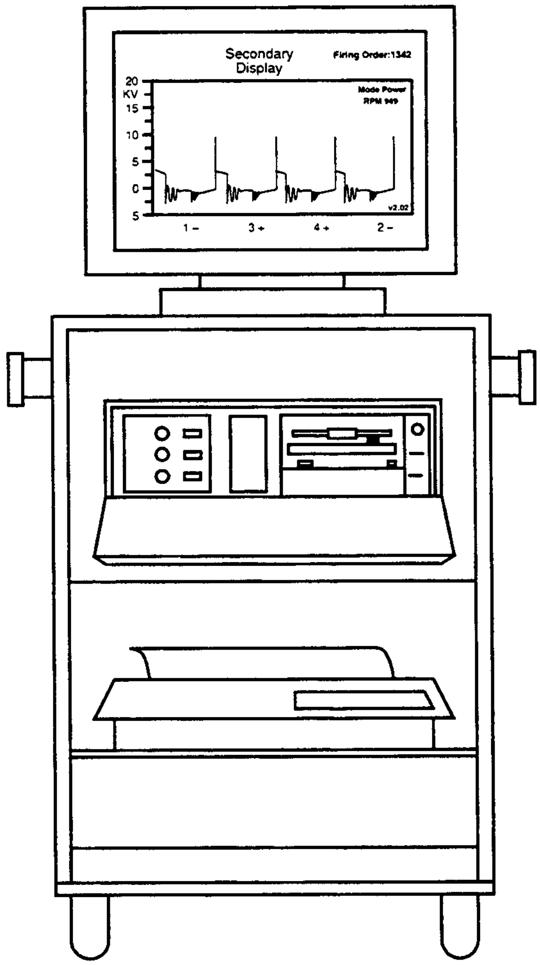
Return the vehicle to normal condition. Clear any stored diagnostic trouble codes.

Notes

OSCILLOSCOPE INTRODUCTION

The "Shop Scope"

The shop scope provides an easy way to perform an ignition system quick check that can also identify engine mechanical problems and air/fuel mixture imbalances.

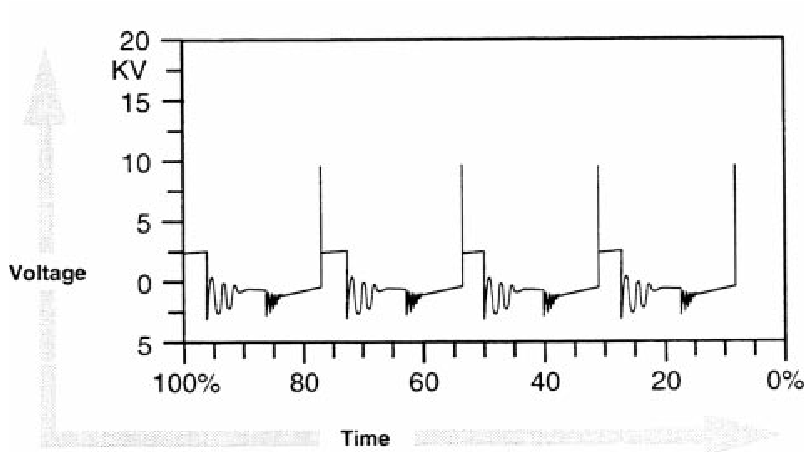


Introduction to Automotive Oscilloscopes

The automotive oscilloscope serves as a valuable tool in the diagnosis of the ignition system, fuel system, charging system, and engine mechanical condition. Commonly referred to as a "scope", the oscilloscope provides the technician a method to observe the ignition events for each of the engine's cylinders, by displaying individual ignition system voltages across an active display.

The oscilloscope pattern is a voltage line plotted over a specific length of time, representing the ignition system's primary or secondary circuit voltage. This pattern is continuously updated to reflect ignition system voltage changes throughout various engine operating conditions. By examining the oscilloscope pattern, the technician can see the ignition system voltage fluctuate from the time the spark plug fires, through the duration of the spark, as the spark is extinguished, and as the ignition coil recharges to fire another cylinder. Many engine problems, ignition related or otherwise, will show up on the oscilloscope pattern as abnormal.

Scope Display



The Display Screen

A traditional volt meter displays the instantaneous voltage for the circuit being measured. Unlike the volt meter, the oscilloscope has the ability to display the voltage changes that take place through a specific time by ”drawing” a line on the screen. The higher the voltage being measured, the higher the line extends vertically. As time passes, the line moves horizontally across the screen to the right. This line, fluctuating up and down across the screen, forms a pattern that is repeated once per ignition cycle. The vertical scale measures voltage in variable ranges, and the horizontal line measures time in selectable increments.

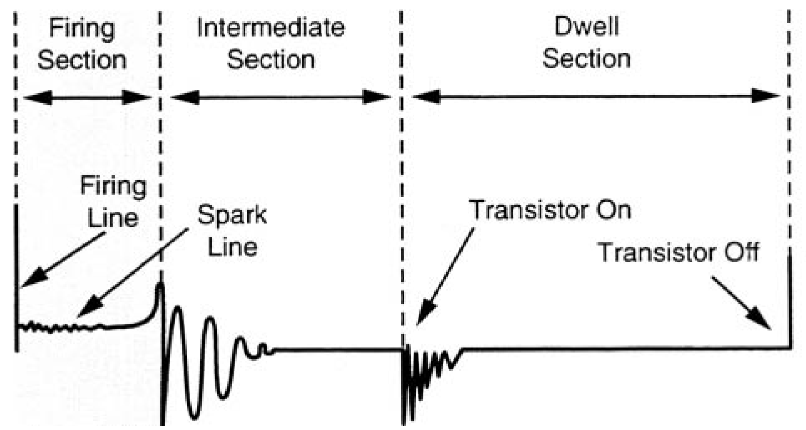
Scope Connections and Adjustment Procedures

Many types and brands of automotive oscilloscopes are available. Modern machines are PC based with built in software files to aid the operator in machine programming, as well as vehicle diagnosis. They may also have updated connectors and interfaces to accommodate modern ignition systems. Older machines are more common and are often adjusted with a set of knobs and switches on the face of the machine. It is advised that you consult the Operator’s Manual provided by the manufacturer for specific information on hook-up, adjustment procedures, and safety precautions.

Secondary Ignition Patterns

The Secondary Scope Pattern is the most useful pattern for diagnosing possible ignition system, engine mechanical, engine electrical system, and emission control system problems. It consists of the **Firing Section, the Intermediate Section,** and the **Dwell Section.** Each section represents a different period of time during the entire ignition sequence for a particular cylinder.

Secondary Pattern

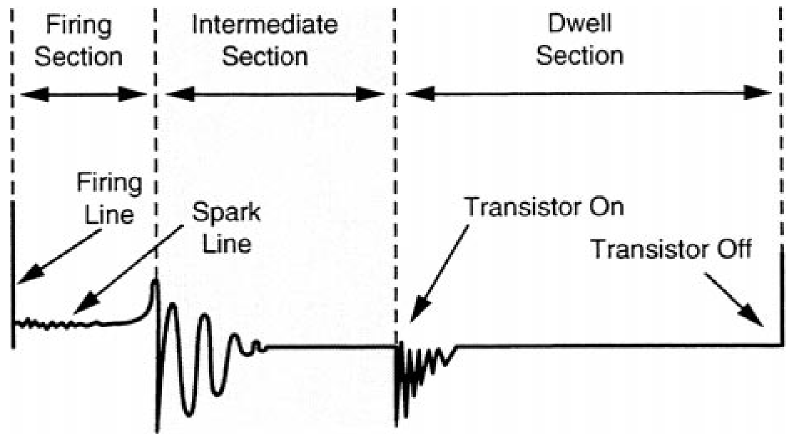


Firing Section

The Firing Section represents the voltage fluctuation of the secondary ignition system from the time the spark is initiated until it is completely extinguished. The **Firing Line** represents the voltage required to overcome the rotor and spark plug gap resistance. Firing voltage is normally between 5 and 15 kilovolts (KV). Typically, Firing Lines should not vary by more than 3 KV between cylinders. Also, the height of the Firing Line increases with secondary resistance. The Firing Line begins when the igniter cuts the primary current flow through the ignition coil and the collapsing magnetic field in the coil induces voltage to the secondary ignition system.

Once spark has been initiated, considerably less voltage is required to maintain the spark. The vertical line immediately following the firing line represents the voltage required to maintain the spark and is known as the **Spark Line.** It should remain fairly level and should measure from 0.8 to 2.2 milliseconds (ms) time on a properly operating engine. The Spark Line is a good indicator of air fuel/ratio and secondary resistance. The point at which the spark line begins to drop sharply is the point at which spark is extinguished.

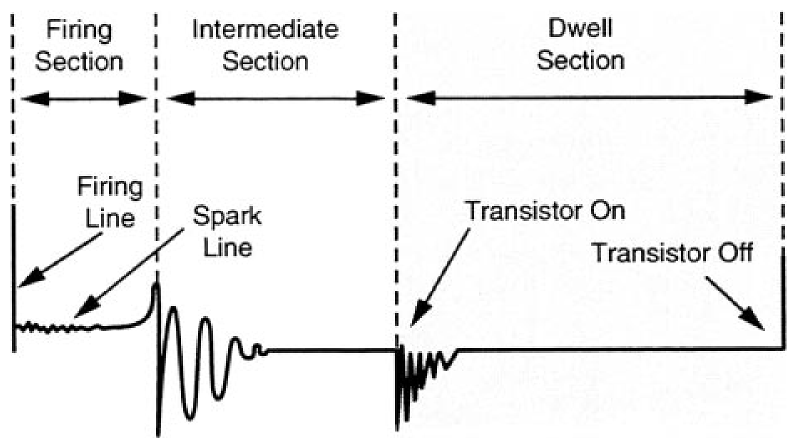
Intermediate Section



The Intermediate Section

The Intermediate Section begins where the Firing Section ends. The voltage oscillations seen on the oscilloscope screen represent the remaining ignition coil energy being dissipated after the spark is extinguished. The Intermediate Section ends when the igniter transistor turns on, applying power to the primary ignition circuit.

Dwell Section



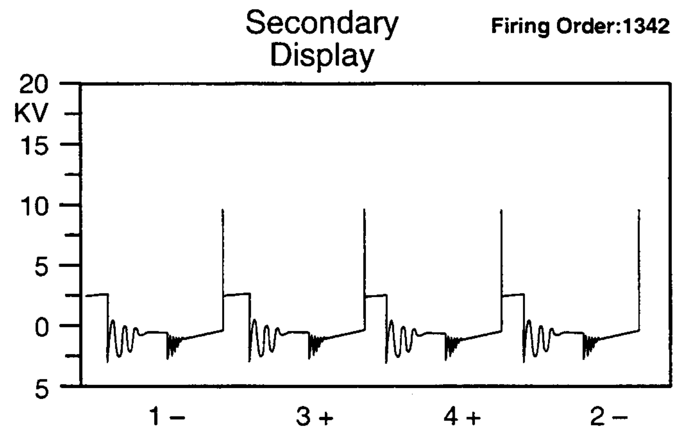
The Dwell Section

The Dwell Section begins when the igniter applies power to the coil, allowing it to ”recharge” to fire the next cylinder. The short down spike followed by diminishing oscillations at the beginning of the Dwell Section represent the build up of the magnetic field in the coil. Normally you should see several oscillations; however, on some electronic ignition systems a single down spike with no oscillations may be normal. The Dwell Section ends when the igniter stops primary current flow causing a spark in the next cylinder.

Scope Patterns

The oscilloscope screen can display secondary ignition patterns for all cylinders simultaneously in the Display, Raster, or Superimposed mode.

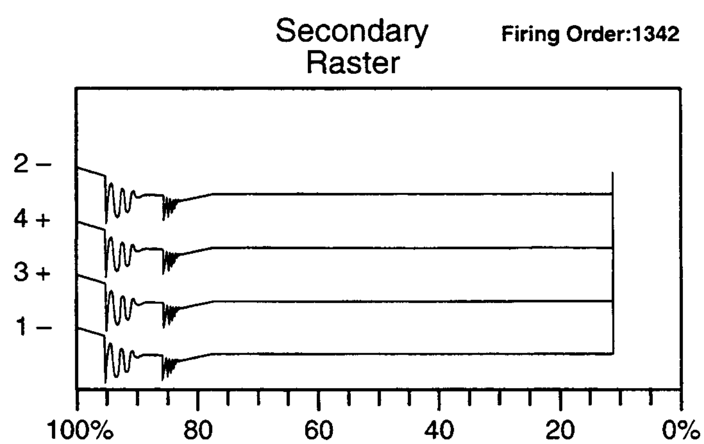
Display Pattern



Display (Parade) Pattern

The Display Pattern shows all of the cylinder patterns one after another, in the sequence of the firing order. On most oscilloscope screens, the Firing Line of the number one cylinder appears at the extreme right. The Display Pattern is primarily used to compare Firing Line height.

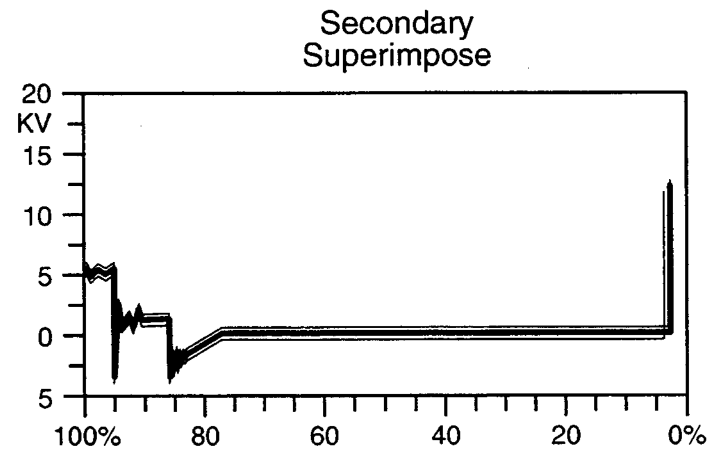
Raster Pattern



Raster (Stacked) Pattern

When the Raster Pattern is chosen the individual cylinder patterns are shown vertically, one above the other. The pattern begins at the bottom of the screen with the first cylinder in firing order and follows the firing order to the top of the screen. The advantage of using the Raster Pattern is it extends the individual cylinder patterns across the entire screen. This gives the technician the ability to examine individual sections of the pattern and to compare any variances. The firing lines for the individual cylinders are displayed at the extreme right.

Superimposed Pattern



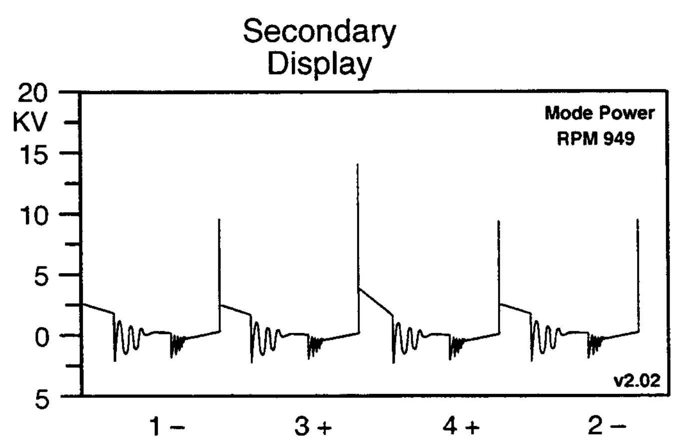
Superimposed Pattern

When the Superimposed Pattern is chosen, the individual cylinder patterns are placed one on top of the other. This pattern is especially useful when checking the overall uniformity of the ignition system. As with the Raster Pattern, the Superimposed Pattern places the Firing Lines on the extreme right of the screen.

Sample Scope Patterns

An essential part of diagnosis with an automotive oscilloscope is a basic understanding of how various system malfunctions appear on the oscilloscope screen. Patterns will vary slightly from textbook illustrations and between engine make and type. For this reason, it is also important to examine oscilloscope patterns for uniformity between cylinders. Look for patterns that are not uniform or that vary greatly from the norm. The following examples show common engine conditions detected by the automotive oscilloscope. They do not represent all possible problems; however, they do serve to familiarize the technician with the oscilloscope's basic diagnostic capabilities.

One Firing Line Higher Than Others



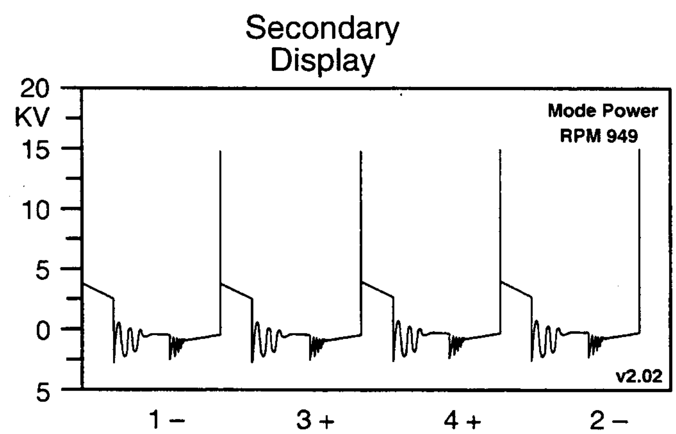
One or More Firing Lines Uneven and Higher Than The Rest

When one or more of the displayed Firing Lines exceeds the others by more than 3KV, a problem exists in the affected cylinder(s) which causes the voltage required to bridge the spark plug and rotor gap to rise. When this happens, the output voltage of the coil continues to rise until it is high enough to fire the spark plug. The raised voltage appears as a higher Firing Line. The voltage of the spark line will also be higher and not as wide.

Possible causes include:

- Worn spark plug
- Breaks in spark plug wire
- Corroded terminal in the distributor cap
- Vacuum leak near the affected cylinder
- Plugged fuel injector in the affected cylinder

Firing Lines Too High



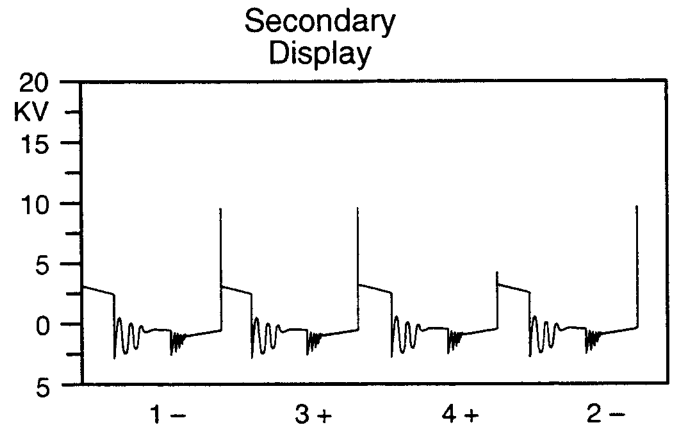
All Firing Lines Too High

A pattern in which all Firing Lines are uniform, but high is caused by a condition that requires excessive voltage to fire the spark plugs.

Possible Causes Include:

- Open high tension coil wire (except on DIS ignition systems)
- Worn spark plugs
- Rotor gap too wide
- Retarded spark timing
- Fuel mixture too lean
- Faulty distributor cap

One Firing Line Lower Than Others

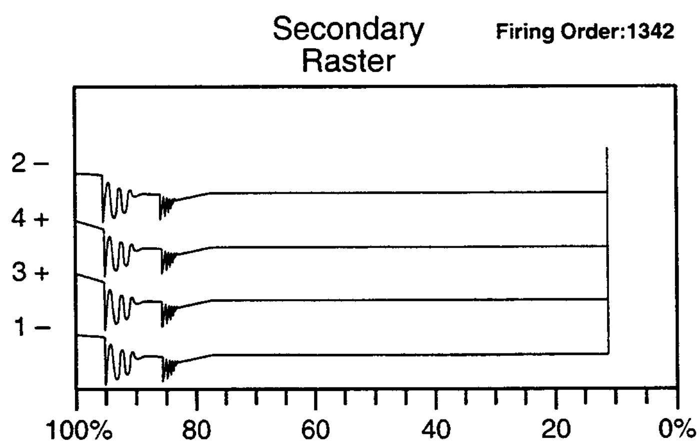


This pattern is caused by low secondary resistance for the affected cylinder. Also, the current for the low cylinder may have found an alternate path to ground that has lower resistance.

Possible Causes Include:

- Low compression
- Fouled spark plug
- Shorted spark plug wire
- Spark plug with too small a gap
- Cracked spark plug insulator
- Leaking injector at affected cylinder

Spark Lines Slope Down



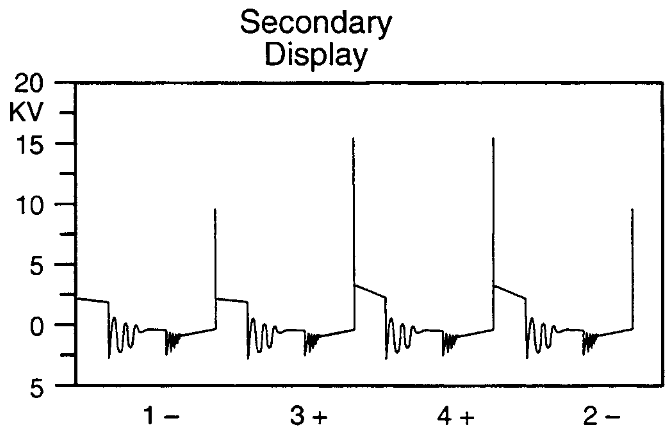
One or More Spark Lines Sloping Down

This pattern is caused by high resistance in the secondary circuit of the affected cylinders).

Possible Causes Include:

- High resistance in the spark plug wire
- Distributor cap terminals burned
- Spark plug with too large a gap
- A leaky injector at the affected cylinder

Excessive Rise on Snap Acceleration



One or More Spark Lines with Excessive Rise on Snap Acceleration

The technician can momentarily snap the throttle and watch the rise of the individual spark lines. Spark Lines should rise uniformly and only slightly (about 3 KV). Spark Lines that show excessive voltage rise may be the result of excessive secondary resistance or fuel mixture imbalances for the affected cylinders). Spark Lines that show no voltage rise may be the result of poor secondary circuit insulation or engine mechanical problems.

Possible Causes of Excessive Voltage Rise Include:

- Spark plug gap too wide
- Open spark plug wire
- Improper fuel mixture
- Open spark plug resistor
- Vacuum leak near the affected cylinder

Possible Causes of No Voltage Rise Include:

- Shorted spark plug wire
- Poor high tension wire insulation
- Fouled spark plug
- Low compression in the affected cylinder

Appendix B

GLOSSARY OF TERMS

A

Acid rain - Air pollution produced when acid chemicals are incorporated into rain, snow, fog or mist. The ”acid” in acid rain comes from sulfur oxides and nitrogen oxides, products of burning coal and other fuels and from certain industrial processes. The sulfur oxides and nitrogen oxides are related to two strong acids: sulfuric acid and nitric acid. When sulfur dioxide and nitrogen oxides are released from power plants and other sources, winds blow them far from their source. If the acid chemicals in the air are blown into areas where the weather is wet, the acids can fall to Earth as rain, snow, fog or mist. In areas where the weather is dry, acid chemicals may become incorporated into dust or smoke. Acid rain can damage the environment, human health, and property.

Alternative fuels - Fuels that can replace ordinary gasoline. Alternative fuels may have particularly desirable energy efficiency and pollution reduction features. Alternative fuels include compressed natural gas, alcohols, liquefied petroleum gas (LPG), and electricity. The 1990 Clean Air Act Amendments encourages development and sale of alternative fuels.

Attainment area - A geographic area in which levels of a criteria air pollutant meet the health-based primary standard (national ambient air quality standards, or NAAQS) for the pollutant. An area may have an acceptable level for one criteria air pollutant, but may have unacceptable levels for others. Thus, an area could be both attainment and nonattainment at the same time. Attainment areas are defined using federal pollutant limits set by EPA.

C

Carbon monoxide (CO) - A colorless, odorless, poisonous gas produced by incomplete burning of carbon-based fuels including gasoline, oil and wood. Carbon monoxide is also produced from incomplete combustion of many natural and synthetic products. For instance, cigarette smoke contains carbon monoxide. When carbon monoxide gets into the body, the carbon monoxide combines with chemicals in the blood and prevents the blood from bringing oxygen to cells, tissues and organs. Body organs need oxygen for energy, so high level exposure to carbon monoxide can cause serious health effects, with death possible from massive exposure. Symptoms of carbon monoxide exposure can include vision problems, reduced alertness, and general reduction in mental and physical functions. Carbon monoxide exposure is especially harmful to people with heart, lung, and circulatory system diseases.

CFCs (chlorofluorocarbons) - These chemicals and some related chemicals have been used in great quantities in industry, for refrigeration and air conditioning, and in consumer products. CFCs and their relatives, when released into the air rise into the stratosphere, a layer of the atmosphere high above the Earth. In the stratosphere, CFCs and their relatives take part in chemical reactions which result in reduction of the stratospheric ozone layer, which protects the Earths surface from harmful effects of radiation from the sun. The 1990 Clean Air Act Amendments includes provisions for reducing releases (emissions) and eliminating production and use of these ozone-destroying chemicals.

Clean Air Act - The original Clean Air Act was passed in 1963, but our national air pollution control program is actually based on the 1970 version of the law. The 1990 Clean Air Act Amendments are the most far-reaching revisions of the 1970 law.

Clean fuels - Low-pollution fuels that can replace ordinary gasoline. There are alternative fuels, including gasohol (gasoline-alcohol mixtures), natural gas and LPG (liquid petroleum gas).

C

Combustion - Many important pollutants, such as sulfur dioxide, nitrogen oxides, and particulates (PM-10) are combustion products, often products of the burning of fuels such as coal, oil, gas, and wood.

Continuous emission monitoring systems (CEMS) - machines which measure, on a continuous basis, pollutants released by a source. The 1990 Clean Air Act Amendments require continuous emission monitoring systems on certain large sources.

Control technology; control measures - equipment, processes or actions used to reduce air pollution. The extent of pollution reduction varies among technologies and measures. In general, control technologies and measures that do the best job of reducing pollution will be required in the areas with the worst pollution. For example, the best available control technology/best available control measures (BACT/BACM) will be required in serious nonattainant areas for particulates, a criteria air pollutant. A similar high level of pollution reduction will be achieved with maximum achievable control technology (MACT) which will be required for sources releasing hazardous air pollutants.

Criteria air pollutants - a group of very common air pollutants regulated by EPA on the basis of criteria (information on health and/or environmental effects of pollution). Criteria air pollutants are widely distributed all over the country.

Curtailment programs - restrictions on operation of fireplaces and woodstoves in areas where these home heat sources make major contributions to pollution.

E

Emission - release of pollutant into the air from a source. Continuous emission monitoring systems (CEMS) are machines which some large sources are required to install, to make continuous measurements of pollutant release.

Enforcement - the legal methods used to make polluters obey the Clean Air Act. Enforcement methods include citations for polluters on violations of the law (citations are much like traffic tickets), fines and even jail terms. EPA and state and local governments are responsible for enforcement of the Clean Air Act, but if they don’t enforce the law, members of the public can sue EPA or the states to get action. Citizens can also sue violating sources, apart from any action EPA or state or local governments have taken. Before the 1990 Clean Air Act Amendments, all enforcement action had to be handled through the courts. The 1990 Clean Air Act Amendments gave EPA authority so that, in some cases, EPA can fine violators without going to court first. The purpose of this new authority is to speed up violating source compliance with the law and reduce court time and cost.

H

Hazardous air pollutants (HAPS) - chemicals that cause serious health and environmental effects. Health effects include cancer, birth defects, nervous system problems and death due to massive accidental releases (example: pesticide release in Bhopal, India). Hazardous air pollutants are released by sources such as chemical plants, dry cleaners, printing plants, and motor vehicles (cars, trucks, buses, etc.)

I

Inspection and maintenance program (I/M program) - Auto inspection programs are required for some polluted areas. These periodic inspections, usually done once a year or once every two years, check whether a car is being maintained to keep pollution down and whether emission control systems are working properly. Vehicles which do not pass inspection must be repaired. As of 1992, 111 urban areas in 35 states already had I/M programs. Under the 1990 Clean Air Act Amendments, some especially polluted areas will have to have Enhanced inspection and maintenance program, using special machines that can check for such things as how much pollution a car produces during actual driving conditions.

International air pollution - Canada and Mexico, the United States' neighbors, share the air at our borders. This international pollution can be serious. The 1990 Clean Air Act Amendments includes provisions for cooperative efforts to reduce pollution that originates in one country and affects another.

Interstate air pollution - In many areas, two or more states share the same air. We say these states are in the same air basin denned by geography and wind patterns. Often, air pollution moves out of the state in which it is produced into another state. Some pollutants, such as the power plant combustion products that cause acid rain, may travel over several states before affecting health, the environment and property. The 1990 Clean Air Act Amendments include many provisions, such as interstate compacts, to help states work together to protect the air they share. Reducing interstate air pollution is very important since Americans live and work in areas where more than one state is part of a single metropolitan area.

M

Material safety data sheets (MSDS) - product safety information sheets prepared by manufacturers and marketers of products containing toxic chemicals. These sheets can be obtained by requesting them from the manufacturer or marketer. Some stores, such as hardware stores, may have material safety data sheets on hand for products they sell.

Mobil sources - moving objects that release pollution; mobile sources include cars, trucks. Buses, planes, trains, motorcycles and gasoline-powered lawn mowers. Mobil sources are divided into two groups: road vehicles, which includes cars, trucks, buses; and non-road vehicles, which includes trains, planes, and lawn mowers.

Monitoring (monitor) - Measurement of air pollution is referred to as monitoring. EPA, state and local agencies measure the types and amounts of pollutants in community air. The 1990 Clean Air Act requires certain large polluters to perform enhanced monitoring to provide an accurate picture of their pollutant releases. Enhanced monitoring programs may include keeping records on materials used by the source, periodic inspections, and installation of continuous emission monitoring systems (CEMS). Continuous emission monitoring systems will measure, on a continuous basis, how much pollution is being released into the air The 1990 Clean Air Act requires states to monitor community air in polluted areas to check on whether the areas are being cleaned up according to schedules set out in the law.

N

Nitrogen oxides (NOx) - a criteria air pollutant. Nitrogen oxides are produced from burning fuels, including gasoline and coal. Nitrogen oxides are smog formers, which react with volatile organic compounds to form smog. Nitrogen oxides are also major components of acid rain.

N

Nonattainment area - a geographic area in which the level of a criteria air pollutant is higher than the level allowed by the federal standards. A single geographic area may have acceptable levels of one criteria air pollutant but unacceptable levels of one or more other criteria air pollutants; thus, an area can be both an attainment and nonattainment area at the same time. It has been estimated that 60% of Americans live in nonattainment areas.

O

Offset - a method used in the 1990 Clean Air Act Amendments to give companies which own or operate large (major) sources in nonattainment areas flexibility in meeting overall pollution reduction requirements. If the owner or operator of the source wishes to increase the release of a criteria air pollutant, an offset (reduction of a somewhat greater amount of the same pollutant) must be obtained either at the same plant or by purchasing offsets from another company.

Oxygenated fuel (oxyfuel) - special type of gasoline, which burns more completely than regular gasoline in cold start conditions; more complete burning results in reduced production of carbon monoxide, a criteria air pollutant. In some parts of the country, carbon monoxide release from cars starting up in cold weather makes a major contribution to pollution. In these areas, gasoline refiners must market oxygenated fuels, which contain a higher oxygen content than regular gasoline. Some gasoline companies started selling oxyfuels in cities with carbon monoxide problems before the 1990 Clean Air Act Amendments were passed.

Ozone - a gas which is a variety of oxygen. The oxygen gas found in the air consists of two oxygen atoms stuck together; this is molecular oxygen. Ozone consists of three oxygen atoms stuck together into an ozone molecule. Ozone occurs in nature; it produces the sharp smell you notice near a lightning strike. High concentrations of ozone gas are found in a layer of the atmosphere - the stratosphere - high above the Earth. Stratospheric ozone shields the Earth against harmful rays from the sun, particularly ultraviolet B. Smog's main component is ozone; this ground-level ozone is a product of reactions among chemicals produced by burning coal, gasoline and other fuels, and chemicals found in products including solvents, paints, hairsprays, etc.

Ozone hole - a thin place in the ozone layer located in the stratosphere high above the Earth. Stratospheric ozone has been linked to the destruction of stratospheric ozone by CFCs and related chemicals. The 1990 Clean Air Act Amendments has provisions to reduce and eliminate ozone destroying chemicals' (production and use). Ozone holes have been found above Antarctica and above Canada and northern parts of the United States, as well as above northern Europe.

P

Particulates; particulate matter (PM-10) - a criteria air pollutant. Particulate matter includes dust, soot and other tiny bits of solid materials that are released into and move around in the air. Particulates are produced by many sources, including burning of diesel fuels by trucks and buses, incineration of garbage, mixing and application of fertilizers and pesticides, road construction, industrial processes such as steelmaking, mining operations, agricultural burning (field and slash burning), and operation of fireplaces and woodstoves. Particulate pollution can cause eye, nose and throat irritation and other health problems.

P

Permit - a document that resembles a license. Required by the Clean Air Act for big (major) sources of air pollution, such as power plants, chemical factories and, in some cases, smaller polluters. Usually permits will be given out by states, but if EPA has disapproved part or all of a state permit program, EPA will give out the permits in that state. The 1990 Clean Air Act Amendments include requirements for permit applications, including provisions for members of the public to participate in state and EPA reviews of permit applications. Permit will have, in one place, information on all the regulated pollutants. Permits include information on which pollutants are being released, how much the source is allowed to release, and the program that will be used to meet pollutant release requirements. Permits are required both for the operation of plants (operating permits) and for the construction of new plants. The 1990 Clean Air Act Amendments introduced a nationwide permit system for air pollution control.

Permit fees - fees paid by businesses to have a permit. Permit fees are like the fees drivers pay to register their cars. The money from permit fees will help pay for state air pollution control activities.

Pollutants (pollution) - unwanted chemicals or other materials found in the air. Pollutants can harm health, the environment and property. Many air pollutants occur as gases or vapors, but some are very tiny solid particles: dust, smoke or soot.

Primary standard - a pollution limit based on health effects. Primary standards are set for criteria air pollutants.

R

Reformulated gasoline - specially refined gasoline with low levels of smog forming volatile organic compounds (VOCs) and low levels of hazardous air pollutants. The 1990 Clean Air Act Amendments requires sale of reformulated gasoline in the nine smoggiest areas. Reformulated gasolines were sold in several smoggy areas even before the 1990 Clean Air Act Amendments were passed.

S

Secondary standard - a pollution limit based on environmental effects such as damage to property, plants, visibility, etc. Secondary standards are set for criteria air pollutants.

SMOG - a mixture of pollutants, principally ground-level ozone, produced by chemical reactions in the air involving smog-forming chemicals. A major portion of smog is formed from the burning of petroleum-based fuels such as gasoline. Other smog forms from volatile organic compounds that are found in products such as paints and solvents. Smog can harm health, damage the environment and cause poor visibility. Major smog occurrences are often linked to heavy motor vehicle traffic, sunshine, high temperatures and calm winds, or temperature inversion (weather condition in which warm air is trapped close to the ground instead of rising). Smog is often worse away from the source of the smog-forming chemicals, since the chemical reactions that result in smog occur in the sky while the reacting chemicals are being blown away from their sources by winds.

S

Source - any place or object from which pollutants are released. A source can be a power plant, factory, dry cleaning business, gas station or farm. Cars, trucks and other motor vehicles are sources, and consumer products and machines used in industry can be sources too. Sources that stay in one place are referred to as stationary sources; sources that move around, such as cars or planes, are called mobile sources.

State implementation plan (SIP) - a detailed description of the program a state will use to carry out the responsibilities under the Clean Air Act. State implementation plans are collections of the regulations used by a state to reduce air pollution. The Clean Air Act requires that EPA approve each state implementation plan. Members of the public are given opportunities to participate in review and approval of state implementation plans.

Stationary source - a place or object from which pollutants are released and which does not move around. Stationary sources include power plants, gas stations, incinerators, houses etc.

Stratosphere - part of the atmosphere, the gases that encircle the Earth. The stratosphere is a layer of the atmosphere 9-31 miles above the Earth. Ozone in the stratosphere filters out harmful sun rays, including a type of sunlight called ultraviolet B, which has been linked to health and environmental damage.

Sulfur dioxide - a criteria air pollutant. Sulfur dioxide is a gas produced by burning coal, most notably in power plants. Some industrial processes, such as production of paper and smelting of metals, produce sulfur dioxide. Sulfur dioxide is closely related to sulfuric acid, a strong acid. Sulfur dioxide plays an important role in the production of acid rain.

T

Temperature inversion - weather condition that is often associated with serious smog. In a temperature inversion, warm air doesn't rise because it is trapped near the ground by a layer of heavy colder air above it. Pollutants in the warm air, especially smog and smog-forming chemicals, including volatile organic compounds are trapped close to the ground. As people continue driving, and sources other than motor vehicles continue to release smog-forming pollutants into the air, the smog level keeps getting worse.

U

Ultraviolet B (UVB) - a type of sunlight. The ozone in the stratosphere, high above the Earth, filters out ultraviolet B rays and keeps them from reaching the Earth. Ultraviolet B exposure has been associated with skin cancer, eye cataracts and damage to the environment. Thinning of the ozone layer in the stratosphere results in increased amounts of ultraviolet B reaching the Earth.

V

Vapor recovery nozzles - special gas pump nozzles that will reduce release of gasoline vapor into the air when people put gas in their cars. There are several types of vapor recovery nozzles, so nozzles may look different at different gas stations. The 1990 Clean Air Act Amendments requires installation of vapor recovery nozzles at gas stations in smoggy areas.

V

Volatile organic compounds (VOCs) - Organic chemicals all contain the element carbon (C); organic chemicals are the basic chemicals found in living things and in products derived from living things, such as coal, petroleum and refined petroleum products. Many of the organic chemicals we use do not occur in nature, but were synthesized by chemists in laboratories. Volatile chemicals produce vapors readily; at room temperature and normal atmospheric pressure, vapors escape easily from volatile liquid chemicals. Volatile organic chemicals include gasoline, industrial chemicals such as benzene, solvents such as toluene and xylene, and tetrachloroethylene (perchloroethylene, the principal dry cleaning solvent). Many volatile organic chemicals are also hazardous air pollutants; for example, benzene causes cancer.

Appendix C

CUSTOMER PROBLEM ANALYSIS CHECK SHEET

ENGINE CONTROL System Check Sheet

Inspector's Name ______________

Customer's name		Model and model year	
Driver's name		Frame no.	
Date vehicle brought in		Engine model	
License no.		Odometer reading	Km miles

Problem Symptoms	☐ Engines does not Start	☐ Engine does not crank ☐ No initial combustion ☐ No complete combustion
	☐ Difficult to Start	☐ Engine cranks slowly ☐ Other ______
	☐ Poor idling	☐ Incorrect first idle ☐ Idling rpm is abnormal [☐ High ☐ Low (rpm)] ☐ Rough idling ☐ Other ______
	☐ Poor Driveability	☐ Hesitation ☐ Back fire ☐ Muffler explosion (after-fire) ☐ Surging ☐ Knocking ☐ Other ______
	☐ Engine Stall	☐ Soon after starting ☐ After accelerator pedal depressed ☐ After accelerator pedal released ☐ During A/C operation ☐ Shifting from N to D ☐ Other ______
	☐ Others	

Dates Poblem Occurred		
Problem Frequency		☐ Constant ☐ Sometimes (times per day/month) ☐ Once only ☐ Other ______
Conditions When Problem Occurs	Weather	☐ Fine ☐ Cloudy ☐ Rainy ☐ Snowy ☐ Various/Other ______
	Outdoor Temperature	☐ Hot ☐ Warm ☐ Cool ☐ Cold (approx. ____ °F/ ____ °C)
	Place	☐ Highway ☐ Suburbs ☐ Inner City ☐ Uphill ☐ Downhill ☐ Rough road ☐ Other ______
	Engine Temp.	☐ Cold ☐ Warming up ☐ After warming up ☐ Any temp. ☐ Other ____
	Engine Operation	☐ Starting ☐ Just after starting [min.] ☐ Idling ☐ Racing ☐ Driving ☐ Constant speed ☐ Acceleration ☐ Deceleration ☐ A/C switch ON/OFF ☐ Other ______

Condition of Malfunction Indicator Lamp		☐ Remains on ☐ Sometimes lights up ☐ Does not light up
Diagnostic Trouble Code Inspection	Normal Mode (Precheck)	☐ Normal ☐ Malfunction code(s) [code] ☐ Freezed frame data [ ]
	Check Mode	☐ Normal ☐ Malfunction code(s) [code] ☐ Freezed frame data [ ]