BASIC CLEAN AIR CAR COURSE STUDENT WORKBOOK

Important Notice to Students Taking the Basic Clean Air Car Course

This course is a minimum of 68 hours in length, and will cover Smog Check inspection procedures for the Basic, and Change of Ownership Smog Check Inspection program areas of the State. In addition, the course will cover On-Board Diagnostic II (OBD II) system theory and operation, and advanced scan tool diagnostics.

This course **is not a beginner course. Prior** to attending this course, it is expected that you will have already completed BAR's Electrical/Electronic course, and the Engine Performance course (or hold ASE certification in these areas). If this is the first automotive course you are attending to become a licensed Smog Check technician, then you will probably have a difficult time understanding the advanced automotive theories and concepts of this course. **BAR recommends that you take the above noted courses prior to taking this course.**

To pass this course, you will need to:

- Successfully complete all the laboratory examinations
- Score 70% (or better) on all the written examinations.
- Attend all course hours.

Second Chance Tests:
BAR certified schools are allowed to adopt a policy for "second chance" examinations, if they so choose. The school is under **no obligation** to provide students who fail **any** initial examination a second chance examination. The BAR policy allows students that fail an initial examination to re-take that examination once without having to repeat the course. If a student fails the initial examination <u>and</u> the second chance examination, **they must repeat the *complete* Basic Clean Air Car Course**. Second chance examination must be completed within 60 days of the course completion date, or the student cannot receive credit for the course.

Attendance:
BAR certified schools are allowed to adopt a policy for missed attendance, if they so choose. The school is under **no obligation** to allow students who miss some portion of the course, to make up that missed course time at some later date. The BAR policy allows students that miss a portion of the course, to make up that missed time at a later date without having to repeat the course. Schools that have adopted this policy **are required** to cover with the student the **exact material** that was covered during the time the student missed that portion of the course. Make up attendance must be completed within 60 days of the course completion date, or the student cannot receive credit for the course.

Photo Identification:
Instructors are required by BAR to examine your California Driver License/ID, or Smog Check license badge on the first day of class. If you do not have one of these forms of identification you may continue to participate in the course. You will not be given BAR credit for the course until you obtain one of the above noted forms of identification, and display it to the instructor. Students must present to the instructor an acceptable form of identification within 60 days of the course completion date, or the student will not receive credit for the course.

TABLE OF CONTENT

- NOTICE -

To become a successful Smog Check technician, students must understand theory and operation of "basic" emission control components and how vehicle air pollution is created. Because many vehicles requiring a Smog Check inspection still use older technology (e.g., carburetors, thermostatic air cleaners, etc.), students must be familiar with the basic principles included in this Basic Clean Air Car Student Workbook. Students should be able to apply these principles to today's more advanced emission control systems.

Mitchell 1 Publications provided the core information contained in this Student Workbook and is responsible for the information and the diagnostic and repair procedures. The contents of this Workbook are not to be reproduced for any other use unless specifically authorized by Mitchell 1.

The California Bureau of Automotive Repair (BAR) has strived to ensure the accuracy of this Workbook. The materials developed by BAR are subject to change as the course evolves in the future. If the reader finds inaccuracies in the document, please contact Wayne Brumett or Marty Gunn at the following e-mail addresses: **wayne_brumett@dca.ca.gov** or **martin_gunn@dca.ca.gov.**

RULES AND REGULATIONS

Reading Assignment: Using the book titled "Automotive Repair – Laws and Regulations," read: Article 5 - 7, 9 - 12 (see table of contents for page numbers), of the California Code of Regulations (CCR), Title 16, Chapter 33.

REVIEW QUESTIONS

Answer the following questions using the material you have just read. In addition, include in your answer the CCR reference number for each of your answers

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Example:

What is the definition of a "work order?"

Answer: ***<u>A document that contains the estimate and memorializes the customers' authorizations for a specific job.</u>***

CCR section where information was found: ***<u>3352(b)</u>*** *?*

Hint: Use the table of contents to find applicable sections to answer the questions. Your instructor will review how to determine the alpha/numerical hierarchy of regulations [e.g., 3352(b)]

Questions:

1. What percentage of the original estimate are you allowed to exceed without obtaining the customer's consent for additional cost for repairs?

Answer: ____

CCR section where information was found: 33____________?

2. A customer has left his vehicle in front of your smog shop's door before business hours with a note bearing his/her name and phone number on it, and a request for a smog inspection. Do you need further authorization for repairs before performing the inspection?

Answer: ____

CCR section where information was found: 33____________?

3. When a technician is renewing his/her Smog Check technician license, how long is the renewed license valid?

Answer: ____

CCR section where information was found: 33____________?

Law And Regulations – (con't)

4. A smog check technician is repairing a failing vehicle by replacing parts and using diagnostic strategies that have worked on similar emission failures on other vehicles. This diagnostic approach is not based on diagnostic procedures from that specific vehicle manufacturer or known industry trade standards. Is this person following regulations? If no, what procedure should that technician be using?"

Answer: ____

CCR section where information was found: 33__________?

5. May a Test-Only station refer a customer, whose vehicle failed an emissions test at their station, to a specific repair facility?

Answer: ____

CCR section where information was found: 33__________?

6. What action(s) may the bureau take against a licensee, if that licensee fraudulently issues a certificate of compliance?

Answer: ____

CCR section where information was found: 33__________?

7. All vehicles having a Smog Check inspection performed, must be tested and repaired in an approved work area. What is the exception?

Answer: ____

CCR section where information was found: 33__________?

8. May a Test and Repair station have ownership of a Test-Only station 60 statute miles away?

Answer: ____

CCR section where information was found: 33__________?

9. How long must a Smog Check station maintain records of station activity (i.e. repair orders, vehicle inspection reports, etc.)?

Answer: ____

CCR section where answer was found: 33__________?

10. What must a Smog Check Test and Repair station do prior to performing an emissions inspection of a customer's vehicle, if they do not have the appropriate scan tool to repair that specific vehicle?

Answer: ____

CCR section where answer was found: 33__________?

SMOG: CAUSE AND EFFECT

This section deals with smog; how it is caused, and what it's effects are. It is important to know not only how to repair vehicles to reduce smog, but what smog is and how it's reduction will benefit us all.

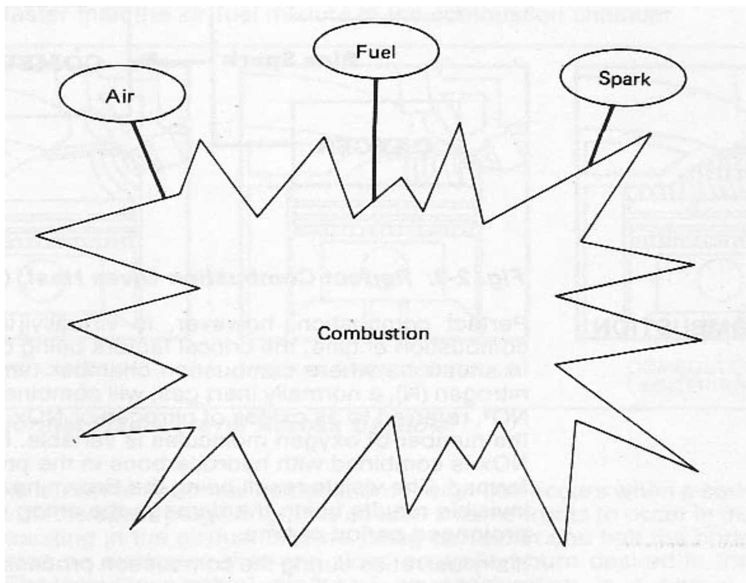
As a Smog Check technician, you are in contact with the public who look upon you as an expert in vehicle pollution control. It is important that you have a firm understanding of California's smog problem. You are a frontline representative of the Smog Check program, the public will look to you to explain to them how repair of their vehicle will reduce air pollution and benefit them.

To successfully complete this section the student must demonstrate knowledge of:

1. Combustion process in internal combustion engines.
2. Formation and effects of carbon monoxide (CO).
3. Formation and effects of hydrocarbons (HC).
4. Formation and effects of oxides of nitrogen (NO_x).
5. Federal and State efforts to control air pollutants from vehicles.

COMBUSTION

The power an engine produces to move a vehicle is the result of a series of chemical reactions between fuel, air, and heat. A mixture of fuel and air will react and expand very quickly when an ignition source (in the form of a spark) is introduced to the mixture. This is the process of combustion. During total combustion, all of the fuel in the mixture will be burned. *See Fig. 2-2.*



Total combustion; however, can only occur if the proper ratio of fuel and air is ignited using an adequate ignition source (i.e. adequate voltage and spark duration). This is especially true of automotive gasoline engines. A mixture of fuel and air is delivered to a cylinder of the engine, then the mixture is compressed by the movement of the cylinder's piston. Compressing the mixture increases its temperature and pressure. When an ignition source is introduced into the cylinder in the form of a spark from a spark plug, combustion occurs.

During the combustion process, fuel, which consists of hydrocarbon (HC) molecules, is broken down into hydrogen (H) and carbon (C) molecules, and combined with the oxygen (O_2) which is drawn in through the air filter. During this process, if the air/fuel ratio is correct, adequate oxygen will exist to combine with all of the split hydrogen and carbon molecules. The results of this oxidizing process consist of heat, water (1-120) and carbon dioxide (CO_2), the by-products of perfect combustion. *See Fig. 2-3.*

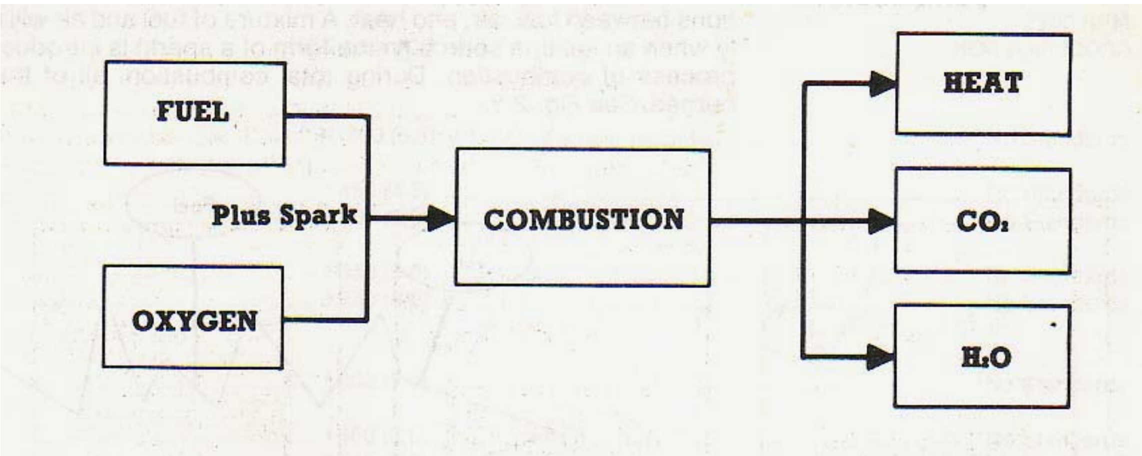


Fig. 2-3: Perfect Combustion Gives Heat, CO_2 & Water

ACTUAL COMBUSTION

Perfect combustion, however, is virtually impossible to achieve in today's internal combustion engine, the critical factors being combustion temperature and air/fuel ratios. In situations where combustion chamber temperatures are allowed to exceed 2500F, nitrogen (N), a normally inert gas, will combine with oxygen molecules to form NO, $N0_2$ or $N0_3$, referred to as oxides of nitrogen or NO_x for short. The small x in NOx indicating that the number of oxygen molecules is variable. NO_x in itself is not harmful; however, when NOx is combined with hydrocarbons in the presence of sunlight, photochemical smog is formed. The visible result being the brown haze over the skyline of many large cities. The invisible results being the damage the smog causes to nature and human health over a prolonged period of time.

If air/fuel ratios during the combustion process are not maintained as close to the stoichiometric ratio of 14.71 (by weight) as possible, the results are the by-products of imperfect combustion; hydrocarbons (in the form of raw gas) and carbon monoxide. If the air/fuel mixture is allowed to run on the lean side of the stoichiometric ratio (14.71), there will not be sufficient fuel in the combustion chamber to carry a smooth flame front across the combustion chamber. In effect, the flame front is starved for fuel and dies out.

In the reverse situation, if the air/fuel mixture is allowed to run on the rich side of the stoichiometric ratio, there will be an insufficient amount of oxygen molecules to combine with the hydrocarbon molecules. This will leave an unburned quantity of fuel in the combustion chamber to be pushed out of the cylinder during the engines exhaust stroke.

The quality of the combustion process depends upon many other factors as well: the type and quality of fuel, the density and quantity of air, the heat caused by compression, and the temperature increase caused by the spark. Today's engines have a variety of systems which monitor and control these variables. Automobile manufacturers are striving to achieve total combustion. If total combustion were to occur, an engine would be highly efficient and would release very few pollutants.

Because total combustion in an automotive engine has yet to be achieved, manufacturer's have also added systems to the engine which convert its emitted pollutants into non-hazardous liquids and gases. Increased emission pollutants and poor driveability may result from a malfunctioning emission control system or device.

FLAME TRAVEL

Although the combustion process is often thought of as a controlled explosion in the combustion chamber, in actuality combustion is more of a slow-burn process, with a flame front beginning at the spark plug and progressing evenly outward toward the cylinder walls. For example: the air/fuel mixture in the combustion chamber takes about 3/1,000 second to burn. This is a relatively slow process compared to an equal amount of gunpowder which takes about 1/50,000 second to burn. In other words, gunpowder burns 150 times faster than the air/fuel mixture in the combustion chamber.

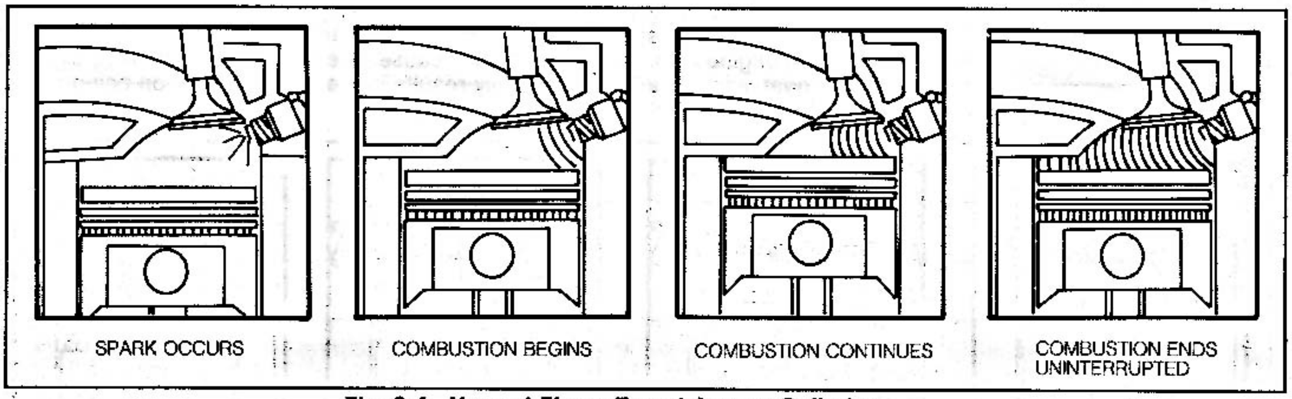


Fig. 2-4: Normal Flame Travel Across Cylinder

Preignition:
Preignition is a form of abnormal combustion. Preignition occurs when a source of ignition occurs prior to the spark plug firing. This causes 2 flame fronts to occur in the combustion chamber, resulting in the air/fuel mixture being burned in one half the normal time. This almost creates an explosion rather than the slow, controlled burn desired in the combustion chamber. The resulting "rattle" or "ping" on acceleration is a typical symptom of preignition.

Preignition occurs when a glowing piece of carbon, an excessively hot exhaust valve, or jagged edge of the combustion chamber becomes heated enough to begin the combustion process before the spark plug fires. Preignition is most commonly caused by poor quality fuel being used in a high compression engine. In severe cases, preignition can occur even after the ignition switch has been turned off. This is especially true of an engine which has been severely overheated. This chugging, rattling after-run condition is called dieseling.

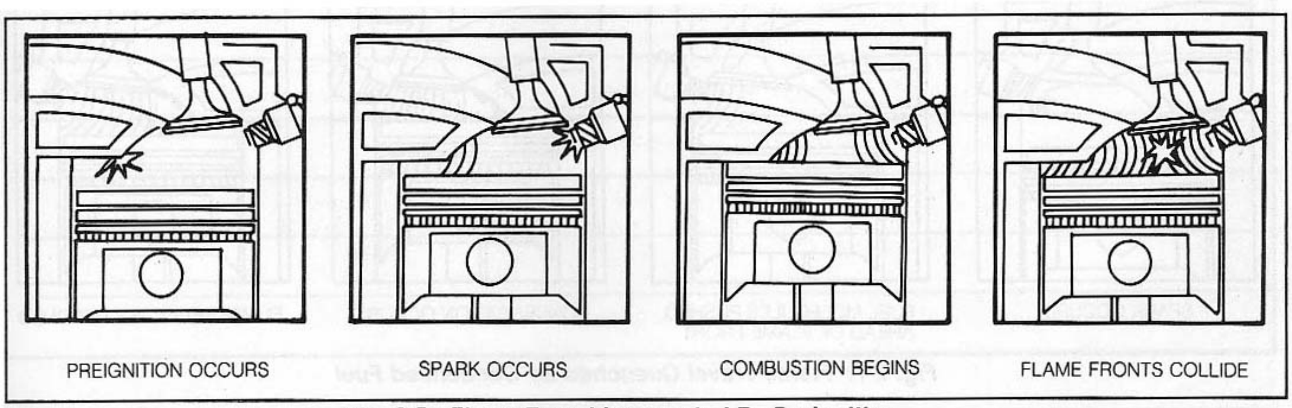


Fig. 2-5: Flame Travel Interrupted By Preignition

Detonation:
Detonation is another form of abnormal combustion and is often confused with preignition. Detonation occurs when excessive temperature in the combustion chamber causes a second source of ignition to occur after the spark plug has fired. Ideally, maximum combustion pressure should occur just after the piston reaches TDC. Detonation causes power output loss due to the erratic timing of peak combustion chamber pressure.

When detonation occurs, a knocking or hammering noise may be heard. However, detonation that occurs at high speed generally cannot be heard due to engine and road noise caused during engine load. Severe detonation causes the top of the piston to be exposed to extreme heat, and if unchecked, usually results in the top of the piston being melted and/or blown through.

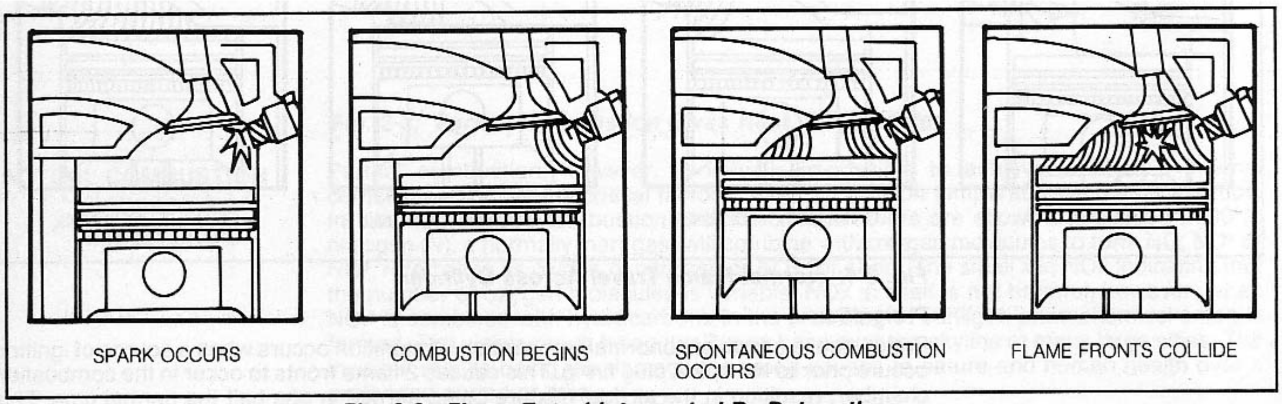


Fig. 2-6: Flame Travel Interrupted By Detonation

Quenching:
During the combustion process, unburned fuel molecules contact the relatively cool surface of the combustion chamber. Heat is removed from the gasses that contact the metal surfaces that are surrounded by the cooling system (water jacket). These cooled gasses are below ignition kindling temperature and will not burn during combustion. Reducing the gas temperature below ignition is known as "quenching". When the exhaust valve opens, burnt and quenched gasses leave the cylinder to enter the exhaust system and atmosphere.

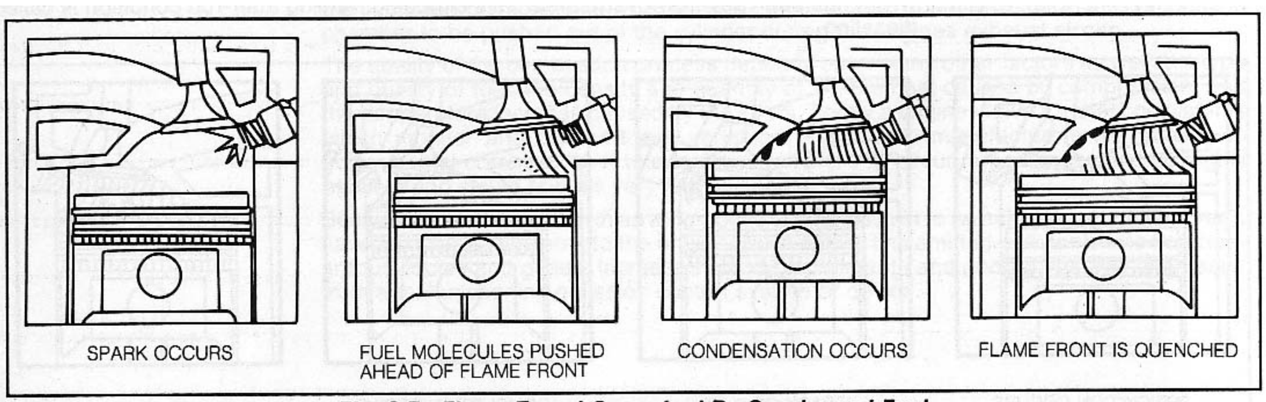


Fig. 2-7: Flame Travel Quenched By Condensed Fuel

(above article reprinted with permission from Mitchell 1)

CALIFORNIA'S AIR POLUTION PROBLEM

According to the California Air Resources Board *(*February 22, 2007), air pollution continues to be an important public health concern. A number of air pollutants, coming out of a variety of industrial processes, impact the health of California residents. Air monitoring shows that over 90 percent of Californians breathe unhealthy levels of one or more air pollutants during some part of the year. The California Air Resources Board (ARB) establishes health-based ambient air quality standards to identify outdoor pollutant levels that are considered safe for the public - including those individuals most sensitive to the effects of air pollution, such as children and the elderly.

Air pollution may be a contributing factor in the many deaths from heart and lung diseases in our state each year. Furthermore, The American Academy of Pediatrics tells us smog levels in most cities could damage children's lungs permanently.

The air contains many pollutants which can be divided into two major types: pollutants **directly emitted into the atmosphere** and pollutants produced **by chemical reactions in the air**, particularly in the presence of sunlight. Substantial amounts of airborne particles exist in both categories of pollutants.

Carbon monoxide (**CO**) is produced by the incomplete combustion (oxidation) of fossil fuels. Many tons of CO are emitted into the atmosphere each day, mostly from mobile sources. This pollutant tightly binds to hemoglobin, the oxygen-carrying protein in blood, reducing the amount of oxygen which reaches the heart, brain, and other body tissues.

Exposure to CO particularly endangers people with coronary artery disease, whose hearts already receive limited supplies of blood and oxygen. Even healthy people who are exposed to low levels of carbon monoxide can experience headaches, fatigue, and slow reflexes from lack of oxygen.

Ozone, a major ingredient in photochemical smog, is produced by **chemical reactions** that are triggered by sunlight and that involve the binding of nitrogen oxides (**NO_x**) and hydrocarbons (**HC**).

Ozone is a strong irritant that attacks the respiratory system, leading to the damage of lung tissue. Asthma, bronchitis and other respiratory ailments as well as cardiovascular disease are aggravated by exposure to ozone. A healthy person exposed to high concentrations may become nauseated or dizzy, may develop a headache or cough, or may experience a burning sensation in the chest.

As you can see, smog is a major health problem in California that affects us all. The Smog Check technician plays a major role in reducing vehicle pollutants through inspection and maintenance of our vehicle population.

REVIEW QUESTIONS

Answer the following questions from the reading material (pp. 5 - 11):

1. If perfect ideal combustion occurred, what two chemicals would be exhausted from the engine?

Answer: ____

2. Gasoline is a fossil fuel (hydrocarbon). What two atoms makeup this fuel?

Answer: ____

3. What typically causes detonation to occur?

Answer: ____

4. How does a glowing piece of carbon in the combustion chamber effect combustion?

Answer: ____

5. How is CO_2 created?

Answer: ____

6. What pollutant is formed by heat and pressure during the combustion process?

Answer: ____

7. Photochemical smog is made up of what chemicals that combine in sunlight?

Answer: ____

8. Carbon **monoxide** binds to hemoglobin in the blood and reduces what to the heart, brain and other body tissues?

Answer: ____

9. A healthy person exposed to high concentrations of ozone may experience what type of symptoms?

Answer: ____

10. What effect does quenching have on combustion?

Answer: ____

OPERATION AND IDENTIFICATION OF

VEHICLE EMISSION CONTROLS

In this section you will be learning: history, theory, operation, testing, maintenance, and BAR 97 EIS functional testing (when applicable) of emission control systems.

To successfully complete this section the student must demonstrate knowledge of:

1. Ability to identify a missing, modified, disconnected or defective emission control system.
2. Ability to perform a visual inspection of emission control systems for completeness and approved parts.
3. Ability to perform a functional test of the exhaust gas recirculation system, ignition timing,

   fillpipe restrictor, and check engine light (MIL).
4. Theory, operation, inspection, and testing of the following emission control systems:

   A. Positive crankcase ventilation.

   B Evaporative control.

   C. Air injection.

   D. Exhaust gas recirculation.

   E. Spark control.

   F . Catalytic converter (2 and 3 way).

   G. Air induction pre-heat.

EMISSION CONTROL SYSTEMS

CRANKCASE VENTILATION

Engines create blow-by fumes and vapors as products of normal combustion. Early engine designers were aware of the damage which these gases cause. Gathering in the crankcase, diluting and contaminating the oil - these impurities could not be allowed to remain there. Early designers took the easy way out, and simply vented the crankcase to the atmosphere. Today, we don't want these vapors floating around outside the crankcase either. The result is the development and widespread use of modern Positive Crankcase ventilation systems.

History & Development

Various vapors and gases are produced during normal engine operation. Some of these by-products of combustion are forced past the piston rings into the crankcase. If these gases and vapors are not vented, the engine oil will become contaminated and sludge will form. Additionally, pressure in the crankcase will increase at higher RPM's and if not vented, could force engine oil past seals and gaskets. To avoid these problems, crankcase ventilation systems were installed on all internal combustion engines.

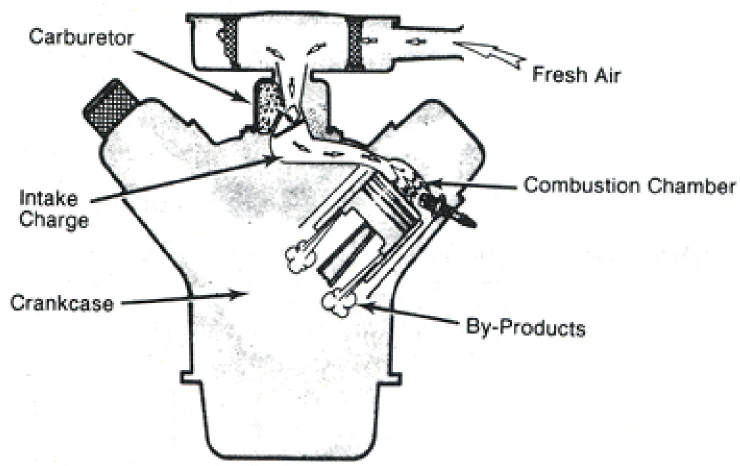


Fig. 9-1: By-Products of Combustion Enter Crankcase During Normal Engine Operation

The first method of crankcase ventilation was the road draft tube. On vehicles using this system, the crankcase is fitted with a vent. This vent is usually located in the valve cover, but it may be at any point on the engine open to crankcase vapors and pressure. A tube is attached to this vent which runs to the bottom of the engine (or in front of a carburetor intake). Airflow past the end of the tube creates a vacuum which draws gases out of the crankcase. As these gases are removed, fresh air enters the crankcase through a vented oil filler cap or breather. This fresh air not only replaces vented gases, but helps to keep fumes and vapors suspended until they are removed.
This type of system has two drawbacks. The first drawback is that the system only works at peak efficiency when the vehicle is at ,speed. Even then, unstable airflow and vacuum lowers the efficiency. At speeds below 20-25 MPH, vacuum at the road draft tube is to low to draw out fumes. This allows fuel vapors to remain in the crankcase, promoting sludge formation, diluting the oil and reducing its ability to properly lubricate the engine. The second drawback with this system, and for our purposes the more important of the two, is that vapors drawn out of the crankcase are vented directly to the atmosphere. This creates unwanted emissions and contributes to the air pollution problem. This was the main reason for the development of mandatory use of PCV systems on all non-commercial vehicles.

These unreliable systems led to the development of the first "Positive" Crankcase Ventilation (PCV) systems. Used, mostly on military and commercial vehicles, they first appeared in the 1950's. The main purpose of the system was to ensure sludge was reduced and oil lubricating qualities maintained.

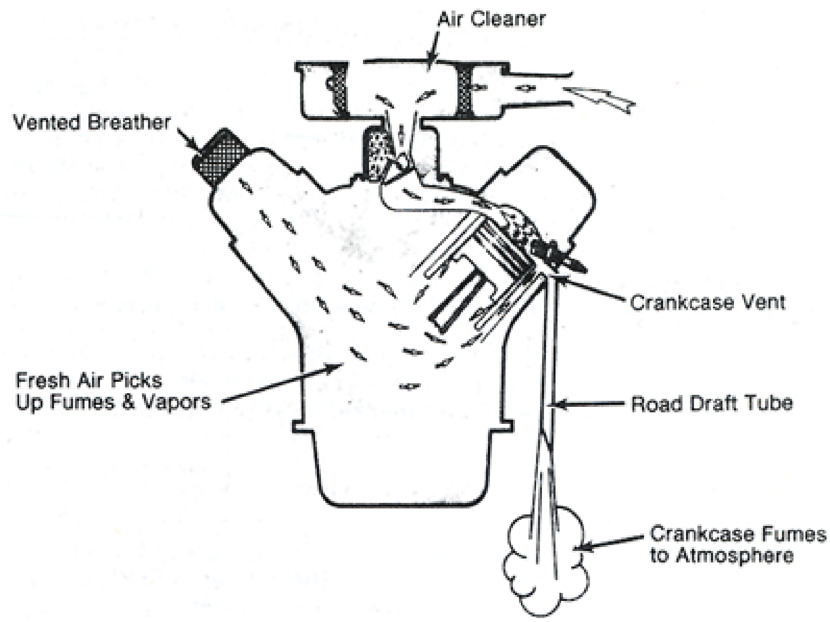


Fig. 9-2: A Typical Road Draft Tube Ventilation System

20% OF EMISSIONS

The automobile engine fell under scrutiny in the early 1960's as a source of air pollution. Research indicated that automobiles, as a group, were responsible for a major portion of the air pollution in this country. Of the emissions produced by non-PCV equipped vehicles, about 20% are from crankcase vapors.

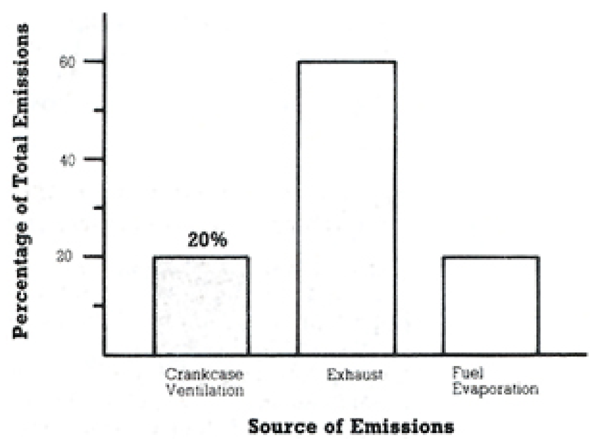


Fig. 9-3: Percentage of Total Emissions From a Non-PCV Equipped Vehicle

DESCRIPTION

This research led to government legislation. California was first, requiring PCV systems in 1961 on passenger cars. Federal regulations required PCV systems on all cars as of 1963.

A Positive Crankcase Ventilation (PCV) system routes crankcase gases to the intake system where they are drawn into the combustion chamber and burned. Actually, a PCV system is quite simple. A breather (air vent) is placed in the valve cover or top of the engine. It allows fresh air into the crankcase and also functions as a separator, condensing some of the fumes and draining them back into the crankcase. A one-way valve (PCV valve) is placed in the valve cover or side of the block. It is connected by a tube to engine vacuum at the base of the carburetor or, intake manifold. As engine vacuum drops, spring tension opens the PCV valve and crankcase vapors are drawn in and burned. The vapor flow into the intake manifold can be adjusted by varying the strength of the spring in the PCV valve and the design of the valve itself.

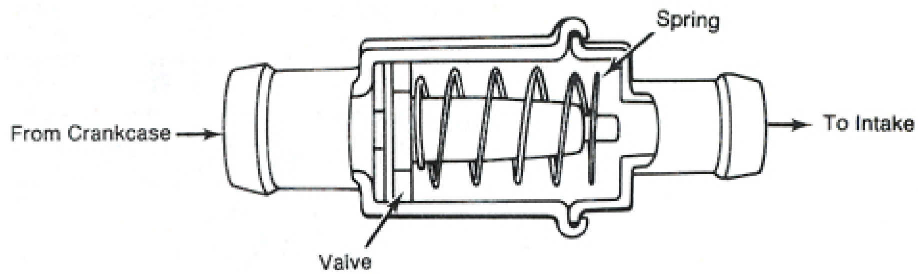


Fig. 9-4: Cutaway View of a Typical PCV Valve

This type of a ventilation system is beneficial in a number of ways. First, it routes crankcase vapors into the engine instead of into the atmosphere. Secondly, vacuum in the intake manifold is stronger, more reliable, and much more predictable than that created by a road draft tube. For this reason, some manufacturers began using PCV systems in noncommercial vehicles long before they were required by law. Chevrolet, for instance, installed PCV systems as early as 1955.

OPERATION

PCV Systems

Two distinct types of PCV systems have been used in the industry, the open system and the closed system. The difference between the two is the breather which allows air into the crankcase. When this breather is vented to the atmosphere, the system is considered open.

Under full throttle conditions, crankcase pressures build up rapidly while vacuum levels drop. Without a vacuum signal, the PCV valve closes, forcing this pressure to go out through the breather. This is true of any PCV system, open or closed. The problem with the open system is that, under these conditions, crankcase fumes and vapors are vented to the atmosphere.

A "closed" PCV system solves this problem by connecting the breather to the air cleaner. When crankcase pressures are excessive, fumes and vapors forced out the breather go into the air cleaner, through the carburetor, and are burned in the engine. In 1968, federal legislation was passed requiring the use of closed systems on all vehicles. So, as of the 1969 model year, all vehicles sold in the U.S were equipped with closed PCV systems.

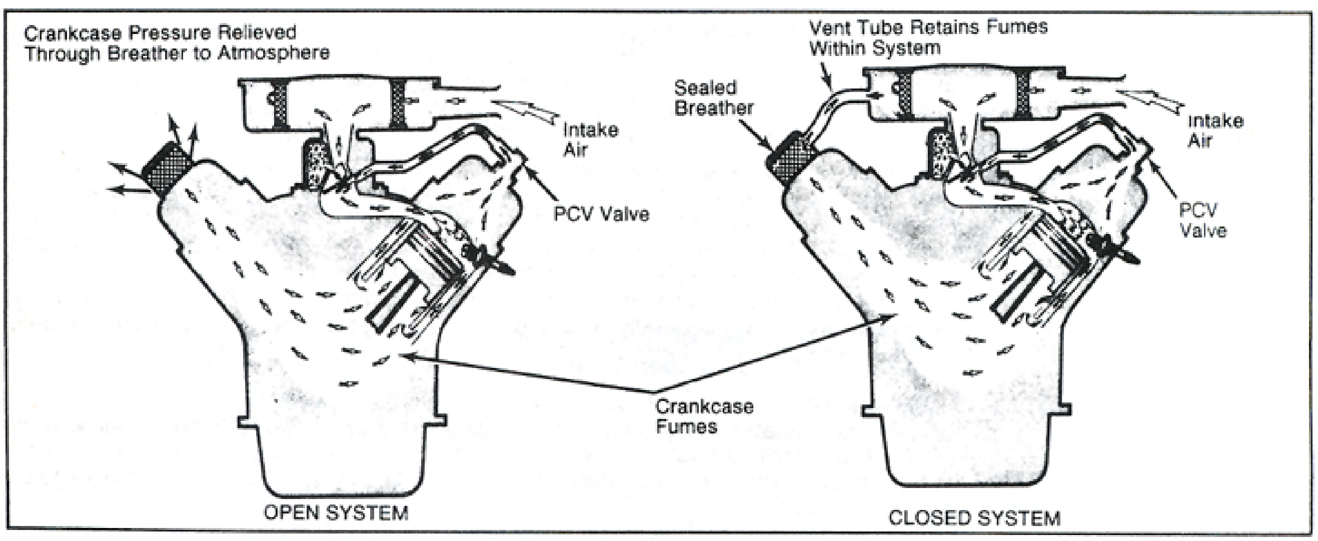


Fig. 9-5 Comparison of Open and Closed PCV Systems

PCV Valves

The function of all PCV valves, regardless of manufacture or application, is basically the same. They control the flow of crankcase fumes into the intake manifold while, at the same time, preventing gases or flames from traveling in the opposite direction.

When an engine is at idle, the vacuum signal to the valve is high. Under such conditions, spring pressure is overcome and the valve opens. A small orifice in the valve allows a metered volume of gas to pass into the intake manifold. By choosing the valve spring and tapering the valve orifice, a designer can tailor the volume and timing of vapor flow for any engine application. These specifications are determined by the manufacturer and vary with each engine.

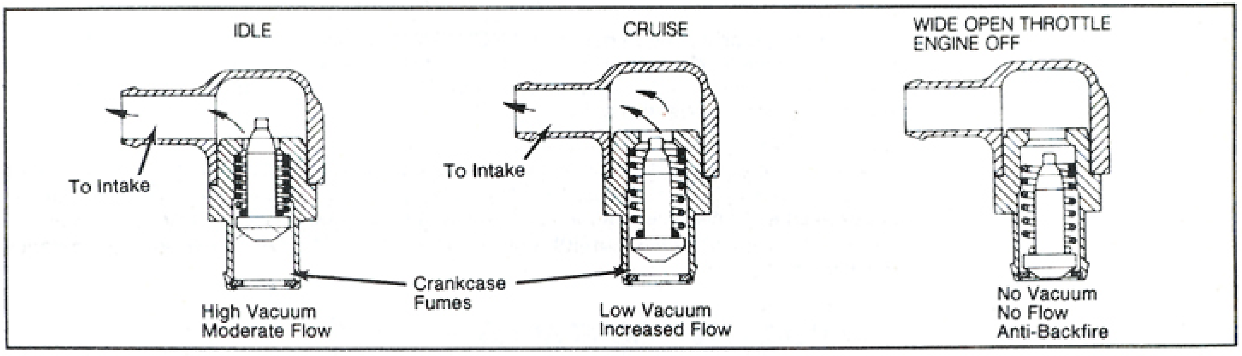


Fig. 9-6: PCV Valve Operation Under Different Vacuum Conditions

As engine speed increases and vacuum level drops, the valve opening is. changed by spring pressure. Full flow is allowed. At full throttle, when vacuum drops to zero and crankcase pressures build the fastest, vapor flow through the valve is cutoff completely. Crankcase fumes (vapors, gases) are forced out through the oil cap or breather, through the air cleaner and into the cylinders where they are burned.

If the engine backfires, flames travel up the intake manifold into the PCV hose. The pressure of the backfire snaps the PCV valve closed, and prevents the flames from reaching the flammable vapors in the crankcase. Without the PCV valve in the system, vapors in the crankcase could explode!

TESTING PROCEDURES

PCV Orifice Systems

Some diesel and gasoline engines do not use a PCV valve. Instead, a carefully-sized hole (orifice) is placed in the system. This hole is large enough to let vapors be pulled through at idle. When too much vapor is being produced, the excess flows back through the breather tube into the intake system (like a standard system does at full throttle). The orifice also prevents backfire flames from entering the crankcase.

PCV systems should be checked at regular intervals of between 12,000 and 30,000 miles, depending on the system. As a rule, the earlier systems (before 1975) should be checked more frequently than the later ones. More important than mileage, however, is engine operation. The system should be checked whenever stalling, rough, idle, or other condition indicating a ventilation system malfunction occurs.

Although variations do exist, the basic design and function of all crankcase ventilation systems is the same. So, generally speaking, the following procedures may be used to determine proper operation of any system.

RPM Drop Test

Attach a tachometer. Bring engine to normal operating temperature. With engine at idle, pinch off or block ventilation tube between the PCV Valve and vacuum source. Engine speed should drop 50 RPM or more. If not, check the valve and system for blockage and clean as necessary:

Vacuum Test

1) With the engine idling at normal operating temperature, disconnect the PCV valve from the rocker cover. If the valve is not plugged, a hissing noise will be heard as air passes through it. A strong vacuum should be felt when a finger is placed over the valve inlet.

2) Reinstall the valve assembly and remove the crankcase breather or oil filler cap. With the engine running at idle, loosely hold a piece of stiff paper over the opening. Within 60 seconds, the paper should be sucked against the opening with noticeable force.

3) Stop engine and remove the valve. A clicking or rattling noise should be heard when the valve is shaken. If not, the valve should be replaced.

4) If test results are correct, system is operating properly. If the system fails any test, replace the indicated component and repeat the tests. If the system still fails any test, clean system thoroughly.

MAINTENANCE PCV systems are normally trouble free, but should be cleaned and checked at every tune-up. The hoses must be clean inside, so blow them out with compressed air if necessary. Route hoses so they' do not get kinked or burned.

PCV Valve

Most manufacturers recommend that PCV valves be replaced rather than cleaned. They are inexpensive and stocked in most parts stores. However, if a new valve is not available, clean the old one in solvent and make sure the check valve rattles. Do not operate the engine without a valve in place.

Breather Filter

There are two basic types of PCV filters; a disposable type (located in air cleaner housing) and a wire mesh type. Replace the disposable type when discolored or clogged. You can clean the mesh filter is solvent. After cleaning turn it upside down and fill it with engine oil. Position filter so excess oil drains thoroughly through the vent nipple, then reinstall it on the engine.

EVAPORATIVE CONTROLS

Gasoline is very volatile, which means in addition to being highly flammable, it evaporates quite easily. Picture a car parked on a hot, sunny street. The gas tank and carburetor float bowl are full of gasoline. As the sun beats down; temperatures in the gas tank and under the hood begin to rise. Some of the fuel evaporates If the tank and float bowl were sealed, pressures could easily build to unsafe levels. Ventilation of the tank and the carburetor are absolutely necessary. But venting these fumes into the atmosphere, as was done for many years, contributes to the air pollution problem or pushes fuel out of the tank onto the street. Evaporative Emissions Control systems were developed to prevent these problems.

HISTORY & DEVELOPMENT In order for an automobile fuel system to operate properly, the fuel tank and carburetor must be ventilated. Originally, the fuel system was vented to the atmosphere. Later, when automotive emissions were recognized as one of the primary sources of man-made pollution, it was found that about 20% of automotive HC emissions come from these vents.

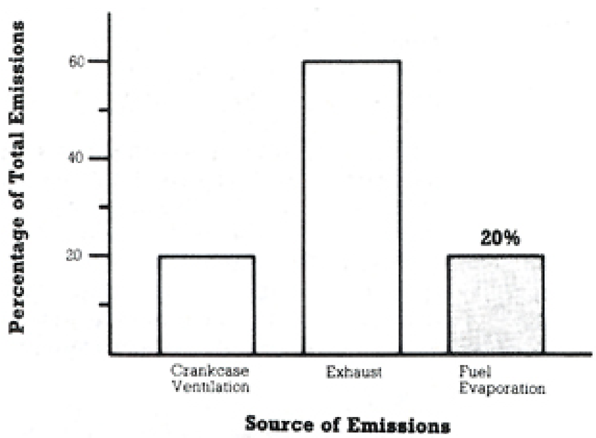


Fig. 9-7: Percentage of Total Emissions From a Non-Pollution Controlled Vehicle

This led to legislation prohibiting venting of fuel vapors into the atmosphere. California acted first, in 1970. The rest of the nation followed in 1971.

The challenge presented by this ruling was to prevent evaporative emissions from reaching the atmosphere, while still allowing atmospheric pressure to influence carburetor operation and fresh air to reach the fuel tank. Fuel Evaporative Emissions Control systems were developed to meet this demand.

DECRIPTION The function of a Fuel Evaporative Emissions Control system is to allow for proper fuel system ventilation while preventing vented fumes from reaching the atmosphere. This means vapors must be caught and stored while the engine is off, when most fuel evaporation occurs. Later, when the engine is started, these fumes removed from storage and burned. In most systems; storage is provided by an activated charcoal (or carbon) canister. On a few early systems, charcoal canisters are not used. Instead, fuel fumes are vented into the PCV system and stored inside the crankcase.

OPERATION The main components of a fuel evaporation system are a redesigned fuel filler cap and fuel tank, a vapor separator and a charcoal canister. Although variations do exist between manufacturers; basic operation is the same for all systems.

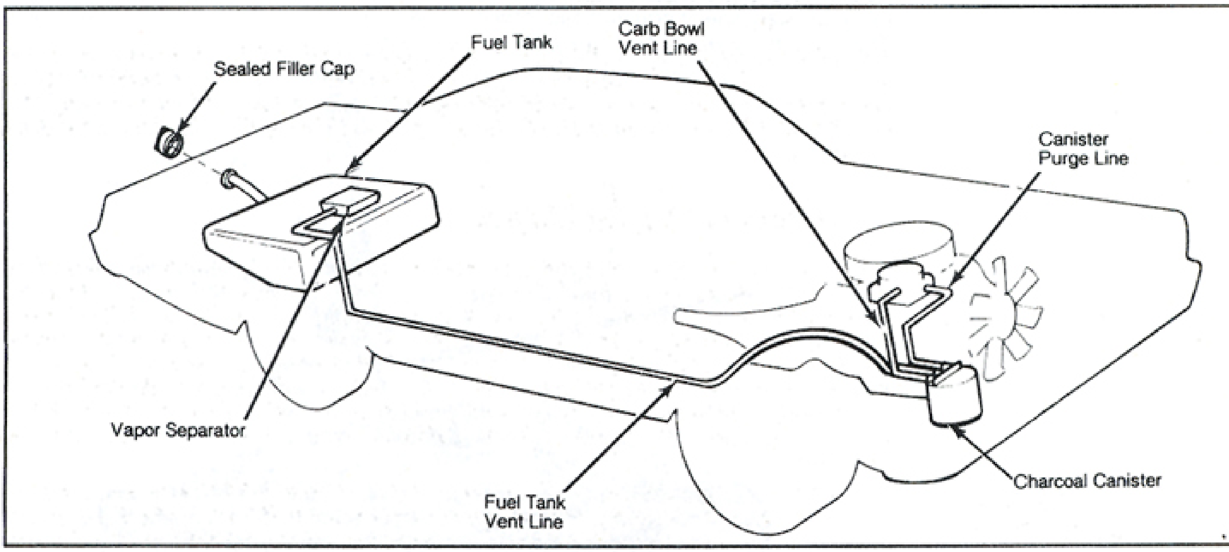


Fig. 9-8: Typical Evaporative Emissions Control System

Fuel Filler Cap
Directly vented fuel filler caps are no longer. used. All fuel filler caps are sealed. Most of them, though sealed, are equipped with pressure/vacuum relief valves. These valves prevent damage to the fuel tank in case of a malfunctioning vent line. If pressure in the tank builds to unsafe levels (due to expanding fuel), the relief valve opens. Otherwise, the tank could explode. If vacuum is too great (due to suction of the fuel pump), the valve opens to keep the tank from collapsing. Most valves are set to operate at about 1.0 psi pressure and .5 in. Hg vacuum. The exact relief point varies, but the function is the same.

Fuel Tank Design
Pre-1970 vehicles release excess fuel vapors through the fuel filler cap and vent tubes in the' fuel tank. The vent tube allows air to enter the tank as fuel is burned. In addition, it serves as an overflow if high temperatures cause fuel to expand beyond the capacity of the tank.
With the fuel filler cap sealed, all ventilation of the fuel tank is through the vent tube. To eliminate possible overflow, tanks were redesigned. Two methods have been used: the addition of a thermal expansion tank inside the main fuel tank, and, a new tank shape which results in a residual 10-12% air space in a "full" tank.

Thermal Expansion Tank - Used on some early evaporative control systems, a thermal expansion tank is a small auxiliary tank, usually about 1 or 2 gallons, installed inside the main tank. Most are open to fuel at the bottom, with one or two small vent holes in the top. The size of these vents restrict tank filling to a much slower rate than that of the main tank. this way, the expansion tank remains relatively empty when the main tank is filled, allowing extra space for any fuel expansion which may occur.

Redesigned Fuel Tank - Most systems solve the problem of fuel evaporation by redesigning the main tank to allow for extra air space. Fuel filler necks on early vehicles mount flush with the tank to allow for complete filling. Very little air space is left in the tank to allow for thermal expansion of fuel. The filler neck is moved below the top of the tank, and extends slightly into the tank so it cannot be filled completely. This design reserves the air space needed to allow for fuel expansion. In some cases, the tank is designed with a raised top, or bulge, to ensure the extra space.

Some systems with an expansion tank add a fill control tube to the filler neck. If fuel is added above the level of. the extension, it runs up the tube and into the filler neck. This cuts off fuel from the automatic fuel nozzles used in most gas stations.

As an extra safety precaution, most systems now incorporate a rollover valve. Located in the vapor vent line, it prevents fuel flow if the vehicle should be turned over in an accident. The average valve will hold pressure to about 3 psi.

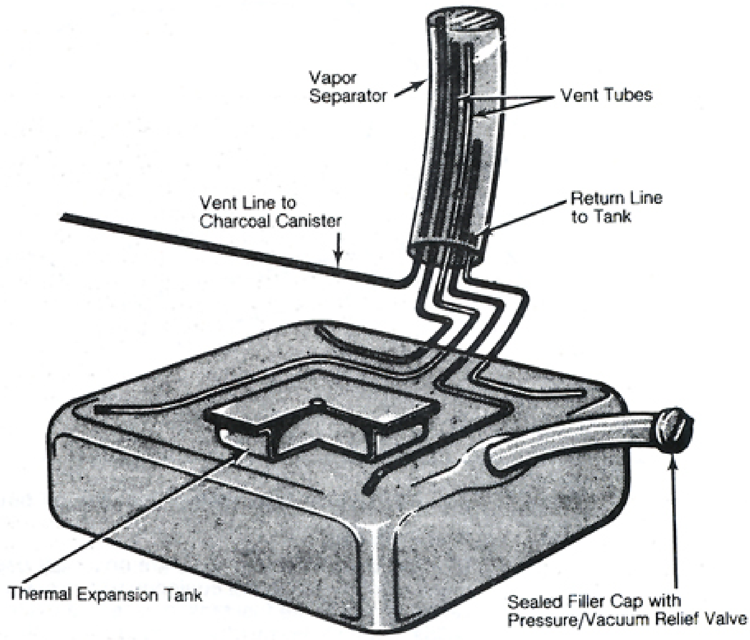


Fig. 9-9: Fuel System With Thermal Expansion Tank and Vapor Separator. Note Relative Lengths of Vent Tubes in Separator.

Vapor Separator

To avoid fuel evaporation, into the atmosphere, standard fuel tank vent tubes were redesigned. Most closed ventilation systems use three or four vent lines in the top of the tank so that at least one line is always above fuel level. This guarantees tank ventilation at any vehicle, angle. On some systems, a vapor separator is used to keep liquid fuel in the tank and out of the vent tube to the charcoal canister.

Though various designs of vapor separator have been used, basic operation is the same: Fuel vapors rise into the separator through vent tubes. Liquid fuel and condensation are drained back to the tank while vapors escape through a vent line to the charcoal canister. This vent line extends to the highest point in the separator and has a small orifice to prevent the transfer of liquid fuel to the canister. On some cars, the vent line runs all the way up the rear roof pillars to ensure vapor separation. The fuel return line, on the other hand, is the shortest in the separator, allowing for fuel drainage back to the tank. The separator itself usually consists of a sealed metal pipe, mounted vertically beside the fuel tank. In other applications, it may be mounted horizontally or inside of the fuel tank itself.

In later years, refinements in basic system design have resulted in downsizing and, in most cases, the complete elimination of a vapor separator. Downsized separators include separator valves and separators mounted on the tank, the latter replacing the large pipe and numerous tubes of earlier systems with a foam separator element and a single vent line to the charcoal canister.

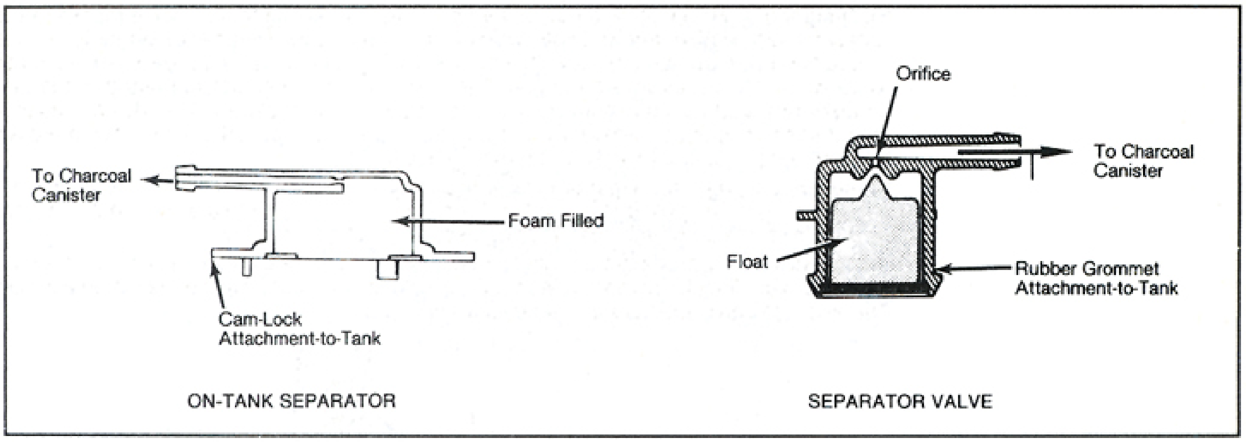


Fig. 9-10: On-Tank Separator & Vapor Separator Valve

Where the vapor separator has been completely eliminated, its function is served by fuel tank design and/or liquid check valves. Fuel tank design replaces the separator by allowing extra air space for vapor condensation within the tank, so that only fuel vapors reach the, vent tube. Check valves of various designs prevent liquid flow to the canister. One design consists of a needle and float assembly, mounted on the fuel tank or in the vapor return line. If liquid fuel enters the valve, the float rises, forcing the needle onto a seat and shutting off flow to the canister. One-way valves and rollover check valves serve the same basic function in slightly different ways.

Carburetor Ventilation
Carburetor evaporation is contained in one of three ways:

- Closed Fuel Bowl Ventilation
- Internal Venting
- Fuel injection

Closed Ventilation - The first method used to contain carburetor evaporative emissions was a simple change in float bowl design. Instead of venting the bowl directly to the atmosphere, the vent was redesigned as a hose fitting and moved to the side of the fuel bowl. A vent hose runs from this fitting to the charcoal canister where vapors are stored. On systems without charcoal canisters, the carburetor is vented into the PCV system at either the sealed breather or the air cleaner housing.

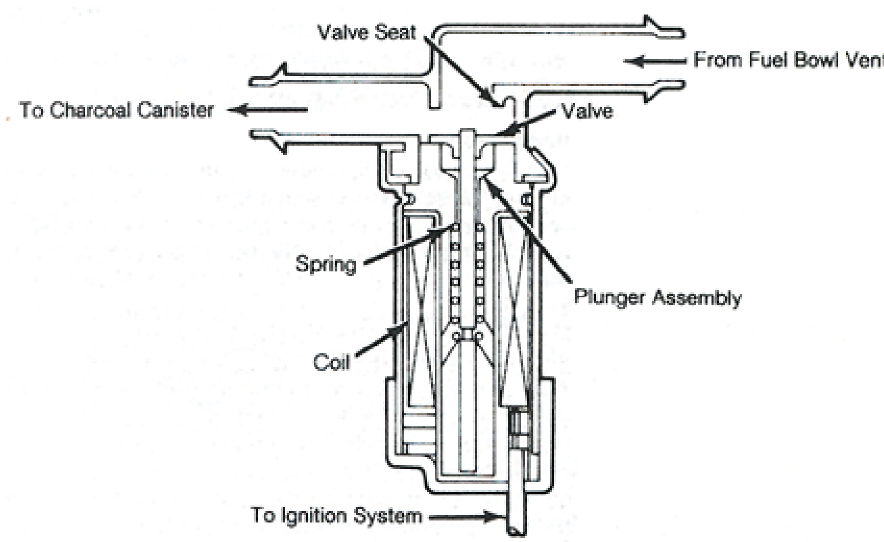


Fig. 9-11: Electrically-Operated Fuel Bowl Vent Valve

On some systems, a control valve is installed in the vapor line between the fuel bowl and the charcoal canister. The purpose of this valve is to prevent float bowl ventilation to the canister during periods of engine operation. The valve closes off the vent line in response to either an electrical signal or manifold vacuum. If a vacuum-operated valve is used, it usually has a temperature override circuit as well.

Electrically-operated valves are supplied with voltage whenever the engine is running. This closes the valve, preventing ventilation to the canister. With this type of vent valve, fuel bowl ventilation can only occur with the engine off.

Vacuum-operated vent valves close in response to a vacuum signal from the intake manifold. Whenever the engine is running, this vacuum signal closes the valve, preventing fuel bowl ventilation. Most vacuum-operated valves include a temperature override which blocks the bowl vent line whenever vent valve temperature is below about 90°F (30°C). Above temperatures of around 120°F (50°C), the override allows ventilation, unless otherwise prevented by the manifold vacuum signal.

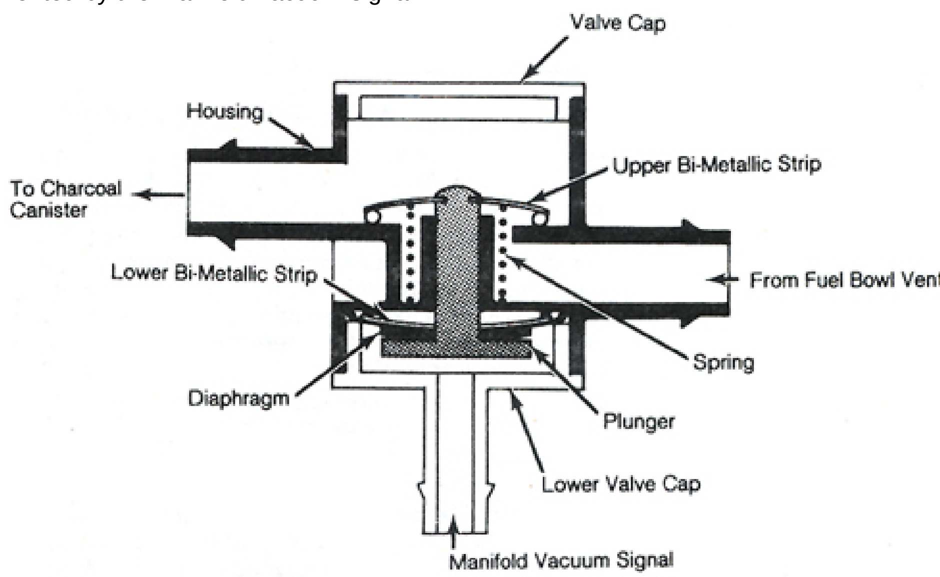


Fig. 9-12: Vacuum-Operated Fuel Bowl Vent Valve with Temperature Override

Internal Fuel Bowl Ventilation - More recently,- internal bowl vents have been developed to control evaporative emissions. Fuel vapors are retained in the air cleaner assembly. When the engine is started, fumes are drawn into the cylinders and burned. Most carburetors with internal vents have external vents as well. The external vents are not always used, though, so you may find the vent tubes are plugged. When the external vents are used, vapors are controlled by a hose to the canister as on other externally vented systems.

Fuel Injection - The use of a fuel injection system is the most efficient means of controlling evaporative emissions because it eliminates the fuel bowl. Only the fuel tank needs to be ventilated on a fuel injection system. Since there is no open contact with the atmosphere and fuel is always under pressure, vapors do not form and ventilation is not needed.

Charcoal Canister

Most fuel evaporation systems use a charcoal canister to store fuel evaporative vapors. Some early systems routed fuel vapors to the sealed breather. Here they combined with crankcase fumes and were controlled by the PCV system. This design was used on a very limited basis, and all vehicles since 1973 have used charcoal canisters.

Canister Function - The charcoal canister consists of a fuel-resistant nylon or plastic container filled with activate charcoal granules. Fuel vapors are attracted to (adsorbed) and stored by the charcoal until "purged". Purging. refers to the process of pulling fresh air through the canister, which forces the fuel vapors out of the charcoal. Some vehicles with large fuel tanks (or dual tanks) use two canisters to insure that sufficient volume is available for vapors.

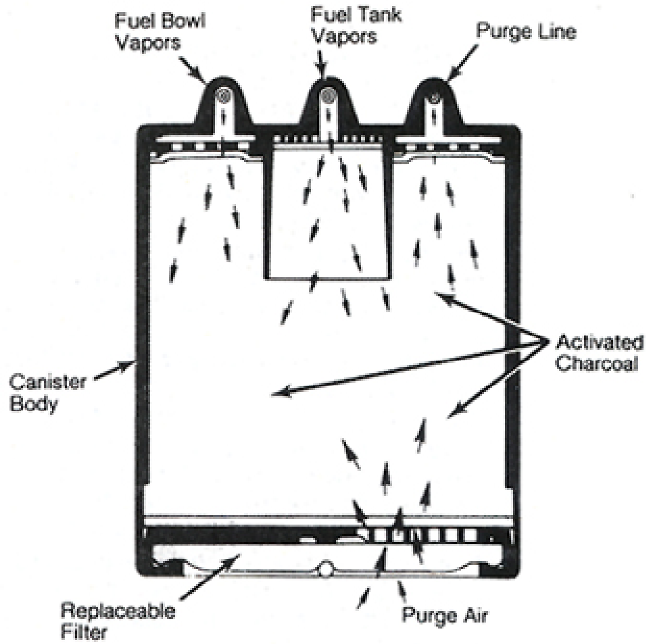


Fig. 9-13: A Typical Charcoal Canister

Vent lines from the fuel tank and carburetor fuel bowl usually join together and go to the top of the canister. These lines carry fuel fumes into the canister for storage when the engine is off. An additional line in the canister leads to the air cleaner, carburetor ported vacuum or the PCV hose. This is the vent or purge line. A third line at the canister may be used. It is attached to a small round valve, called the purge valve.

Most charcoal canisters include a replaceable air filter in the bottom of the can. Fresh air enters the canister through this filter to carry off the vapors when purging takes place. On some systems, air enters from the top of the canister and travels down a central tube to the air space below the filter.

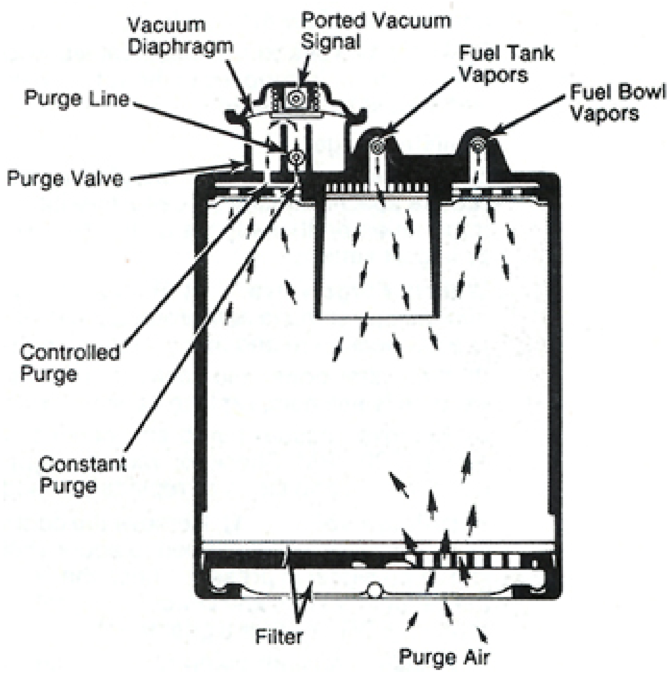


Fig. 9-14: Charcoal Canister With Purge Valve

Canister Purge - A basic charcoal canister has a single purge line from the top of the canister to the air cleaner, PCV line or intake manifold. When the engine starts, manifold vacuum draws fuel vapors out of the canister. This purging action restores the activated charcoal. The only control over canister purging is the location of the vacuum source. To gain more control, a purge valve is used. This valve allows the manufacturer to tailor purge timing, as well as the volume of canister fumes purged, to suit a particular application or engine operating condition.

The purge valve is vacuum operated. It usually has two vacuum lines connected to it, one to intake manifold vacuum, the other to ported carburetor vacuum. The manifold line is the purge line, while the ported line controls the valve. When the engine is at idle, ported vacuum is low and a spring loaded diaphragm within the valve is closed. Vapor flow through the purge line is limited by an orifice within the valve. As the throttle opens, ported vacuum level increases and the diaphragm is pulled open. This permits maximum purging when the engine can handle the additional fumes.

Purge valves can be tailored to a particular application by altering spring rate and size of the purge openings. Additional control is gained by altering the signal timing with vacuum switches or valves. In some later; systems, the vacuum signal to the purge valve is controlled by an on-board computer:

TESTING

The Fuel Evaporative Emissions Control system is generally dependable and does not usually require testing. However, fuel bowl vent valve operation may be checked as can charcoal canister purging action, if improper operation is suspected.

Fuel Bowl Vent Valves

Vacuum-Operated Valves - 1) Disconnect the vacuum line and 'both bowl vent lines from the valve and remove the valve. Attach a handheld vacuum pump to the vacuum connection of the valve; but do not apply vacuum.

2) blow through the valve. With no vacuum applied, air should flow through it. Apply a small vacuum signal to the valve. This should close the valve and block airflow.

3) If the valve is equipped with a temperature override, no air will pass through it, regardless of vacuum, if valve temperature is below 90°F (30°C). With valve temperature at or above 120°F (50°C), the valve should respond as in step 2). If the valve does not respond as indicated in any step, it is faulty and should be replaced.

Electrically Operated Valves - **1)** Disconnect valve wiring at the electrical connector. Disconnect both bowl vent dines from the valve and remove it. Blow through the valve. Air should easily flow through it.

2) Apply 12 volts to the electrical lead from the valve. Air should not pass through it as long as power is supplied to the valve: If the valve does not respond as indicated, it is faulty and should be replaced.

Canister Purge

Some late model canister purging systems are electrically-controlled. These systems require specific testing procedures which are beyond the scope of this manual. For further information on these types of systems, refer to a service and repair manual for domestic or import vehicles.

Without Purge Valve - **1)** Remove purge line from canister and attach a hand-held vacuum pump. Remove carburetor bowl vent line (if present) and fuel tank vent line. Plug vent line connection(s) and apply vacuum with pump. Canister should not hold vacuum.

2) If canister does hold vacuum, remove canister filter, (if equipped) and check again. If vacuum instill held, replace canister. If canister no longer holds vacuum, replace filter.

3) Remove vacuum pump and connect vent lines to canister. Start engine and run at about 1500 RPM. Check for vacuum signal at purge line. If signal is absent, check line for obstructions and clean or replace as needed.

With Purge Valve - **1)** Remove the control vacuum lien (to ported vacuum) from the purge valve. Bring engine speed to about 1500 RPM and check for a vacuum signal from this line. If no signal is present, check the line for blockage. If the line is clear, remove it from the vacuum source and check for signal there. If vacuum signal is still absent, check hose routing, EGR or other signal there.

2) Attach a vacuum pump to the control vacuum port. Apply vacuum: if the purge valve does not hold vacuum, replace the canister assembly. If vacuum holds, remove purge line and check for vacuum from line. If a vacuum signal is absent, check hose routing or PCV system.

3) Turn engine off. Disconnect fuel vent lines to canister. Plug vent line ports on valve. Attach vacuum pump at purge line port and apply vacuum. If canister holds vacuum, remove filter (if equipped) and try again. If canister still holds vacuum, replace canister. If vacuum is no longer held, replace filter.

MAINTENACE

Charcoal canisters are sealed units and virtually maintenance free. Replace the filter at the bottom of the canister if dirty, plugged, or damaged. Install new filter, making sure it is properly seated. Inspect canister for damage or cracks. Check for disconnected, misrouted, kinked or damaged hoses.

Note If the charcoal canister cracks, becomes saturated with fuel or is damaged in any way, it must be replaced as a complete assembly. Use only fuel-resistant hose when replacing any evaporative system hose.

AIR INJECTION

If the engines used to run our cars burned fuel with 100% efficiency, hydrocarbon emissions would not be a problem. However, engines are not perfect, and under the various conditions of operation there are times when a significant amount of fuel passes through the engine unburned. To control these emissions, we need to complete the burning process before the unburned fuel reaches the atmosphere. Air injection systems use the exhaust system for this purpose.

HISTORY & DEVELOPMENT

Internal combustion engines require fuel, oxygen and heat. Without any one of these three elements, combustion cannot occur. In an internal combustion engine, fuel is supplied from the carburetor or injection system; oxygen from the atmosphere and heat from the ignition system. Since automobile engines are not 100% efficient, a small amount of unburned fuel remains at the end of the combustion cycle to be expelled with the exhaust gases. This left-over fuel is a major source of HC and CO emissions. If combustion could be maintained until all fuel is burned, HC and CO levels would be significantly reduced. Heat in the exhaust system is sufficient to ignite an air/fuel mixture. Unburned fuel is present in the exhaust manifold along with traces of oxygen. With the three requirements of combustion met, some continued burning of excess fuel occurs. However, combustion is limited by the amount of oxygen present. This means that excess fuel is burnt in the exhaust system only until all the oxygen is gone. Air Injection systems were developed to provide extra oxygen in the exhaust system to complete the burning process.

DESCRIPTION

There are 2 basic air type emission systems. One uses an injection pump to supply air to the exhaust system. The other, known as pulse air system, is designed to use negative pressure pulses from the exhaust system to draw fresh air into the exhaust manifold.

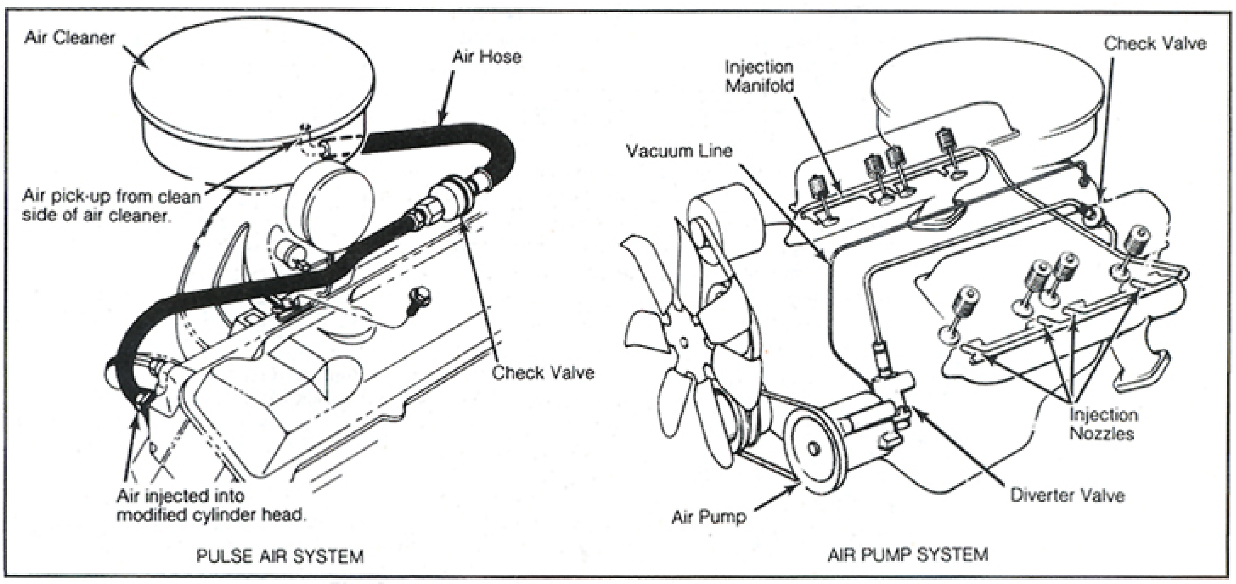


Fig. 9-15: Basic Air Injection

No matter which system is used, the purpose is the same. A controlled amount of fresh air is injected into the exhaust system so the combustion process can be completed. The result is a reduction of HC and CO emissions.

Air Pump System

Air Pump - The air pump system uses a belt-driven pump to pressurize air. This air is then routed, through pipes and/or hoses, to an air injection (distribution) rail or pipe. This injection rail or pipe is usually mounted on the exhaust manifold so that injected air enters close to the exhaust valves. This fresh supply of oxygen combines with any remaining fuel in the exhaust and is ignited by the heat of the exhaust manifold. Some systems also inject air into: the catalytic converter on initial start-up. This injection of air heats the converter due to flash burning of the exhaust inside the converter. The catalytic converter then can begin to operate sooner as designed:

NOTE Some air pump systems inject air into the intake manifold exhaust heat crossover passage or into special passages in the cylinder head, eliminating the need for injection rails or pipes.

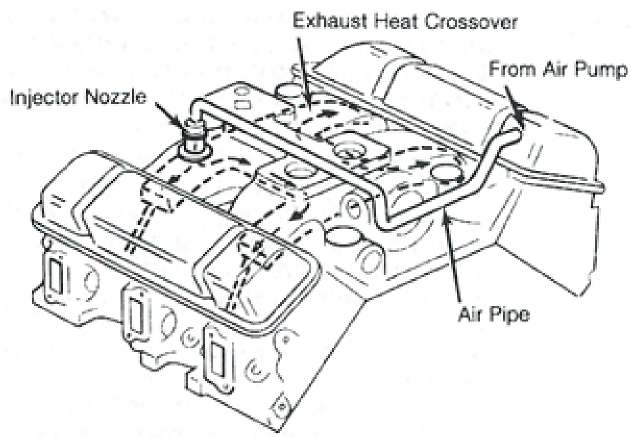


Fig. 9-16: Air injection Into Intake Manifold Exhaust Heat Crossover

In-Line Valves - Two valves are usually located in the air line between the pump and the exhaust manifold. One is a diverter valve, the other a one-way check valve. The diverter valve prevents backfires during rapid deceleration. Quickly closing the throttle at high engine speeds results- in a very rich air/fuel mixture. Since this mixture cannot be completely burned in the engine, the exhaust gases become very rich. When the air pump injects fresh air into this rich, exhaust stream, rapid combustion (backfiring) occurs. The diverter valve prevents these backfires by temporarily diverting air away from the exhaust system during rapid deceleration.

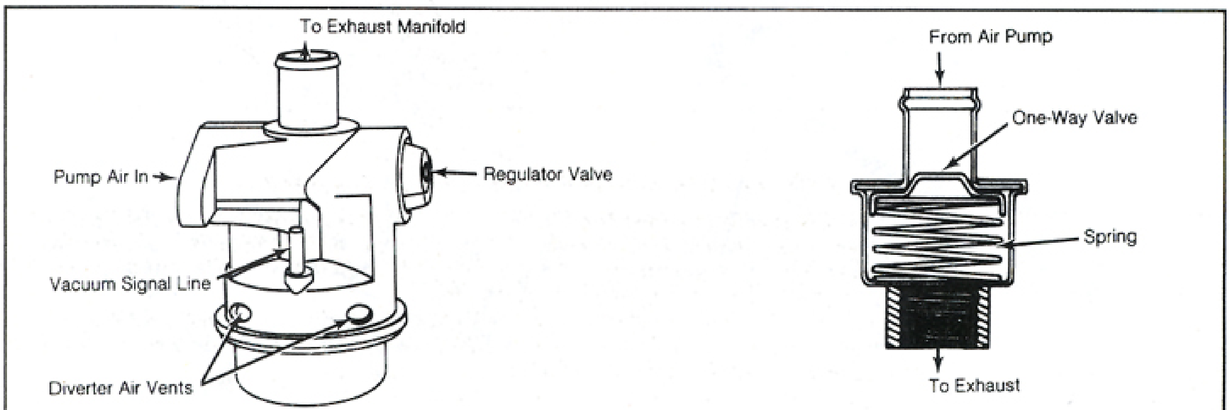


Fig. 3: Typical Diverter Valve

Fig. 4: Typical Air Pump System Check Valve

Fig. 9-17: Typical Diverter Valve & Air Pump System Check Valve

In the event of air pump failure, or exhaust system pressure exceeding the air injection system pressure, exhaust gases could be forced up the air injection pipe and into the injection system. This could cause extensive damage to the system and must be prevented. Check valves are located in the air injection lines to protect the system. A one-way check valve allows air into the manifold while preventing exhaust flow into the air injection system.

Pulse Air System

The pulse air system eliminates the need for an air pump and most of the associated hardware. Most systems consist of air delivery pipe(s), pulse valve(s) and check valve(s). See Fig. 9-15. The check valve performs the same function in this system as in the air pump system, that is, to prevent exhaust gases from' entering the air injection system.

Exhaust pressure is very high when the exhaust valves open, creating a wave of high pressure in the exhaust system. When the exhaust valves close, gases flowing out of the system cause a vacuum to form. The pulse air check valves are connected to the exhaust system so that this vacuum pulls fresh air into the system. The valve closes in response to high exhaust pressure peaks (exhaust valves open), preventing the flow of exhaust gas out through the air tube.

OPERATION

Air injection systems are of 2 types, air pump or pulse air. The typical air pump system consist of the pump, a diverter valve, a check valve and injection manifold(s) or pipe(s). In addition, an air pressure relief valve may be built into the air pump housing. The pulse air system is much simpler, consisting primarily of a pulse check valve assembly and air pipe(s),

Air Pump Injection

Air Injection Pump - The air pump is a belt-driven vane type pump, mounted to the engine in combination with other accessories. Air entering the pump is filtered by either an internal filtering device, a small auxiliary air cleaner or by the main fuel system air cleaner. In the latter design, an air hose or pipe is connected between the air intake of the pump and the clean air side of the air cleaner assembly.

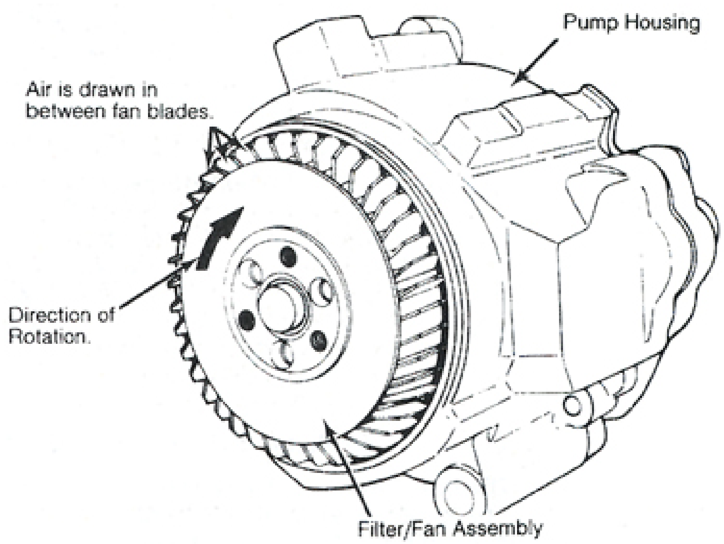


Fig. 9-18: Air Pump with Centrifugal Filter/Fan Assembly

The filter plumbing is eliminated when the internal design is used. By far the most popular design, it consists of a centrifugal filter/fan assembly which is mounted between the pump pulley and the air pump itself. Air is drawn in through the unit while dirt and debris are removed by the centrifugal action of the fan.

The air pump itself consists of the pump housing, an inner air cavity, a rotor and a vane assembly. As the vanes turn in the housing, air is drawn in through the intake port and pushed out through the exhaust port.

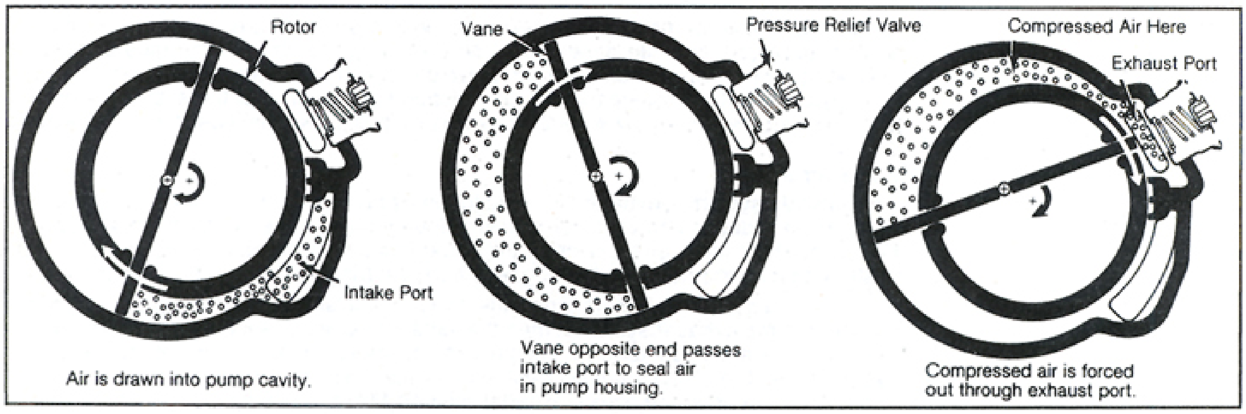


Fig. 9-19: Cutaway View of Air Pump Operation

The volume of air discharged by the pump changes with engine speed, while system pressure is controlled by a :pressure relief valve. Pressure will vary with the application, but it is normally under 5 psi. Pressure control is required to avoid excessive pressure at high engine speed and to limit the amount of air injected. This pressure relief function is built into the diverter valve on some systems. On others, a spring-loaded valve is included as apart of the air pump housing. When pressure in the pump exceeds a pre-set level, the relief valve spring compresses and the valve opens. Excess air passes through the valve into the atmosphere. With pump pressures again at a safe level, the relief valve closes and normal operation is resumed.

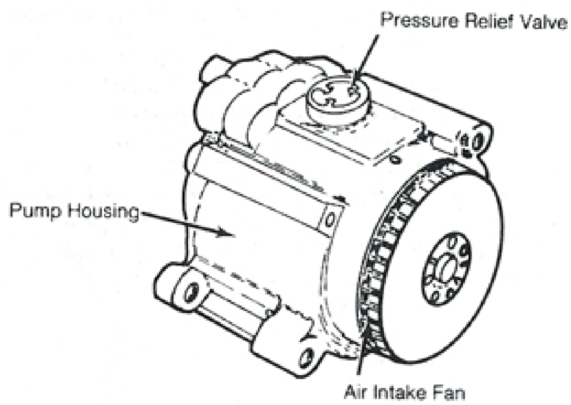


Fig. 9-20: Air Pump with Pressure Relief Valve

Diverter Valve - The diverter valve prevents exhaust system backfires during high speed deceleration. If air injection occurs at this time, the sudden introduction of oxygen into the hot, rich exhaust stream results in backfiring. The diverter valve prevents this by momentarily diverting air injection from the exhaust system. In addition, most diverter valves include a pressure relief valve to control system pressures. When this type of diverter/pressure relief valve is used, the built-in relief valve in the air pump housing is eliminated. Most diverter/pressure relief valves consist of 2 valves, either vacuum diaphragm or electronic solenoid controlled. These valves are connected together with a passageway running between them. The assembly has an inlet connection from the air pump and an outlet connection to the exhaust system. A manifold vacuum or electronic signal controls the valve. Some variations in basic design are used, but the function of the valve is the same.
During normal operation, pressurized air from the air pump passes through the diverter valve to the exhaust system. When the throttle is closed quickly at high speeds, a high manifold vacuum signal is produced. On vacuum controlled vehicles, this signal causes an imbalance between the 2 vacuum chambers in the diverter valve assembly. This causes the diaphragm to deflect, moving the valve plates and by-passing pressurized air to the atmosphere or air cleaner. A small orifice in the diaphragm balances the chambers in

about 2 to 3 seconds, restoring normal valve operation. Therefore air is diverted to the atmosphere for the first few seconds of deceleration only, when excessively rich air/fuel mixtures are liable to cause a backfire.

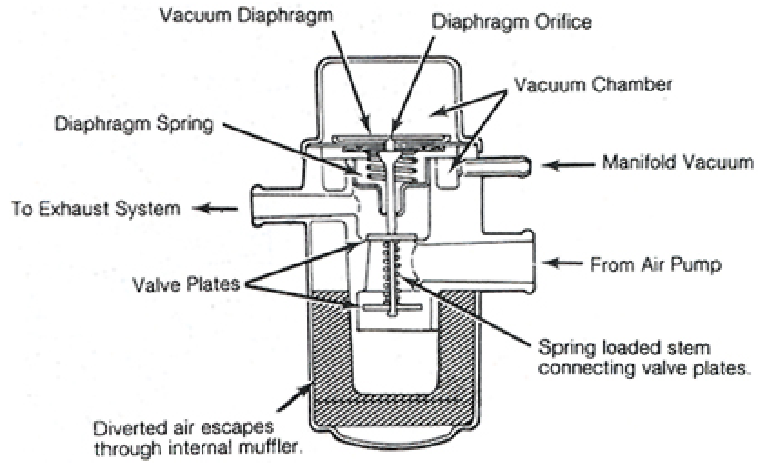


Fig. 9-21: Diverter Valve Operation with Valve Shown in By-Pass Mode

Excessively high air pressures are possible at high engine speeds. If a combination diverter/pressure relief valve is used, this excess pressure moves the lower valve plate off its seat. If a separate regulator valve is used (built into the diverter valve assembly), the spring pressure of the valve is overcome by excess pressure. Either way, correct air pressure is maintained in the system.

Variations to the basic design, including electronically controlled systems, function the same way as the typical diverter valve, diverting pump air during high speed deceleration. Some systems also use a gulp valve which diverts pressurized air into the intake manifold, where it also leans out the rich air/fuel mixture avoiding the backfire situation.
Another variation injects diverted air, under proper conditions, into the catalytic converter. This is done primarily to supply the converter (usually the second stage of a dual stage converter) with the oxygen properly convert HC and CO. Depending on operating conditions, pressurized air may be injected into the exhaust manifold, to the converter, or by-passed completely and diverted to the atmosphere.

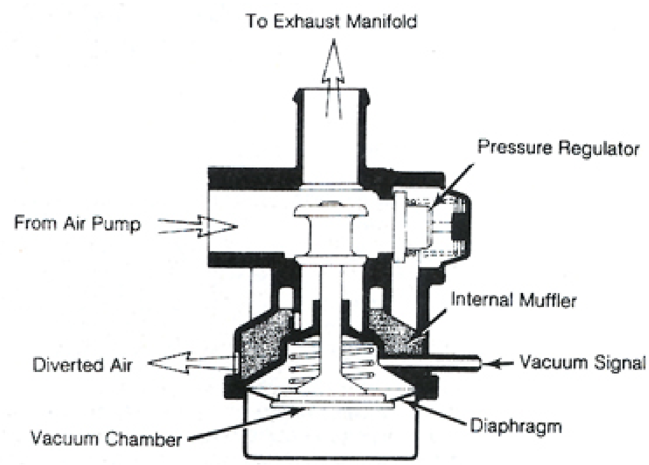


Fig. 9-22 Diverter Valve with Separate Built-1n Pressure Regulator

Diverter valve design has grown increasingly complex in the last few years. Separate valves were originally used to relieve pressure, divert air injection to air cleaner or manifold, or to sense deceleration. When sophisticated computers began to control valves all these functions were combined into one component. Modern designs contain 2 or more internal valves with vacuum and electrical control of air diversion. The greatly improved accuracy provided by these valves and the improvement in system efficiency, justify their increased complexity. These new valves are known as air management valves. Used mainly by General Motors, they vary greatly in specific control, but are all similar in that multiple air diversion functions are performed by a single valve assembly. See Fig. 9-23.

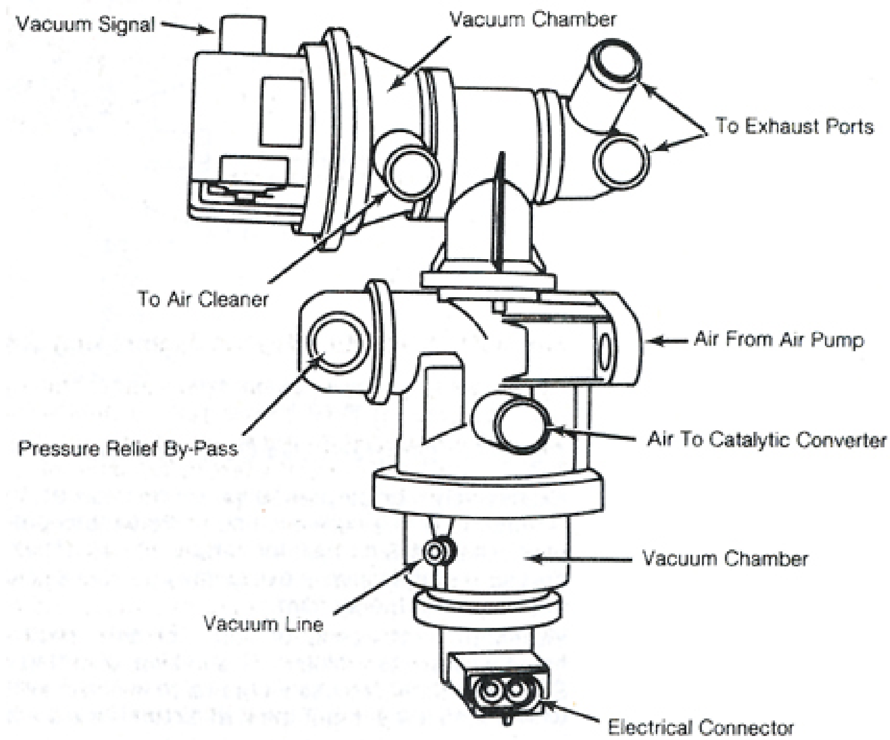


Fig. 9-23: Typical Multi-Function Air Management Valve with Electronic Control

Injection (Distribution) Manifold -. The purpose of the air injection manifold is to distribute pump air to each exhaust port. This manifold, usually constructed of stainless steel tubing, includes a common air pipe with one injection nozzle for each exhaust port. Air is injected at each individual port through a fitting in the exhaust manifold. On "V" type engines 2 manifolds are usually used, one for each cylinder bank. See Fig. 9-15.

On some systems, the injection manifold consists of little more than a. single tube connected to either the intake manifold exhaust heat: crossover passage or back of the cylinder head. In the latter design special passages have been cast in the cylinder head to allow for one central, injection point, with the air distributed inside the head itself. This cuts down on both the amount of plumbing and system maintenance.

Check Valve - The purpose of the check valve is to prevent the flow of exhaust gases into the air injection system where damage to the air pump could occur. The valve itself is a simple, one-way spring-loaded device which allows injected air to pass through while preventing exhaust flow through the valve in the other direction. See Fig. 9-17. On "V" design engines with 2 injection manifolds, 2 check valves may be used.

Pulse Air Injection

The simplest pulse air system consists of single air injection hose and a check valve. Other systems consist of an air pipe per cylinder, using as many as one pulse air (check) valve per line. Proper system operation is dependent upon the correct operation of the check valve(s). The valve(s) are constantly fluctuating between open, allowing air into the manifold, and closed blocking exhaust flow out of the manifold. Air for the system is usually drawn through a hose or pipe from the clean air side of the air cleaner, although a small separate air cleaner may be used. silencer is sometimes added to the system to muffle noise due to pressure pulsations although on most systems the air cleaner assembly serves as a muffler. No anti-backfire (gulp) valve is required with this system.

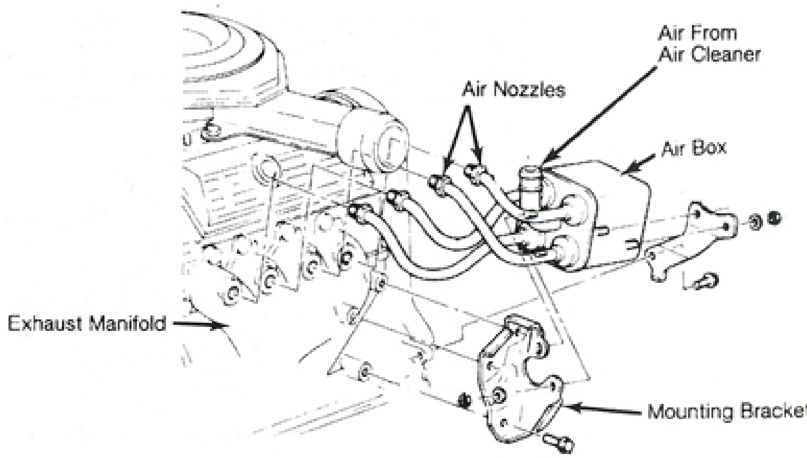


Fig. 9-24: Pulse Air Injection System with Single Air Box

One common pulse air system uses an air pipe running from the air cleaner to the exhaust manifold. See Fig. 9-15. This is a very simple system requiring only one pipe and one check valve. Another system draws air into a central air box. Multiple pipes, generally one per cylinder, carry air out of the box to the exhaust system. One check valve per pipe is usually located in the air box. On larger in-line engines, the volume of airflow required exceeds the limitations of a single air box. In these applications, 2 or more separate boxes may be used, each with its own air supply and each feeding a specific number of cylinders.

On late model Chrysler and Mitsubishi vehicles with the 2.6L engine, a variation known as the Pulse Air Feeder (PAF) system is, used. It consists of a special valve containing 2 reed valves and connecting air lines. The main reed valve reacts to pressure pulses from the No. 3 cylinder crankcase. This individual crankcase is sealed by a seal cover. See Fig. 9-26. The second reed valve reacts to exhaust system pulsations, like other pulse systems, taken from the exhaust pipe between the 2 catalytic converters.

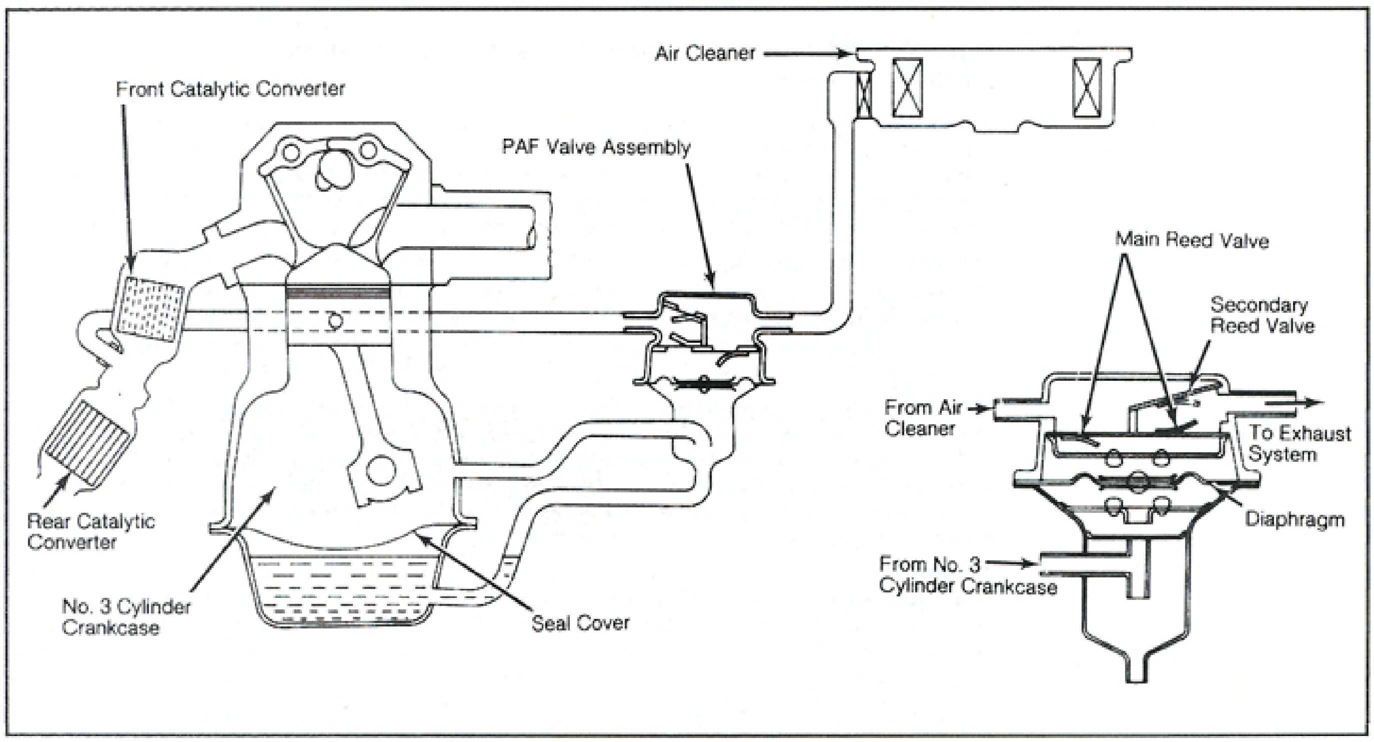


Fig. 9-25: Chrysler & Mitsubishi 2.6L Pulse Air Feeder System

Both reed and diaphragm check valves are used with pulse air systems. The reed check valve consists of a flapper valve assembly fixed over an orifice in the valve housing. The flapper valve is located on the exhaust side of the orifice so that it is pulled open by negative exhaust pulses. This allows air to flow in the direction of the exhaust system. Positive exhaust pulsations push the valve shut, preventing exhaust gas from flowing into the air injection system. The diaphragm valve operates in a similar manner, using a diaphragm assembly in place of the flapper valve. See Fig. 9-26.

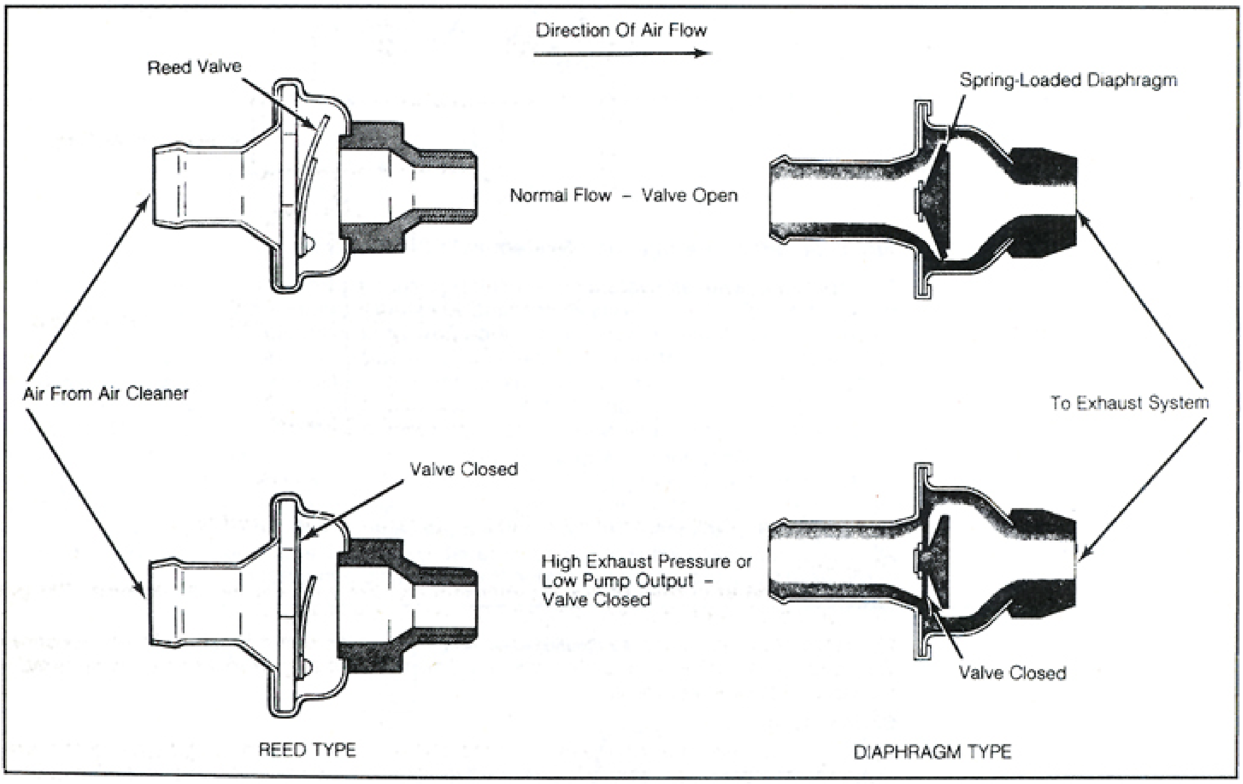


Fig. 9-26: Pulse Air System Check Valves

TESTING

Preliminary Testing

Before beginning specific system tests, ensure that all hoses, injection manifolds and valves are securely attached and properly routed. With the engine running, apply a soapy water solution to all hose connections and joints to check for air leaks. Repair as needed.

Air Pump

The air pump is a positive displacement vane type pump which is permanently lubricated and requires no periodic maintenance. Accelerate engine to approximately 1500 RPM and observe airflow from hoses. If airflow increases as engine speed increases, pump is operating satisfactorily. If airflow does not increase or is not present, check for a leaking pressure relief valve and replace if necessary. Also check belt tension. If all are correct, yet pump still does not operate correctly, replace pump.

Diverter Valve

Standard Design (Only) - **1)** With the engine idling, at normal operating temperature, hold finger over vent to check for airflow. No air should escape from the vent under these conditions.

2) increase engine speed to increase pump output volume. At high engine RPM, some air should be felt as the relief valve in the diverter valve assembly operates.

3) Place a finger over the diverter valve vent and reduce engine speed rapidly. Diverted air should be felt from this vent for 2 or 3 seconds. If valve operation is not as described, cheek for a restricted vacuum line. Replace as needed. If the vacuum line is okay, but valve function is still incorrect, replace the diverter valve.

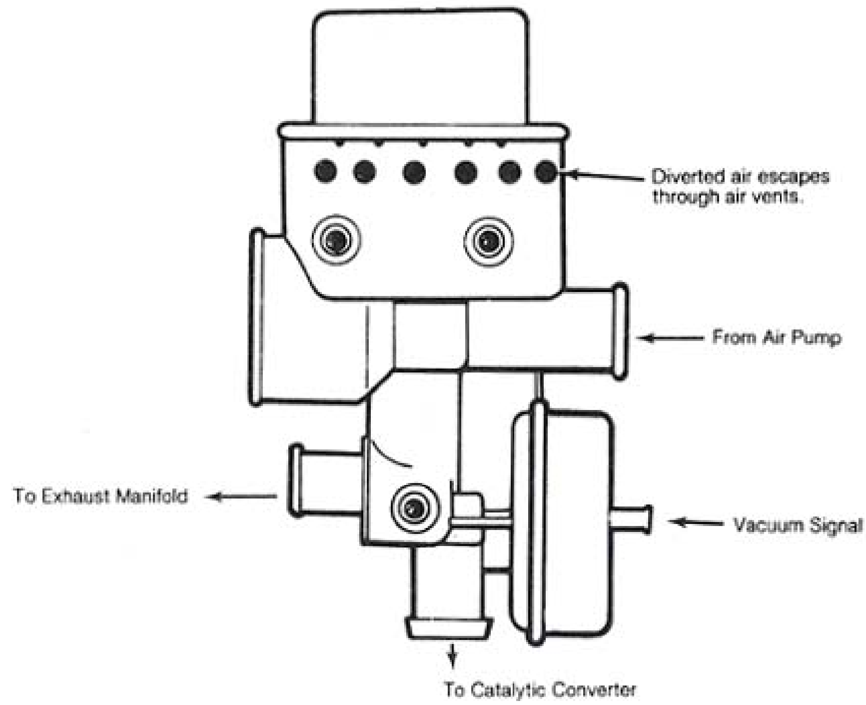


Fig. 9-27: Air Vent Locations for Testing Diverter Valve Function

Gulp Valve
1) With engine at normal operating temperature, pinch off the air line between the gulp valve and the intake manifold. Engine idle should not change.
2) Disconnect the vacuum signal line to the valve. Wait about 5 seconds and reconnect line. Engine should run rough for about 1-3 seconds. If engine idle does not respond as indicated, replace the valve.

Check Valve
1) Disconnect the air supply pipe from the check valve. With the engine idling at normal operating temperature, carefully check valve for any leakage at the inlet side. No exhaust gases should escape from the valve. If any leakage is detected, replace the valve.
2) Turn the engine off. If check valve is on an air, pump system, insert a small screwdriver or rod into the valve and push down lightly on the spring. The valve should move freely. If valve sticks or is difficult to move, replace valve.

MAINTENANCE

Little maintenance is needed on the air pump system. As with most emission control systems, check condition of all hoses.

Air Pump
Servicing the air pump is limited to replacement of the intake filter or centrifugal filter fan. If the engine or underhood compartment is to be cleaned, mask off pump to prevent liquids from entering. Liquids will ruin the pump vanes and sealing surfaces.

NOTE Centrifugal fan should not be removed from pump unless it is damaged. Removal will destroy the fan itself.

To replace fan, remove belt, pulley bolts and pulley. Insert a pair of needle nose pliers between fins' and remove fan from hub. Do not remove fan by inserting a screwdriver between pump and fan as it will damage sealing lip. Do not attempt to remove metal drive hub. Be sure fan fragments do not enter air intake hole.
Install new fan using pulley and bolts to draw fan into position. Tighten bolts alternately, making sure outer edge of fan slips into housing. A slight amount of interference with housing bore is normal. Some pumps may squeal upon initial operation until sealing lip is worn in. The pump is not completely noiseless, under normal conditions noise levels increase as engine RPM increases.

Drive Belt

Inspect drive belt for wear or cracks. Install belt, making sure it is seated and fully secured in grooves. If only an adjustment is necessary, loosen pump mounting and adjusting arm bolts. Move pump toward or away from engine until correct tension is obtained. Hold belt tension while tightening mounting bolts.

CAUTION Do not use a pry bar to move pump for belt adjustment. The aluminum housing is easily damaged.

EXHAUST GAS RECIRCULATION

Heat is produced as a by-product of the combustion of air and fuel in the cylinders of an internal combustion engine. The amount of heat produced is directly related to how much fuel is available to burn. If the temperature in the combustion chamber gets too high, Oxides of Nitrogen (NO_x) are formed. The cylinder combustion chamber temperature can be controlled by introducing an inert gas into the cylinder. This inert gas will dilute the intake mixture and in the end lower combustion temperatures. This lower combustion temperature is achieved by reduction of the oxygen content in the combustion mixture. Exhaust Gas Recirculation (EGR) systems were designed to do just that.

HISTORY & DEVELOPMENT

The atmosphere around us is composed of about 78% nitrogen. At normal temperatures and pressures, nitrogen is an inert gas. This means that it has no tendency to change form or to combine with other elements and form new compounds. However, when nitrogen is exposed to high pressures and very high temperatures (as in the combustion chamber), its characteristics change. At temperatures above 2500°F (1370°C), nitrogen combines with oxygen. When they combine they form molecules :composed of one nitrogen atom and varying numbers of oxygen atoms, such as NO, NO_2, and NO_3. These compounds are referred to as NO_x emissions, the "X" representing any number of oxygen atoms.

Airborne NO_x emissions combine with Hydrocarbons (HC), another by-product of combustion and bright sunlight to form Ozone (O_3), Nitrogen Oxide (NO_2) and Nitrogen Nitrate (NO_3). Nitrogen dioxides a light brawn gas known to many as Smog. It is the main cause of visible air pollution.

When it was discovered that automobile exhaust was a significant source of NO_x, legislation was passed restricting levels of NO_x emissions in new automobile exhaust. Federal standards were established in 1973, with California levels a few years earlier. One of the earliest and most effective means developed for the control of these emissions was the Exhaust Gas Recirculation (EGR) system.

DESCRIPTION

EGR systems control NO_x emissions by keeping combustion temperatures below that which produces NO_x. A small amount of exhaust gas (14 percent maximum) is rerouted into the intake cycle to dilute the intake charge, reducing combustion mixture oxygen content and therefore combustion temperatures. The amount of exhaust gas mixed with the intake charge is controlled by an EGR valve on all systems, with one exception.

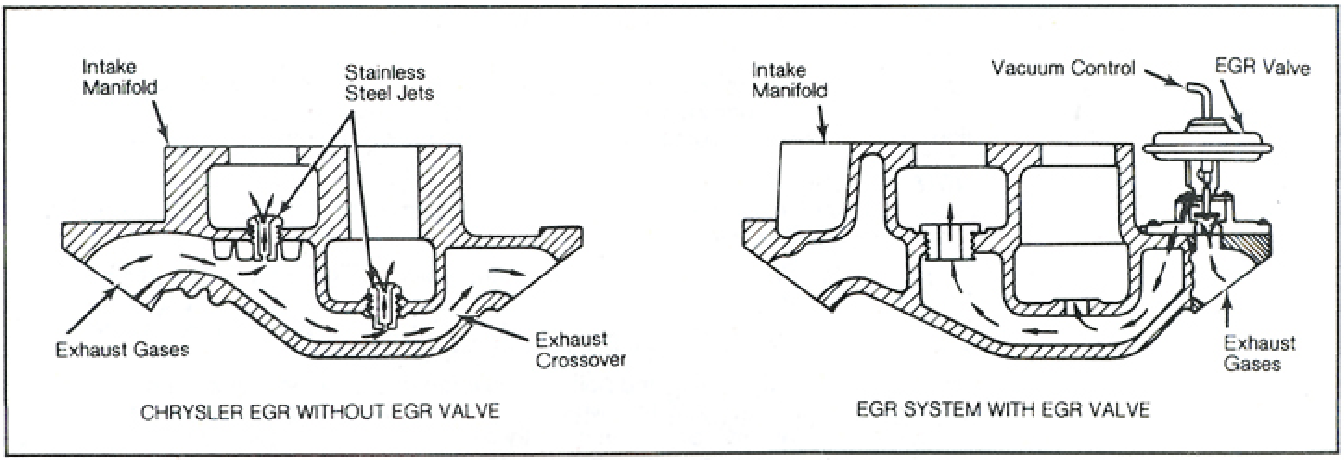


Fig. 9-28: Basic EGR System Designs

One EGR system without an EGR valve was used on 1972-73 Chrysler 340" and 400" engines with 4-barrel carburetors. Two stainless steel jets were threaded into the floor of the intake manifold, connecting the intake runners to the exhaust heat crossover. This provided a constant flow of exhaust gas into the intake system. In later years, when stricter emission standards led to the need for greater EGR system control, this system was discontinued.

In addition to its widespread use on gasoline engines, EGR is also the only major emission control system currently used on diesel engines.

OPERATION

Most EGR systems include an EGR valve, temperature thermovalve, vacuum lines and an exhaust backpressure sensor (internal or external). Temperature thermovalves may monitor engine coolant, ambient air or intake charge temperature. The backpressure sensor is used on later model systems.

Since EGR systems introduce an inert gas into the combustion chamber, it reduces engine power output. The EGR system can also cause rough running or stalling if the EGR is activated at idle, during cold warm-up or wide open throttle conditions. EGR control systems were developed to avoid these problems by defining specific operating conditions.

NOTE The following components and system descriptions cover most of the various systems used. Not all components and systems are the same. Some, still today, are quite simple and others are quite complex. This section on EGR valves is a basic overview of all these systems.

EGR Valves

The basic EGR valve, known as a Port EGR valve, consists of a basic diaphragm vacuum actuated needle valve. All EGR valves are of the normally closed type. The closed position is held constant by the valve spring. Vacuum is applied to the upper diaphragm vacuum chamber which overcomes the spring tension and thereby opens the valve.

EGR valves are usually mounted directly to the intake manifold, yet some are mounted elsewhere and are connected to the intake manifold by means of a piping system. Exhaust gases pass through the base when the valve is open and into the intake system. When gasoline engines are at idle or wide open throttle (little or no vacuum present), the diaphragm spring holds the valve closed. During light acceleration or cruise conditions, the vacuum signal increases and pulls the diaphragm and valve open. This allows exhaust gas to flow into the intake system. Diesel EGR systems are completely open during idle conditions.

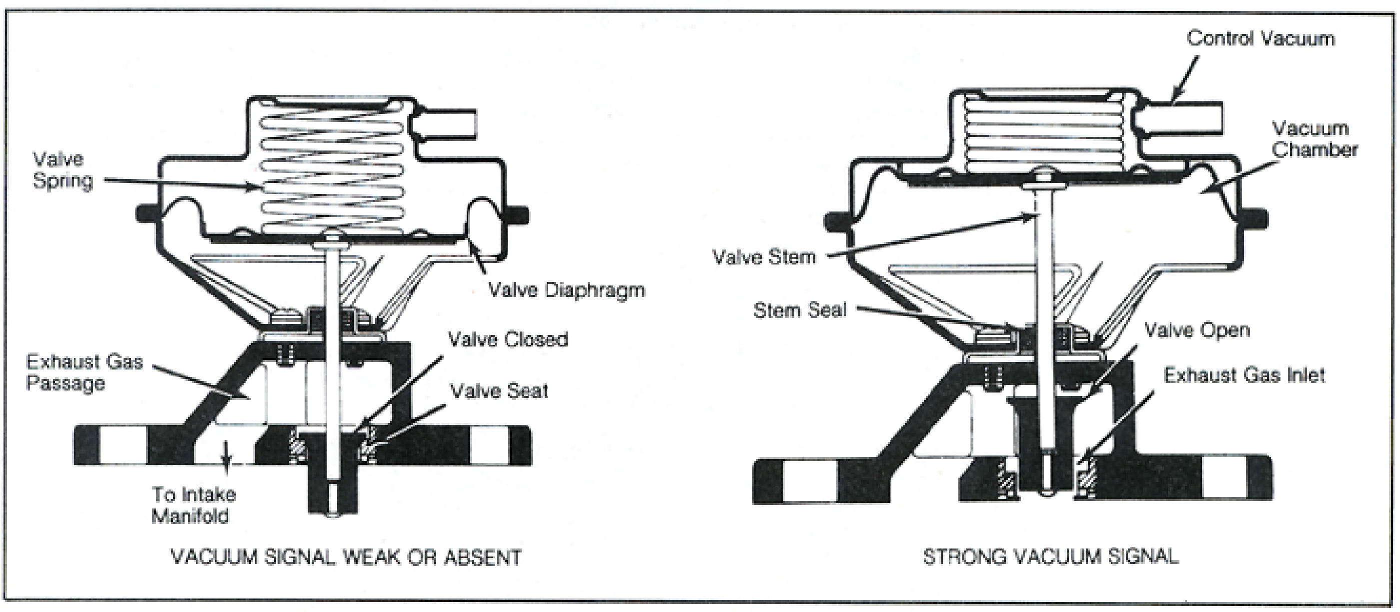


Fig. 9-29: Basic EGR Valve Operation

Temperature Valves

Most gasoline. engine vehicles with EGR systems are equipped with a temperature valve of some type. The valve is mounted so it can sense coolant temperature, and may be located in the intake manifold, cylinder head, thermostat housing or top radiator tank. The valve senses engine temperature and, blocks the vacuum signal to the EGR valve until a specific engine temperature is reached.

The vacuum control signal must pass through the valve before it reaches the EGR valve. When coolant temperature is low, vacuum to the valve is blocked off. As coolant temperature increases, the valve opens to complete the vacuum circuit. The valve opens in varying degrees depending upon coolant temperature. In doing this, the valve also regulates the extent to which the EGR valve can open. The use of this valve improves cold engine drivability.

Some early systems use sensors which detect ambient air temperature or intake charge temperature as an alternate method of determining engine temperature. Whichever temperature is monitored, the outcome is still the same, to prevent EGR when the engine is cold.

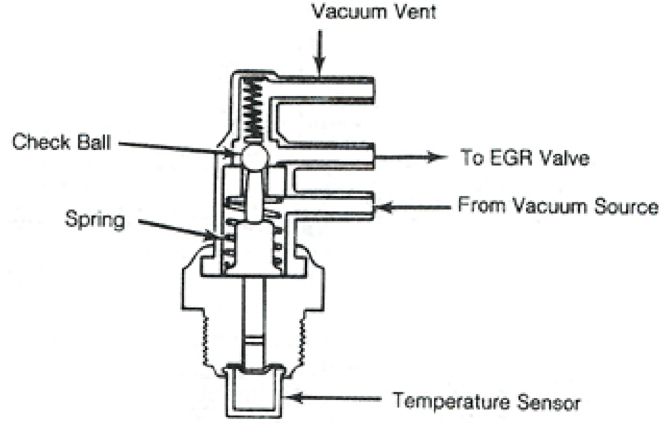


Fig. 9-30 Coolant Temperature Vacuum Valve

Vacuum Signal

EGR valves are vacuum operated: Both carburetor ported vacuum and Venturi vacuum are used to control valve operation on gasoline powered vehicles, or vacuum supplied from a separate pump on diesel applications.

Ported Vacuum - Ported vacuum signals come from a port in the carburetor, located just above or below (or both), the throttle plate. On those models with ported vacuum above and below the throttle plate, a vacuum modulator is used to switch from one or the other port depending on engine operating conditions. See Fig. 9-31. These port systems all work on the same basic principle. When. the throttle plate opens, more of the port is exposed to manifold vacuum increasing EGR operation. At wide open throttle, manifold vacuum drops and EGR, operation ceases.

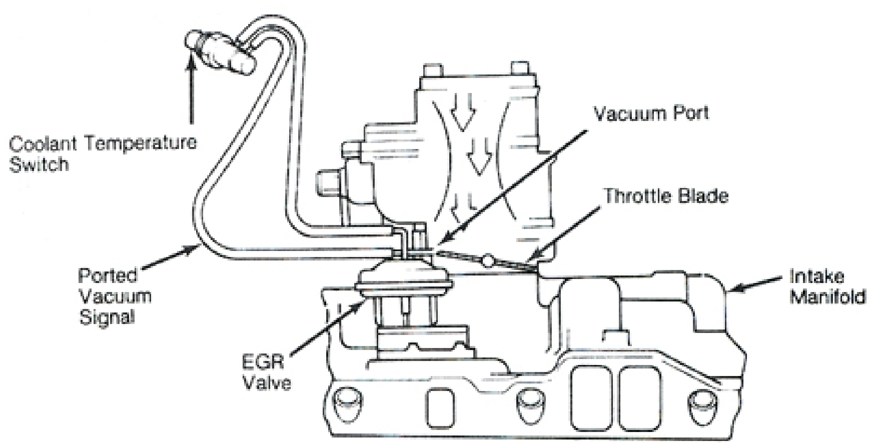


Fig. 9-31: Ported Vacuum Controlled EGR System

Venturi Vacuum - The vacuum signal produced at the carburetor venturi is highly sensitive to changing engine conditions, providing the most accurate source of EGR control. However, the venturi signal is too weak to operate the EGR valve. Straight manifold vacuum on the other hand, provides a strong, consistent signal. Unfortunately, this consistency makes it incompatible with optimum EGR operation as the systems needs change with different operating conditions:

On some models, to combine the advantages of both venturi control and the strength of manifold vacuum, a vacuum amplifier is added to the system. See Fig. 9-32. Manifold vacuum is supplied to the EGR valve via the vacuum amplifier. The amplifier allows venturi vacuum to regulate the strength of the manifold signal. This provides the EGR valve with a sufficient vacuum signal; without sacrificing the accuracy of venturi control.

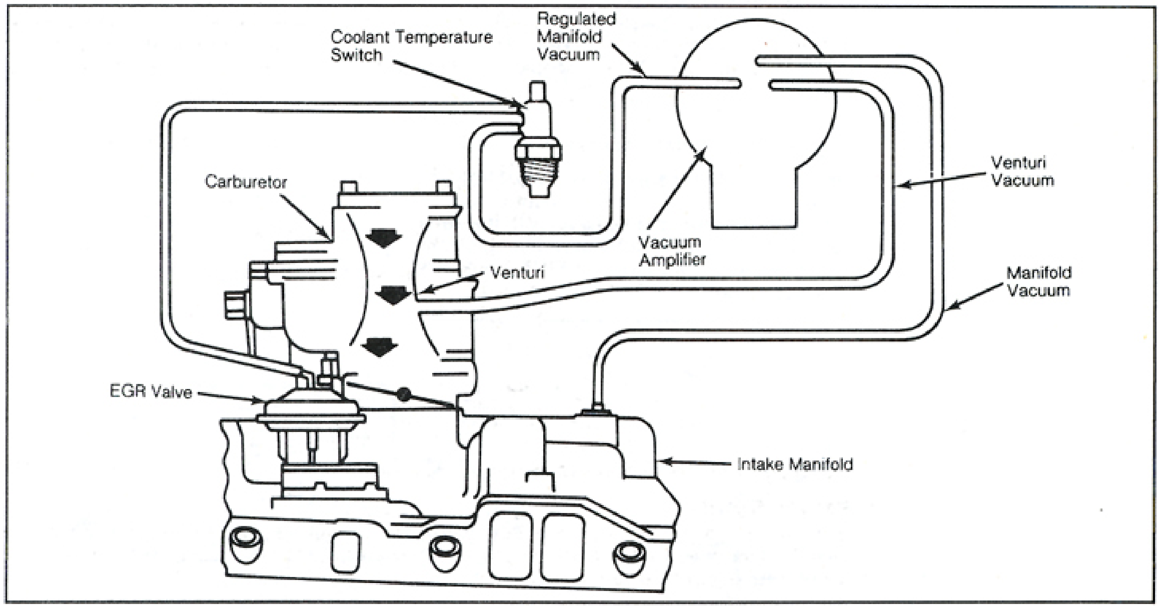


Fig. 9-32: Venturi Vacuum Controlled EGR System With Vacuum Amplifier

At low engine speeds, vacuum at the carburetor venturi is low. This means a weak control signal to the amplifier, blocking manifold vacuum to the EGR valve. As engine speed increases, the venturi control signal increases, allowing manifold vacuum to reach the EGR valve and exhaust gas recirculation to' occur. At wide open throttle when venturi vacuum is the strongest, manifold vacuum drops to very low levels. Therefore, when the venturi control signal allows full manifold vacuum to the EGR valve, manifold vacuum is too weak to open the valve, preventing EGR operation at wide open throttle.

Modulated EGR Valves

Most manufacturers have improved EGR operation by modulating or controlling the EGR itself rather than just using vacuum control. This control has been achieved by the addition of some type of exhaust backpressure sensor to the system. Initially these sensors were a separate part of the EGR valve. More recently, the sensor has been built into the EGR valve, eliminating the need for a separate component.

Exhaust Backpressure Sensor (Separate) - A spacer plate is mounted between the EGR valve and the intake manifold. A tube in the plate is exposed to the exhaust gases and pressure cunning through the valve. A vacuum line from the tube to the exhaust backpressure sensor provides the sensor with an exhaust pressure signal. The sensor, mounted between the temperature thermovalve and the EGR valve, contains a spring-loaded diaphragm and an air bleed.

When exhaust backpressure is low, the air bleed is open. Air is bled into the EGR vacuum line, reducing the vacuum signal and preventing EGR operation. As exhaust backpressure builds, the diaphragm in the backpressure sensor is forced upward, blocking off the air bleed and allowing EGR operation. At wide open throttle, high exhaust pressure still blocks the air bleed, yet ported vacuum is too low to open the EGR valve, and recirculation does not occur.

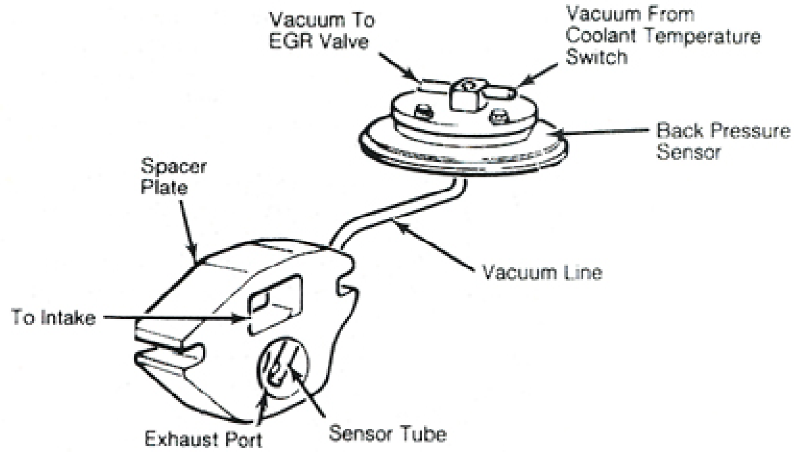


Fig. 9-33: Exhaust Backpressure Sensor (External) System Components

Integral Backpressure Sensor EGR Valves - EGR valves designed to eliminate a separate exhaust backpressure sensor contain an internal air bleed valve. Operation of these valves is basically the same as with the separate sensor. They allow EGR flow only when exhaust system backpressure is sufficiently high or low, depending upon what type of valve is used. Two types of EGR valves are used, Positive Backpressure and Negative Backpressure.

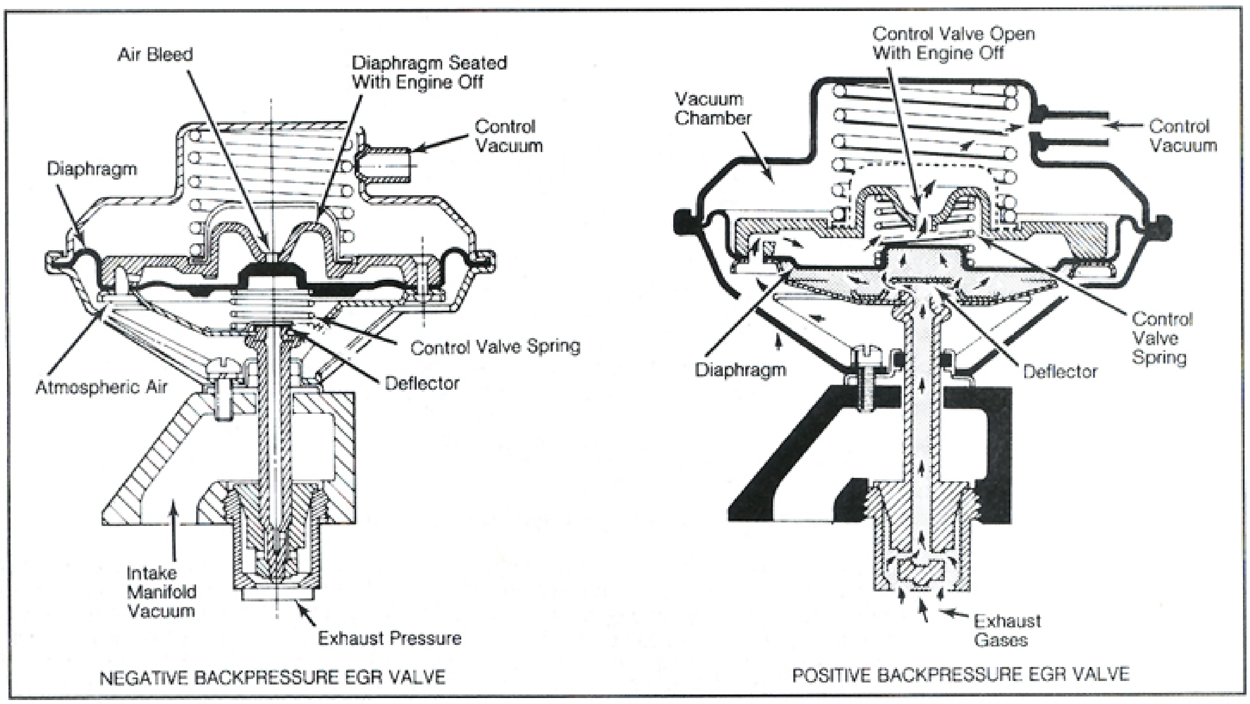


Fig. 9-34: Backpressure Sensitive EGR valves

Both types of valves have a vacuum bleed inside the valve itself. The amount of backpressure determines whether the bleed is open or closed. Exhaust backpressure pulses are used to open and close the air bleed. Since backpressure pulses are higher when the engine is under load, the bleed will open less, and the EGR valve will open more.

Positive backpressure EGR valves contain an air bleed that works in conjunction with positive exhaust backpressure. This air bleed, located inside the EGR valve assembly, acts as a vacuum regulator. This bleed valve controls the amount of vacuum in the vacuum chamber of the EGR valve by bleeding vacuum to the atmosphere during the open phase of the cycle. When the EGR receives sufficient exhaust backpressure, it closes the bleed hole. At this point, maximum obtainable vacuum is applied to the diaphragm and the EGR valve opens. If there is little or no vacuum in the vacuum chamber, such as idle or wide open throttle, or if there is little or no pressure in the exhaust manifold, the EGR valve will not open.

Negative backpressure EGR valves work in conjunction with negative exhaust pressure. The diaphragm on this EGR valve also has an internal vacuum bleed hole which is held closed by a small spring when there is no exhaust backpressure. Engine vacuum opens the EGR valve against the pressure of the upper chamber spring. When manifold vacuum combines with negative exhaust backpressure, the vacuum bleed hole closes and the EGR valve opens.

Computer-Controlled EGR Valves

Pulse Width Modulated EGR - Some new engines are equipped with a Pulse Width Modulated EGR valve. This simply means that short electrical pulses are sent by the engine computer to the control assembly/solenoid. The solenoid opens and closes a vacuum valve about 30 times a second. The length (width) of the pulse determines the strength of the vacuum signal sent to the EGR valve. This system lets the computer adjust .EGR operation based on signals from any or, all of the following switches and sensors: Torque Converter Clutch (TCC), park/neutral switch and manifold vacuum. A small vacuum switch, usually the manifold. absolute pressure sensor, lets the computer determine whether the vacuum valve is operating properly or not.

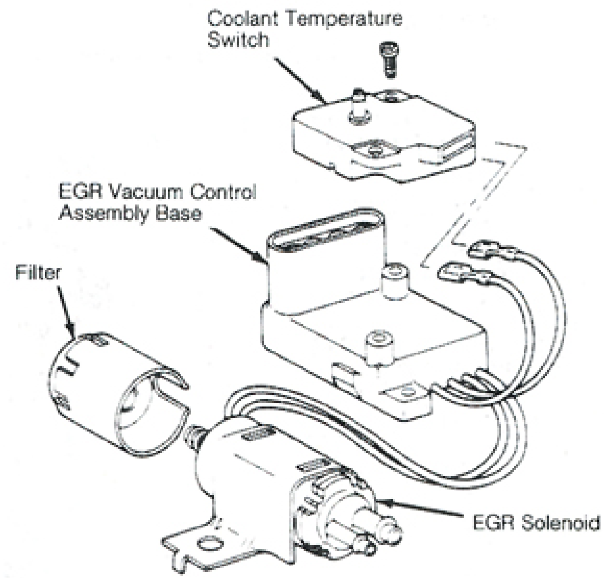


Fig. -35: EGR Vacuum Control Solenoid Assembly

Integrated Electronic EGR - The integrated electronic EGR valve functions similar to a ported EGR valve with a remote vacuum regulator. The internal solenoid is normally open, which causes the vacuum signal to be vented off to the atmosphere when EGR is not controlled by the ECM. This EGR valve has a sealed cap. The solenoid valve opens and closes the vacuum signal, which controls the amount of vacuum applied to the diaphragm. The electronic EGR valve contains a voltage regulator, which converts ECM signal and regulates current to the solenoid. The ECM controls EGR flow with a pulse width modulated signal based on airflow, Throttle Position Sensor FPS), and RPM. This system also contains a pintle position sensor, which works similarly to a TPS sensor. As EGR flow is increased, the sensor output increases.

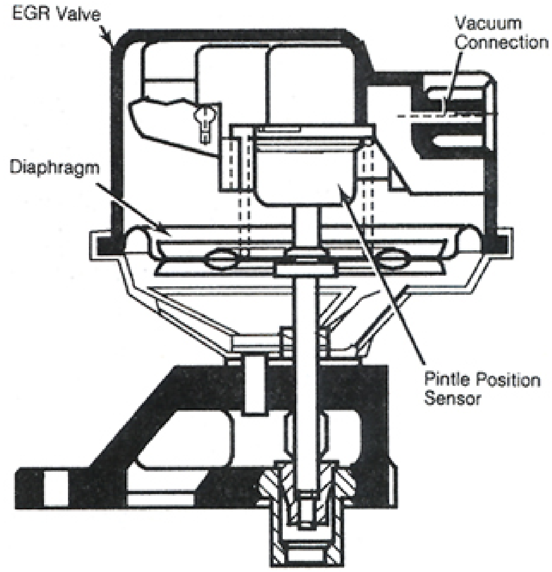


Fig. 9-36:' Cutaway View of Integrated Electronic EGR Valve

Integrated Electronic EGR - the integrated electronic EGR valve functions similar to a ported EGR valve with a remote vacuum regulator. The internal solenoid is normally open, which causes the vacuum signal to be vented off to the atmosphere when EGR is not controlled by the ECM. This EGR valve has a sealed cap. The solenoid valve opens and closes the vacuum signal, which controls the amount of vacuum applied to the diaphragm. The electronic EGR valve contains a voltage regulator, which converts ECM signal and regulates current to the solenoid. The ECM controls EGR flow with a pulse width modulated signal based on airflow, Throttle Position Sensor (TPS), and RPM. This system also contains a pintle position sensor, which works similarly to a TPS sensor. As EGR flow is increased, the sensor output increases.

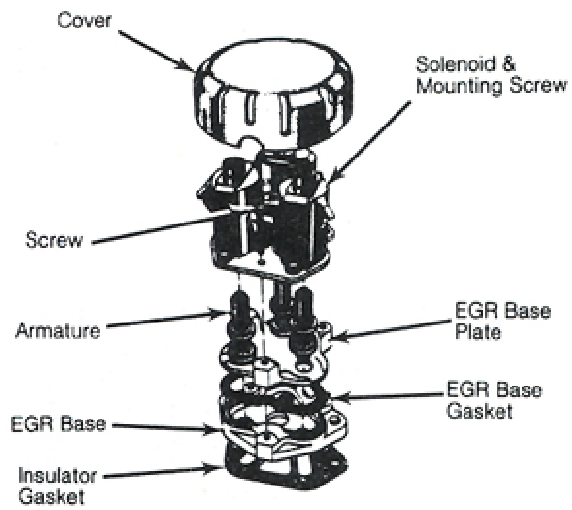


Fig. 9-37: Digital EGR Valve

Digital EGR - The digital EGR valve operates independently of engine manifold vacuum. This EGR valve controls EGR flow through 3 orifices. These 3 orifices are opened and closed by electric solenoids. The solenoids are, in turn, controlled by the ECM. When a solenoid is energized, the armature, with attached shaft and swivel pintle is lifted, opening the orifice. The ECM uses inputs from Coolant Temperature (CTS), Throttle Position (TPS) and Mass Airflow (MAO) sensors to increment the EGR orifices to make 7 different combinations to precisely control EGR flow. During engine idle, the EGR valve will allow a very small amount of exhaust gas to enter the intake manifold. This EGR valve normally operates above idle speed during warm engine operation.

Diesel EGR

Basic diesel engine operation is dependent upon very high combustion temperatures and pressures. Therefore, diesel engines are a source of NO_x production, especially at idle when the air/fuel ratio is very lean. EGR systems are used to reduce NO_x production to lower levels. The operation of a diesel EGR system is similar to a gasoline engine. Exhaust gases are added to the intake charge to dilute the incoming air. As in any EGR system, this reduces the amount of available oxygen, which in turn reduces combustion temperature and NO_x emissions. Since diesel engine operation is based upon high compression ratios, EGR is the only common method of NO_x reduction which can be used with a diesel engine. The one major difference between EGR systems used on diesel engines and those used on gasoline engines is in terms of vacuum. Vacuum is provided by a vacuum pump. Signal strength from the pump to the EGR valve is controlled by a vacuum regulator valve. The signal is, highest at idle, decreasing to zero at wide open throttle. The diesel EGR valve is fully open at idle and closed at full throttle, unlike EGR valves on gasoline systems.

Most diesel EGR systems include an EGR valve, water temperature thermoswitch, injection pump control lever position sensor, engine speed sensor, electronic vacuum switching valve and an EGR controller. The EGR controller, based on inputs from the engine speed sensor, coolant thermoswitch and injection pump control lever position sensor, sends electrical pulses to the vacuum switching valve, opening and closing the EGR valve. This system works in much the same way as the computer controlled EGR valves previously described.

In addition to these sensors, General Motors V6 and V8 systems include a thermostatic vacuum switch to cut EGR when the engine is cold. A torque converter clutch solenoid cuts EGR when the converter clutch is engaged. An altitude sensor, solenoid and reducer valve modify EGR operation depending on altitude. A response vacuum reducer valve or quick vacuum response valve allows the' EGR valve to react quickly to changes in throttle position and vacuum signal strength.

Because these engines make use of the EGR system mainly during idle conditions, some systems use an Exhaust Pressure Regulator (EPR) valve to increase exhaust backpressure. This increase in backpressure therefore increases the exhaust gas flow through the EGR valve when it is in operation. The EPR valve is of the vacuum diaphragm type and is

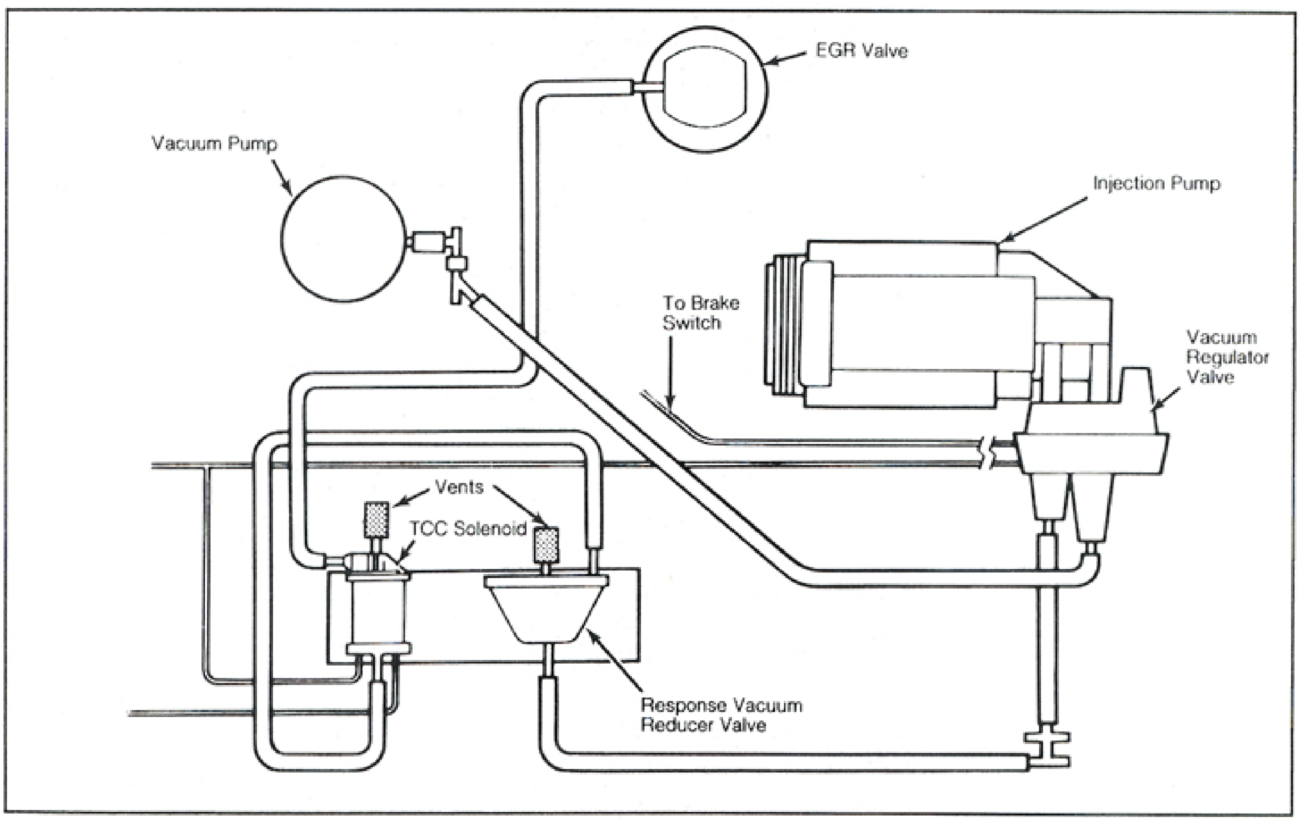


Fig. 9-38: Typical General Motors V8 Diesel EGR System

controlled by an electronic vacuum solenoid. The solenoid gets a signal from a throttle position sensor. When the throttle position sensor indicates closed throttle or idle, the EPR solenoid is energized allowing vacuum to the EPR valve. The EPR valve then increases exhaust backpressure which increases the exhaust gas flow through the EGR valve. This increase in gas flow causes a measurable difference in tail pipe emissions.

TESTING **EGR Valves**

Single Diaphragm EGR Valves - 1) With engine idling at normal operating temperature, disconnect the vacuum line from the EGR valve and attach a hand vacuum pump to the valve. Apply 10-15 in. Hg of vacuum to the valve. The engine should begin to idle roughly, or stall. When the vacuum signal is removed, normal idling should resume.

2) If engine response is correct, the valve is operating properly and the intake manifold exhaust passages are, clear, allowing exhaust gas recirculation to occur. If engine idle is not affected, either the valve diaphragm is leaking, the valve is not seating tightly, or the intake manifold exhaust passages are blocked.

3) With the engine off, watch the valve stem closely as vacuum is applied and released. If stem movement is hard to detect, or if the stem is not readily visible, place a gloved finger under the valve to feel diaphragm movement. If the diaphragm is intact, the stem and diaphragm will. move up with vacuum, and back down when vacuum is removed. If not, replace the valve.

4) If valve operation is correct, remove and check valve and valve passages for blockage. Clean as needed.

Negative Backpressure Valves - 1) Connect a vacuum pump to the EGR valve. Using a mirror, observe the EGR diaphragm while applying vacuum to the valve. Diaphragm should move freely and hold vacuum for at least 20 seconds.

2) If the valve operates correctly, according to the above guidelines, the valve is functioning correctly. If valve does not operate as outlined, replace valve.

Positive Backpressure Valves - 1) Start the test by making a physical check of all hoses and electrical connections. Start engine and warm to operating temperature.

2) With engine idling, manually push underside of EGR valve diaphragm to open valve. When this is done, idle RPM should drop. If idle RPM drops, this indicates that the valve is working properly. If idle RPM does not drop, check EGR valve passages for blockage, and clean as necessary.

3) Restrict exhaust gas flow at tail pipe. Increase engine speed to 2000 RPM. Check for movement of diaphragm. If no movement is detected, check vacuum source. If vacuum source is functioning, check EGR vacuum controls such as vacuum solenoids and EGR controller or engine computer. If vacuum is present and. all controls are operating, replace EGR valve.

Pulse Width Modulated EGR Valves - 1) Check vacuum lines for leaks and electrical connectors for proper connections. Place transmission in "Park" or "Neutral". With engine at normal operating temperature and engine idling, push up on underside of EGR valve diaphragm. Engine RPM should drop. If engine RPM does not drop, clean EGR valve or passages. If RPM still does not drop, replace EG'R valve. If engine RPM does drop, check for EGR valve diaphragm movement with engine speed change from 2000 RPM to idle. EGR valve diaphragm should not move.

2) If EGR valve diaphragm moves with idle change, check Park/Neutral switch for open circuit or misadjustment of switch. If EGR valve diaphragm does not move, disconnect EST connector and ground test terminal. If EGR valve diaphragm moves, EGR valve is functioning properly. If EGR valve diaphragm still does not move, stop engine and disconnect EGR solenoid connector. Connect 12-volt test light between EGR solenoid connector terminals. Turn ignition on and ground test terminal. Test light should flash repeatedly.

3) If test light flashes, check for vacuum to EGR solenoid at 2000-3000 RPM. If engine does not use a vacuum regulator, there should beat least 7 in. Hg vacuum at solenoid. If engine is equipped with a vacuum regulator, there should be 2-10 in. Hg vacuum. If vacuum is greater than' 10 in. Hg, replace regulator. If vacuum is less than 2 in. Hg, vacuum at solenoid is okay. Check EGR solenoid connections and/or faulty EGR solenoid.

4) If test light was on steady, check for ground in wire to ECM terminal "T". If terminal is not grounded, check for faulty ECM. If test light is off, connect test light from each EGR connector terminal to ground and note light. If test light is on at both terminals, check for short to battery positive in wire to ECM terminal "T". Repair and recheck as required, ECM may be damaged.

5) If test light is off, repair open in wire from solenoid to ignition. Check for blown fuse. If test light is on only at one terminal; check for open in wire to ECM terminal "T". If wire is not open, check resistance of EGR solenoid. Resistance should be more than 20 ohms. If resistance is less than 20 ohms, replace EGR solenoid and ECM. If resistance is more than 20 ohms, ECM or connections may be faulty. If further testing is required, refer to service and repair manual for import and domestic vehicles.

Integrated Electronic EGR Valves - 1) Turn ignition off. Connect vacuum gauge to EGR Valve. Apply vacuum and observe EGR valve. EGR valve should not move. If EGR valve moves, remove EGR filter and repeat test. EGR valve should not move. If valve moves, replace EGR valve. If valve does not move, replace filter. When applying vacuum, if EGR valve does not move, turn ignition on and repeat test. EGR valve should not move. If EGR valve moves, disconnect electrical connector.
2) Connect 12-volt test light between terminals "A" and "D". Test light should not illuminate. If test light does not illuminate, EGR valve is faulty. If' test light illuminates, circuit 435 is shorted to ground or ECM is faulty. With ignition on, ground diagnostic test terminal and repeat test. Valve should move. If valve does not move, remove EGR electrical connector. Connect test light between terminals "A" and "D".
3) Test light should illuminate. If test light illuminates, EGR valve or connection is faulty. If test light does not illuminate, probe terminal "D" with test light to ground. Test light should illuminate. If test light does illuminate, circuit 435 or ECM is faulty. If test light did not illuminate, circuit 39 is open. When diagnostic terminal was grounded, see if EGR valve moved. If so, disconnect vacuum hose at valve and connect vacuum gauge to hose.
4) EGR valve should be able to obtain and hold 3-7 in. Hg vacuum. If valve holds more than 7 in. Hg vacuum, remove EGR filter and repeat test. If vacuum is more than 7 in. Hg, replace EGR valve. If vacuum was 3-7 in. Hg, replace EGR filter.
5) If EGR valve is holding 3-7 in. Hg vacuum, start engine and lift EGR diaphragm. Idle should become rough. If idle does not become rough, remove EGR valve and clean passages. If idle did become rough, EGR valve is okay. Check for ported vacuum to EGR valve and check for leaks or restrictions in vacuum hoses. There should be at least 7 in. Hg vacuum at 2000 RPM. If further testing is required, refer to service and repair manual for import and' domestic vehicles.

Digital EGR Valves - 1) Turn engine off. Disconnect EGR connector. Using Tool Kit (J35616), install jumper harness connector terminal` "D" to terminal "D" of EGR valve. Connect jumper to ground. Start engine. Engine RPM, should change as each EGR valve terminal "A", "B" or "C" is contacted. For terminal location "C" is contacted. For terminal location, refer to Mitchell's EMISSION CONTROL SERVICE & REPAIR manual for import and domestic vehicles.
2) If engine RPM does not change, check for restriction in EGR supply tube or plugged EGR orifice. If EGR valve is not restricted or plugged, replace EGR valve. If engine RPM does change, digital EGR valve is functioning properly. If further testing is required, refer to service and repair manual for import and domestic vehicles.

EGR System Tests

NOTE The following test procedures apply to complete systems. Find the test for the system which most closely describes the system you are working on and use that test procedure:

Ported Vacuum Controlled Systems - 1) With engine cold, watch the EGR valve stem closely while raising engine speed to 2000 RPM The valve should not move as engine speed is increased: If the valve stem does move, the temperature thermovalve is defective and should be replaced.
2) If the valve does of open, bring engine to normal operating temperature and repeat test. As engine speed is increased, the valve stem should rise, indicating that the vacuum signal through the temperature valve is reaching the EGR valve and that the valve is operating properly:
3) If the valve does not open, disconnect the vacuum control line from the temperature switch and attach a vacuum gauge to this line. Watch the gauge while increasing engine speed. If no vacuum signal is indicated, check the carburetor port for blockage and the vacuum line for dirt or any other debris which could clog the line. Clean as needed.
4) If vacuum signal is present from the control line, remove the vacuum gauge and reconnect a vacuum gauge to it. Watch the gauge for a vacuum signal as engine speed is increased. If no signal is indicated, the temperature valve is defective.

5) If vacuum signal is present, the temperature valve is operating properly. Turn engine off and connect a hand vacuum pump to the EGR valve. Watch the valve stem while applying vacuum to the valve. If it still does not open, the EGR valve is defective.

Venturi Vacuum Controlled System - 1) Tap a vacuum gauge into the vacuum line leading to the EGR valve. With engine cold, start engine and check vacuum gauge. There should be no vacuum to the EGR at 3000 RPM. If vacuum is present, replace temperature valve.
2) Warm engine to operating temperature. With engine running at 3000 RPM, recheck vacuum gauge. At this time, the gauge should indicate low vacuum. If not, replace temperature valve.
3) Check EGR valve operation. Disconnect vacuum line to EGR valve. Connect a vacuum pump to the EGR: Start engine and apply vacuum to the EGR valve. If engine then runs rough or stalls, valve is operating correctly.

Systems, With External Exhaust Backpressure Sensors - 1) Install vacuum gauge inline with EGR valve. With engine cold, start and bring to 2000 RPM. If gauge indicates any vacuum signal at all, the temperature valve is defective and should be replaced. Let the engine warm to operating temperature and repeat test. The vacuum gauge should read 1-4 in. Hg.
2) If the gauge remains at zero, trace the vacuum line from the temperature valve to the exhaust backpressure sensor and disconnect at the sensor. Attach a vacuum gauge to the vacuum line and run engine at 2000 RPM. If the gauge stays at zero, the temperature switch is defective.
3) If the gauge shows a vacuum reading, the backpressure sensor is not operating correctly. Remove the sensor and use a wire brush to clean any carbon or lead deposits from the signal tube and surrounding area. Install the sensor.
4) Reconnect all vacuum lines and install vacuum gauge as in step **1)**. With engine at normal operating temperature, bring engine speed to 2000 RPM and watch gauge. If a vacuum signal is still not present, the backpressure sensor is defective and must be replaced.

Negative Backpressure Systems - 1) With the ignition on and the engine not running, check the EGR vacuum control solenoid position with a vacuum pump. The solenoid should be closed, yet a slow bleed off is normal and should not be considered a fault. If valve is open, replace.
2) Connect a vacuum pump to the EGR vacuum port. Using a mirror, observe the EGR diaphragm while applying vacuum to the valve. Diaphragm should move freely and hold vacuum for at least 20 seconds. If the valve operates as outlined, it is operating correctly. If not, replace EGR valve.
3) Apply vacuum to EGR valve to open it. Start engine and observe valve diaphragm. Valve should close and vacuum drop as soon as the engine starts. If not, replace EGR valve. If the valve operates as outlined, system is operating properly.

Positive Backpressure Systems - 1) Begin test by making a physical check of all hose and electrical connections. With engine at normal operating temperature and running at idle, open EGR valve by pushing up on underside of valve diaphragm. Idle speed should drop at this time.
2) If idle does not drop, check EGR passageways for blockage. If passageways are blocked, remove blockage. If no blockage is found or cleaning does not help operation, replace EGR valve.
3) If idle does drop, recheck for movement with engine RPM increased to 2000, and returned to idle. If movement is observed, go to step 5). If no movement is observed, check for vacuum on the EGR side of the vacuum solenoid. If vacuum is sufficient, check for a restricted hose between vacuum solenoid and EGR valve.
4) If vacuum is not sufficient, check vacuum on input side of vacuum solenoid. If not okay, check cause of poor vacuum source. If vacuum is present check cause of solenoid malfunction. Malfunction could be solenoid itself, or EGR solenoid controller (engine computer).
5) With engine running, connect a vacuum gauge in place of EGR valve. Vacuum should at least be 7 in. Hg. If insufficient vacuum is obtained, check vacuum hoses and vacuum source for blockage, and vacuum control solenoid operation.
6) If sufficient vacuum is obtained, disconnect vacuum control solenoid and check vacuum. If no vacuum is present, system is operating properly. If vacuum is present, check for 12 volts at solenoid power input. If power is present, replace vacuum control solenoid.

7) If no present; check for open circuit between solenoid and engine computer or ignition circuit. If no trouble is found and rough idle still exists, make physical check for loose EGR valve assembly.

Diesel EGR Systems - 1) Begin test by making a complete physical check of all hose and electrical connections. With engine off and a vacuum pump attached to the EGR valve, apply vacuum to it and check for movement of the valve.
2) If movement is observed and the vacuum holds for at least 20 seconds, the valve is functioning, properly. If no movement is observed; replace valve.
3) Connect a vacuum gauge to the EGR vacuum line. With engine cold, start engine and observe vacuum gauge. If vacuum is present, vacuum control solenoid valve and engine computer are functioning properly.
4) If vacuum is of present, check vacuum control solenoid operation. Valve should be open when engine is cold. If valve is not open, check for power to solenoid. If power is present, replace vacuum control solenoid.
5) Warm engine to operating temperature and recheck for power at solenoid. If power is still not present, check wiring to and from EGR controller. If wiring is okay, replace temperature switch. Recheck system operation. If valve is still not operating correctly, replace EGR controller.

MAINTENACE

Check hose routing and ensure all hoses and electrical connections are in their proper locations. Check Engine Emission label for emission control diagrams (if available).

EGR Valve

Maintenance to the EGR valve itself should consist of no more than light cleaning with a wire brush. Cleaning of the passageways to and from EGR valve is permitted.
When reinstalling EGR valve, always use a new base gasket. Loss of EGR flow to the engine can possibly cause preignition; piston burning and scuffing.

SPARK CONTROL

Ignition timing is one of the major, factors in emission control. Ignition timing determines whether the fuel/air mixture undergoes combustion at the right time. Fire the mixture too soon, and preignition will result; fire the mixture too late, and some of the mixture is pushed out of the cylinder before Combustion is complete. Either of these conditions will result in high levels of emissions. Modern spark control systems are designed to ensure that the mixture is ignited at the best possible moment, to provide optimum efficiency, power; and cleaner emissions.

INTRODUCTION

The most effective way to reduce emissions is to strictly control the combustion process. A high percentage of the oxides of nitrogen, hydrocarbon, and carbon monoxide emissions are produced because of the inefficient combustion of fuel. Sometimes, the combustion takes place too soon; sometimes; too late. In either case the mixture is not consumed entirely, leaving the residue to be dispersed into the air. The function of an effective system then, is to provide a way for the engine to burn the correct air/fuel mixture properly and efficiently. The two main approaches to accomplish this are Exhaust Gas Recirculation (EGR) and control of ignition timing or Spark Control. This chapter is concerned with Spark Control Systems.

The Process

Spark control concerns itself with the control of ignition timing. Ignition timing is the process through which an electrical impulse is introduced at the correct (or optimum) time to ignite the fuel mixture within: the cylinders. This impulse originates at the coil. From there it goes to the distributor. Once there, it is then delivered to the spark plug. The spark plug, in turn, release this impulse within the cylinder. This ignites the air/fuel mixture, which in turn produces the power that drives the vehicle, and so on.
Now, direct control of this system takes place mainly at the distributor. The distributor takes the impulse from the coil, and delivers it at a given time to the spark plugs. This moment is preset, by means of internal mechanisms, so that ignition will always occur at the same time. This works fine, but sometimes this moment must be advanced or retarded so that ignition occurs consistently under any situation (.e. at idle, hot temperatures, high speeds, deceleration, cold starting, etc.). This is where spark control comes in.

Spark control systems control ignition by governing the systems that advance/retard timing at the distributor. These systems have been operated by vacuum sources for years. A ported carburetor signal is one such vacuum source. This port has been traditionally used as the source of distributor vacuum advance. Vacuum level at this port varies greatly at low vehicle speeds; rising or falling with changes in throttle position. At higher speeds, when throttle motion stabilizes, this vacuum signal becomes steadier, more predictable, and therefore easier to control. Spark control works in much the same way as does the vacuum signal at high speeds: it stabilizes vacuum signals so that more precise control of ignition timing is achieved.

Modern spark control systems are of 2 basic designs. Both have their greatest effect on timing control at relatively low vehicle speeds. One system blocks the vacuum signal to the distributor, while the other uses a special valve to delay vacuum. The valve increases the time required for a strong vacuum signal to reach and act on the advance unit. Both designs modify the inconsistent, low-speed vacuum signal to provide more precise control of ignition timing. In recent years, use of ported vacuum has been completely replaced by the ignition computer.

Modern spark control systems have become highly sophisticated and effective. In recent years, use of ported vacuum has been completely replaced by the ignition computer. Spark control allows the computer to determine the exact instant that ignition is required. It then signals the ignition coil to produce electrical impulses which fire the spark plugs. The computer eliminates the need for either vacuum advance units or centrifugal advance weights.

Some early spark control devices do not fit into either of these categories. They were much simpler devices, usually consisting of a single component added to the normal vacuum advance system. So before getting to modern spark control systems, a brief discussion of these early systems is in order.

HISTORY & DEVELOPMENT

Some early spark control systems were designed to provide full spark advance during deceleration. The main component of these systems is the "deceleration" or "vacuum control" valve.

Early Spark Controls

Deceleration/Vacuum Control Valve - A version of this valve has been used by American Motors (1970), Chrysler Corp. (1966-69) and Ford Motor Co. (1971-73). It serves the same function on all these systems. Located in the vacuum line to the distributor vacuum advance unit, its purpose is to ADVANCE timing during engine deceleration. This helps avoid afterburning, or backfiring, in the exhaust system. It also reduces HC emission.

The deceleration valve is a spring-loaded device with two vacuum input lines (one from the ported carburetor vacuum and one from the intake manifold vacuum). A vacuum output line goes to the distributor advance unit. Under normal operating conditions, ported vacuum passes through the valve to the distributor vacuum advance mechanism. During engine deceleration, manifold vacuum increases while ported vacuum drops. When the manifold vacuum signal exceeds a pre-set value, a piston in the valve is pulled down. This blocks ported vacuum and allows intake manifold vacuum to act on the distributor advance unit instead. The manifold-vacuum signal, very high during deceleration, gives full spark advance. When deceleration stops, manifold vacuum signal strength is reduced and normal vacuum advance is restored.

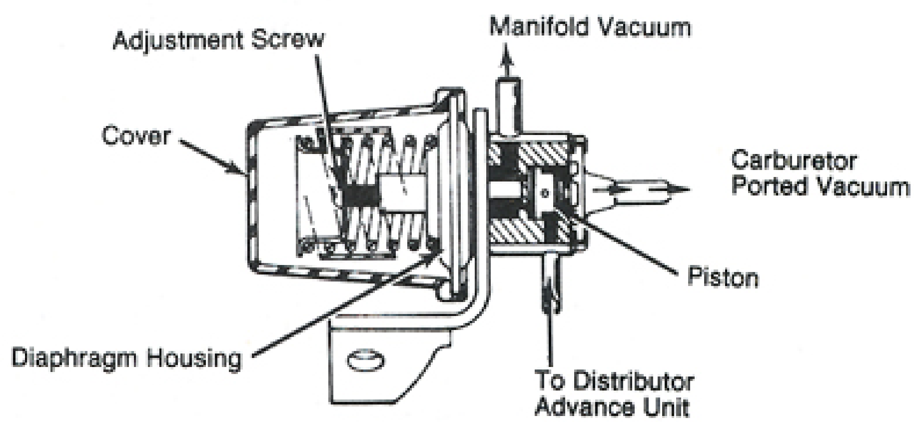


Fig. 9-39: Declaration or Vacuum Control Valve

Other early spark control devices were designed to RETARD timing during deceleration and at idle conditions. Two different approaches were used: Chrysler's Distributor Modulator (1970-71), and Ford's Dual Diaphragm Vacuum Advance and Retard Unit (1968-74). A third approach, called the Chrysler Distributor Solenoid (1972-74), was used on some engines to provide additional spark advance while cranking. Although specific domestic car systems are described here, other manufacturers have used these types of systems as well.

Distributor Modulator - Distributors using this modulator can be identified by the presence of a small black box, on the side of the vacuum advance unit, with two wires leading from it. The system consists of a solenoid switch (built into the advance unit), and a control module (the black box). The solenoid switch retards ignition timing during closed throttle conditions, while the control module limits current flow to the solenoid to protect it from full system voltage.
Power to the solenoid is supplied through the ignition circuit. The solenoid is grounded through insulated contacts on the throttle lever of the carburetor, when the throttle is closed. When activated, the solenoid cancels vacuum advance to retard ignition timing. Once the throttle is opened, contact is broken, and normal vacuum advance is resumed.

Dual Diaphragm Vacuum Advance & Retard Unit - Distributors equipped with this system can be identified by the presence of two vacuum lines to the distributor advance mechanism.

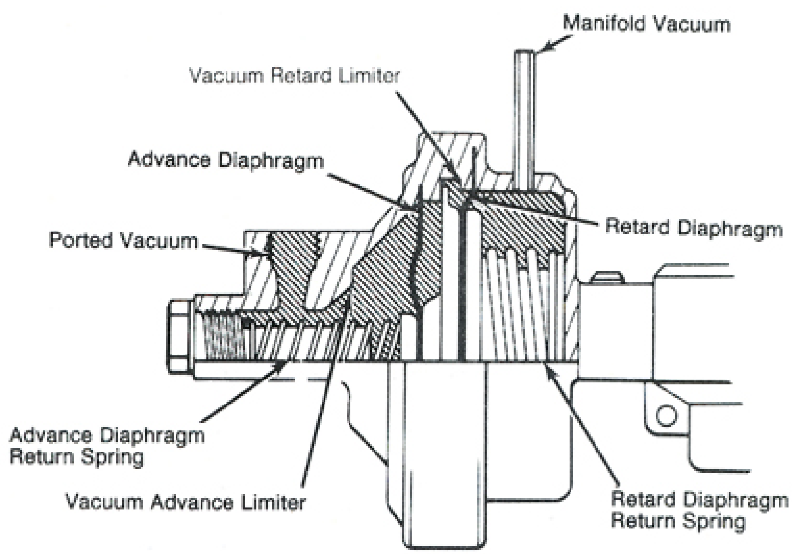


Fig. 9-40: Dual Diaphragm Vacuum Advance & Retard Unit

This advance unit contains two spring-loaded vacuum diaphragms. The outer diaphragm is operated by ported vacuum to advance timing in the conventional manner. The inner diaphragm is operated by manifold vacuum to retard timing. During deceleration or idle (throttle blades closed), ported vacuum is zero and manifold vacuum is high. The inner diaphragm is pulled inward by the manifold vacuum signal, retarding ignition timing. This system ensures that timing is automatically retarded during deceleration or idle.

Distributor Solenoid - Used on some 400 and 440 CID engines, distributors with this solenoid are identified by the presence of a wire attached to a tang at the base of the advance unit. The solenoid ensures easier starting by advancing ignition timing an additional 7.5° during cranking. The solenoid itself is located inside of the distributor advance unit, and is activated only when the ignition switch is in the "START" position.

Miscellaneous Controls

In addition to the early controls, several variations have been used. Most of these consist primarily of vacuum valves, coolant temperature sensors and electrical relays. Most of these affect spark timing by modifying vacuum advance in response to particular coolant or air temperatures. In general, they provide manifold vacuum for full advance (to increase idle and cool an overheated engine, or to improve cold engine drivability) or block the vacuum signal to retard ignition timing.
Scores of names have been used for the various vacuum valves and switches, depending on the manufacturer, but the function of most is quite similar. Let us now take a look at modern spark control.

Modern Spark Control

Computerized Spark Control - Modern spark controls have become highly sophisticated: they are computer operated so they may provide maximum efficiency. The computer determines the exact instant that ignition is required by means of the signals it receives from its sensors. Once these signals have been processed, a command is issued. Signals are sent to the. coil. An electrical impulse is released. The spark plugs deliver the spark, and combustion takes place at exactly the right time.

Computerized spark control eliminates the need for either vacuum advance units, or for centrifugal advance weights. Spark control operates in one of two modes: start mode, or run mode. In the start mode, during cranking; an electrical signal from the distributor is fed into the computer. The computer then determines the amount of advance. In the run mode, once the engine starts, and is operating normally, the timing will be controlled by the computer. The amount of spark advance, in this mode, is determined by engine speed and engine vacuum. Advance based upon engine vacuum is allowed by the computer when the carburetor switch is open. The amount of advance is programmed, based upon information received from the data sensors. The correct advance is proportional to the amount of vacuum and engine RPM. Advance based upon engine speed (RPM) is allowed by the computer when the carburetor switch is open, and advance from vacuum is not changing. This advance is also programmed into the computer, based upon data received from the sensors.

The spark control computer consists of a printed circuit board. The processing unit of this system simultaneously receives signals from all data sensors. It analyzes these signals, and then determines correct ignition determines correct ignition timing and air/fuel mixture. Some of the data sensors involved in this process are: the Hall Effect pick-up assembly, coolant sensors, vacuum transducers, carburetor switches, oxygen sensors, engine speed sensors, knock sensors, barometric switches, idle speed control units, thermactor controls, solenoids, and vacuum switches.

Modern Systems - Computerized systems; as we have seen, are effective, efficient, and very sophisticated. But these systems are just beginning. Most of the new vehicles are equipped with these computers, but some vehicles still in operation rely on the previous, but still very modern, spark control methods. Let us look at those now.

The modern spark control systems eliminate or modify vacuum advance during low speed operation. Two primary designs are used. One blocks the vacuum signal to the distributor during low speed operation, the other delays any increase in vacuum signal strength. Either system may be modified by the addition of a Coolant Temperature Override (CTO) switch. The purpose of this switch is` to modify the vacuum control signal to either improve cold drivability or reduce the temperature of an overheated engine.

Systems Which Block Vacuum

There are two main system designs for blocking the vacuum signal during low speed operation,. The difference between the two designs is the method used to determine vehicle speed. One uses a transmission switch, the other a vehicle speed sensor. The heart of

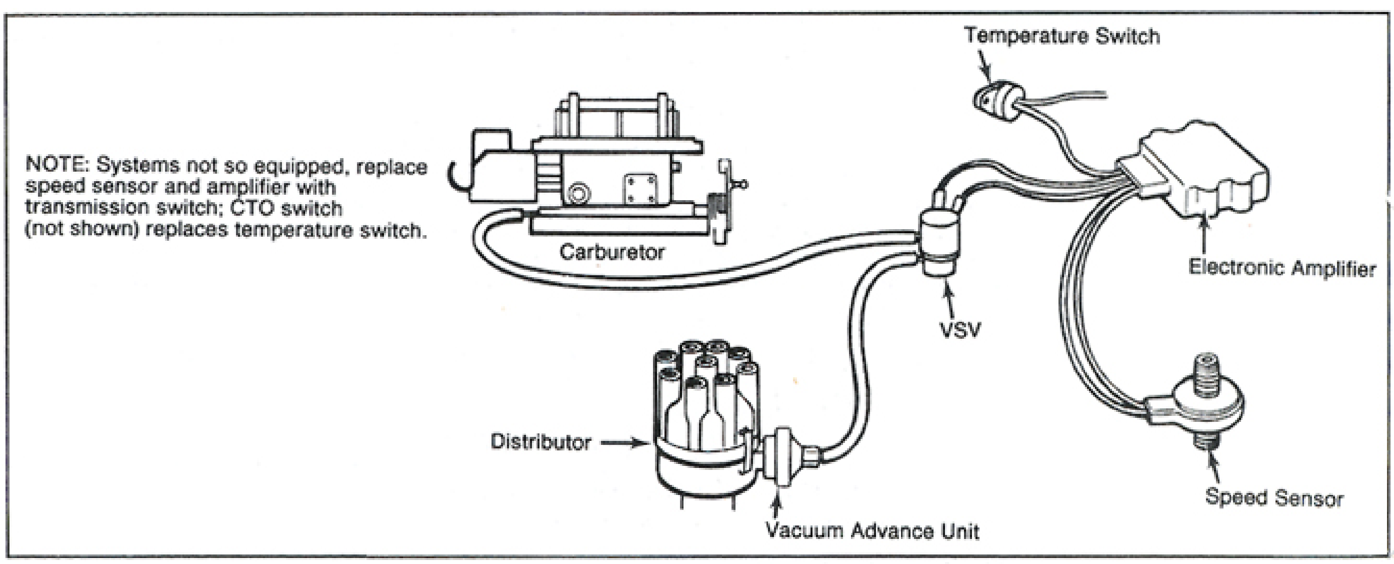


Fig. 9-41: Spark Control System with Speed Sensor & Air Temperature Switch

either system is the vacuum solenoid valve. This electrically-operated valve is located in the vacuum line between the carburetor port and the distributor advance mechanism. When activated, it blocks the vacuum signal to the advance unit and bleeds off any vacuum which maybe acting on the advance diaphragm. In addition, some systems may use an ambient air temperature switch to improve c o l d driveability.

Vacuum Solenoid Valve - During normal vehicle operation, a ported vacuum signal passes through the vacuum solenoid valve (VSV) to the distributor vacuum advance mechanism. This results in normal vacuum advance. When current is applied to the VSV, the vacuum signal is blocked, and an air bleed into the advance line is opened. The air bleed vents vacuum from the vacuum advance unit to atmosphere, thereby canceling any advance which may be present. When the electrical signal is removed, normal vacuum control resumes:

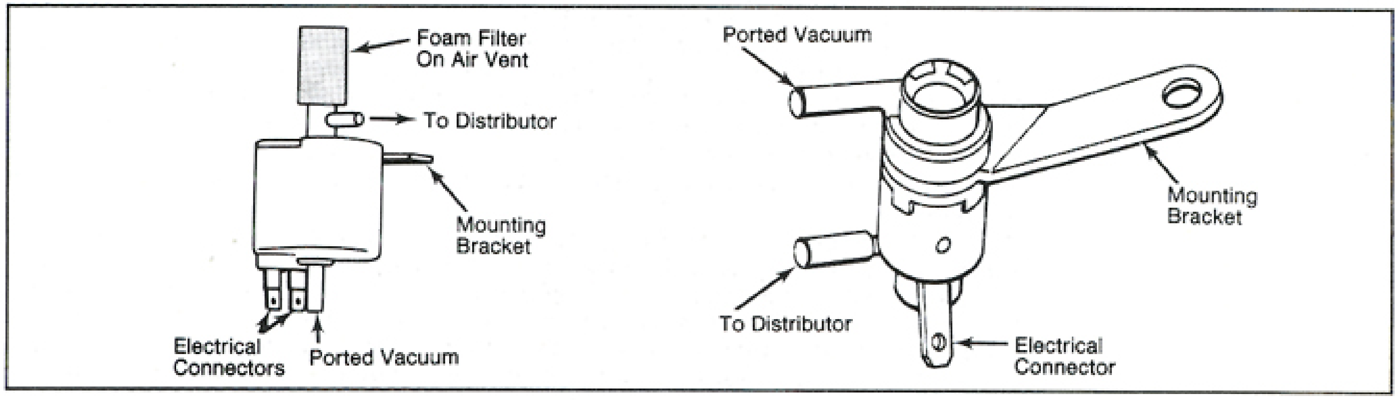


Fig. 9-42. Typical Vacuum Solenoid Valves

Transmission Switch - Two types of transmission switches are used: one for automatic, and one for manual transmissions: The function of both switches is the same. At low vehicle speeds, electrical current passes through the transmission switch and on to the VSV. When sufficiently high. speeds have been reached, or when the manual transmission is shifted into high gear, electrical current through the transmission switch is broken, thus deactivating the VSV:

Speed Sensor - Some systems do not use a transmission switch. Instead, a speed sensor is installed in the speedometer cable to indicate vehicle speed. When this sensor is used, an electronic amplifier is added to the system. The amplifier is needed because the signal produced by the speed sensor is too weak to activate the VSV. The amplifier reads the sensor signal, and generates a stronger one to activate the VSV.

Coolant Temperature Override (CTO) Switch – Any design may be modified with the addition of a coolant temperature override (CTO) switch. CTO switches may be activated when cold or hot. The cold CTO switch provides full manifold vacuum to the distributor during cold engine operation. The extra advance improves driveability and gives quicker warm-ups.

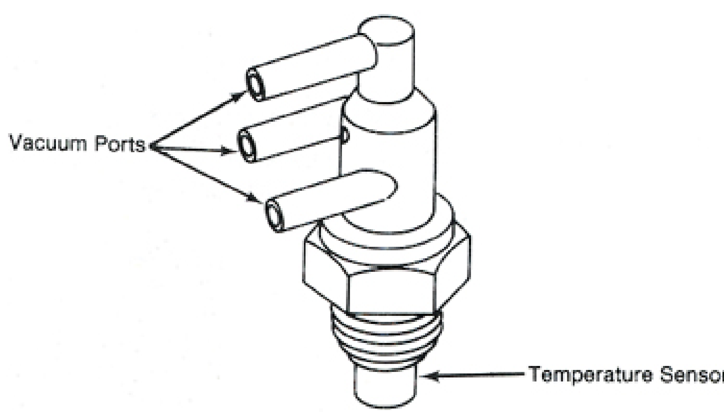


Fig. 9-43: Coolant Temperature Override Switch

The hot CTO switch functions in the same manner as the cold switch, except that full manifold vacuum is supplied when the engine becomes overheated (i.e. at extended idle, or while operating in high ambient temperatures). This extra advance increases engine idle speed to aid in engine cooling. The higher idle speed circulates coolant faster, and gives more airflow through: the radiator. As soon as the engine cools, regular operation of the spark control system is resumed.

Ambient Air Temperature Sensor - Some systems do not use coolant temperature as a control factor in system operation. Instead, a sensor is used to measure the temperature of ambient air. This sensor is an electrical relay built into the VSV power circuit. Below a specific temperature, the relay remains open, preventing activation of the VSV. Normal advance is maintained until air temperature is high enough to close the switch and activate the spark control system.

Systems Which Delay Vacuum Signal

Spark control systems which delay an increase in vacuum signal strength are very simple. They consist of a single valve in the vacuum line between carburetor ported vacuum and the distributor advance unit. Two types of valves are used. One is known as a spark delay valve; the other, used on Chrysler Motors vehicles, is the Orifice Spark Advance Control (OSAC) valve.

Both valves are designed to delay any increase in vacuum strength (vacuum advance) by several seconds. An interesting aspect of these valves is that while vacuum signals which increase in strength are delayed, decreasing signals are immediately relayed to the advance unit. Therefore, vacuum advance is delayed while ignition retard is immediate. The one major difference between the delay valve and the OSAC valve is that some OSAC valves are temperature sensitive. At certain specific low temperatures, the delay function of the valve is by-passed, allowing immediate vacuum advance as signal strength increases. At higher temperature, normal delay operation is resumed.

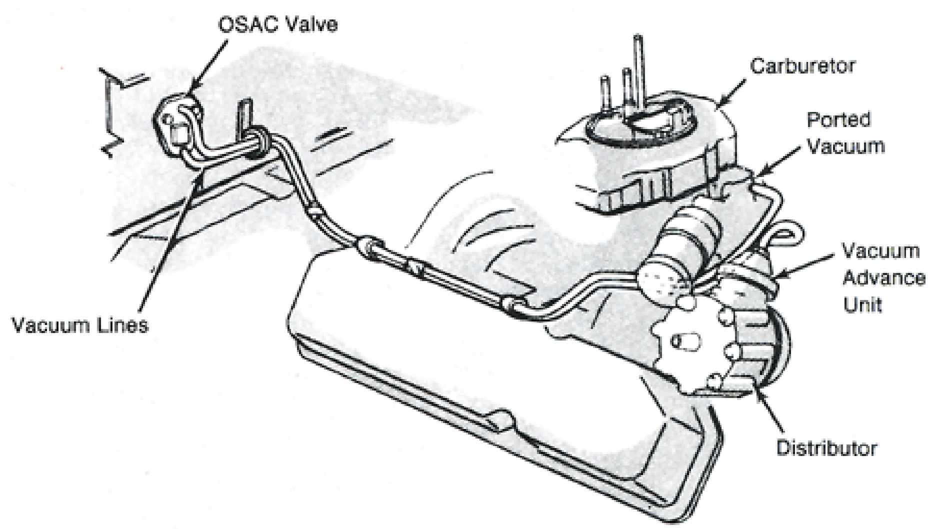


Fig. 9-44: Chrysler Spark Control System with OSAC Valve

OPERATION

Vacuum Solenoid Valve

The purpose of the Vacuum Solenoid Valve (VSV) is to block the vacuum signal to the distributor advance unit during low speed operation. The VSV has a plastic housing with vacuum fittings, an air vent, and electrical connections.

When the activated, it blocks vacuum going to the advance unit and opens an air vent. This releases vacuum already in the advance line. When the coil is deactivated, the air vent closes; the vacuum advance line opens, and normal vacuum advance continues.

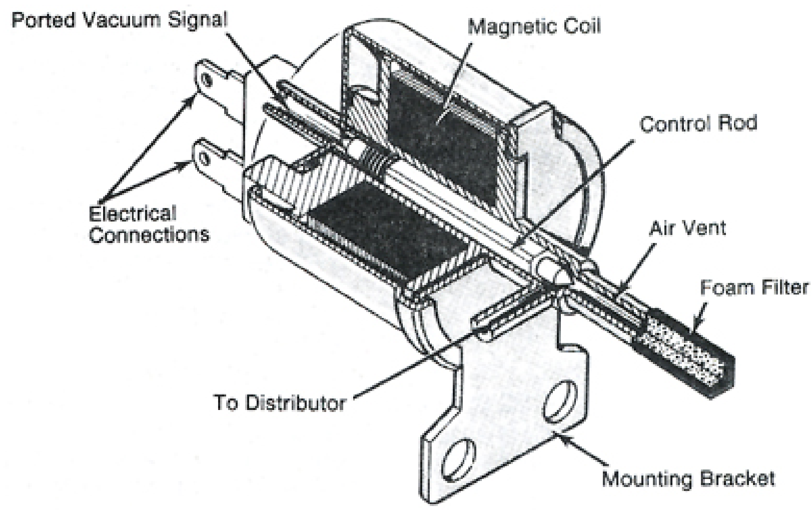


Fig. 9-45: Cutaway View. of Vacuum Solenoid Valve Operation

Transmission Switch
As noted earlier, the VSV is designed to prevent vacuum advance operation only during low. speed operation. In most cases, this speed is determined by a transmission switch. The VSV Coil is activated by electrical current that passes through the ignition switch, the coil, and is then grounded through the transmission switch. In other words, with the transmission switch off, the coil is not activated, and normal vacuum advance occurs. The transmission switches used on automatic and manual transmissions are of different designs, and will be discussed separately.

Automatic Transmission Switch - The automatic transmission switch is in the transmission case, and is subject to internal transmission fluid pressure. As vehicle speed increases, fluid pressure in the transmission increases as well. The transmission switch is designed to react to the pressure present at about 30 MPH. Until then, it remains closed, grounding the VSV circuit and activating the VSV coil. When fluid pressure is high enough, it opens the transmission switch. With the transmission switch open, the electrical circuit to the VSV is broken, and normal vacuum advance continues. On the other hand, when vehicle speed and fluid pressures drop enough, the circuit is completed, and the VSV coil is again activated.

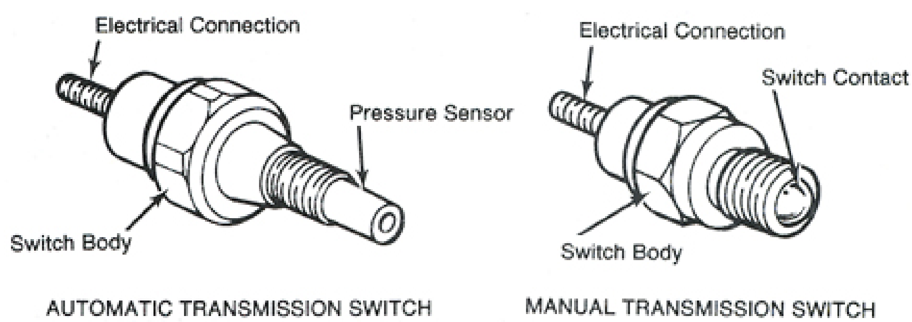


Fig. 9-46: Typical Transmission Switches

Manual Transmission Switch - The switch used on manual transmissions is mounted so that the shift linkage contacts it when the transmission is in high gear. This opens the switch, breaking the VSV circuit. In the lower gear ranges, contact with the switch is broken and the switch closes. As with the automatic version, when the switch closes, this completes the circuit, and the VSV coil restores spark control operation.

Speed Sensor
On some systems vehicle speed is determined by a speed sensor and an electronic amplifier, instead of a transmission switch.

Speed Sensor - The speed sensor is installed in the speedometer cable. As speed increases, an electrical signal through the sensor also increases. This signal is then processed through an electronic amplifier. The amplifier magnifies this signal so that the VSV can be operated in direct response to speed sensor information.

Electronic Amplifier - Amplifier control of the VSV circuit is triggered by the voltage signal from the speed sensor. When the speed sensor signal to the amplifier indicates a vehicle speed of 25-35 MPH, the amplifier breaks the VSV circuit, cutting off power to the VSV coil. Later, as vehicle speed drops to below 18 MPH, amplifier effect on the circuit is removed and the coil is activated once more.

NOTE All references to vehicle and engine speed, temperature settings, and vacuum pressures are approximate, and will vary with manufacturer.

CTO Switches

CTO switches are designed to modify the vacuum control signal to either improve cold drivability, or to reduce the temperature of an overheated engine. One type provides full manifold vacuum to the distributor advance unit when coolant is below a given temperature, while another provides manifold vacuum with coolant above a certain temperature. Both switches operate the same way.

The CTO switch (hot or cold) is mounted in an engine coolant passage (in the intake manifold, cylinder head, engine block or thermostat housing). The center vacuum connection is connected to the distributor unit. On cold CTO switches, the bottom connection is attached to the carburetor ported vacuum, and the top one, to the manifold vacuum. On hot CTO switches, manifold and ported vacuum line positions are reversed.

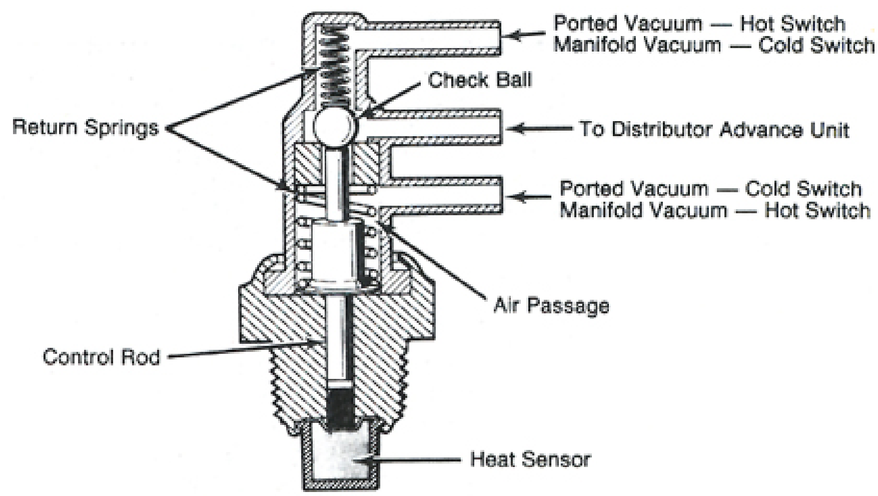


Fig. 9-47: Typical Coolant Temperature Override Switch

Whether a CTO switch is hot or cold depends on the temperature at which it operates. When coolant is cold, a check ball is at the bottom of the passage. In this position the top vacuum connection is open to the middle (distributor) connection. When coolant temperature exceeds a specific level, the check ball is moved up in the air passage, blocking the top vacuum connection, and opening the bottom one. The cold CTO switch seats the check ball at about 160°F (70°C); the hot CTO switch at about 225°F (105°C). So at normal operating temperatures the system is open to ported vacuum through the top connection of a hot CTO switch, or through the bottom one of a cold switch.

In either case, the manifold vacuum passes directly through the switch to the advance unit. The, ported vacuum signal, however, passes first through the vacuum solenoid valve, before reaching the CTO switch. In this way manifold vacuum can provide full ignition advance, regardless of VSV position, while VSV operation is not affected during normal operating conditions.

Some switches use a piston rather than a check ball. This difference is strictly internal, and has no effect on the overall operation of the system. This type of switch may be identified by the position of the distributor vacuum line connection. With a piston-type switch operating "cold", the distributor connection is at the top of the switch, the manifold vacuum signal in the middle, and the ported and manifold vacuum line positions are reversed on a hot switch.

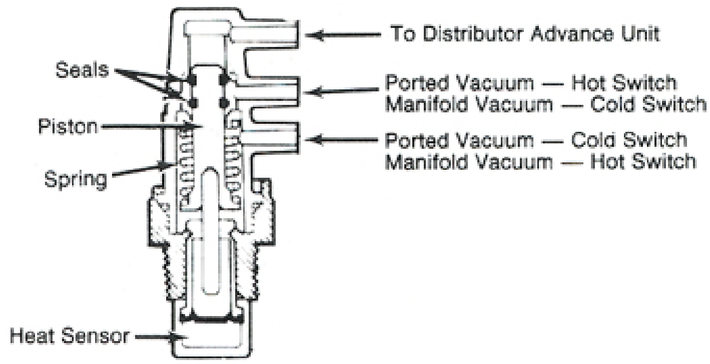


Fig. 9-48: Coolant Temperature Override Switch with Internal Piston

The CTO switch is one of the most popular emissions control devices in use, and is known by a variety of different names. But regardless of the term used for the switch, its purpose and function remain the same. In addition, the switch may be used with or without any other spark control devices. When the switch is used without a vacuum solenoid valve (or similar device), the ported vacuum line to the CTO switch is connected directly to ported carburetor vacuum.

Ambient Air Temperature Sensor - Used mostly on control systems with a speed sensor and amplifier, the ambient air temperature sensor performs a function similar to that of the CTO switch. During cold engine operation, the sensor prevents VSV function so that normal vacuum advance can occur until the engine warms up.
The air temperature sensor is wired into the VSV circuit. Below about 60°F (15°C) the sensor interrupts the circuit, deactivating the valve. This permits normal vacuum advance while the engine is warming up. When air temperature reaches 60°F (15°C), the circuit is restored and VSV operation continues as needed.

Delay Valves

Spark Delay Valve - The simplest spark control system used consists of a delay valve in the vacuum line between the carburetor port and the vacuum advance unit. The purpose of the valve is to slow spark advance by delaying increasing vacuum signals to the advance unit. The valve consists of a color-coded plastic housing with two vacuum connections, an internal sintered-metal delay orifice, and a one-way check valve.
A ported vacuum signal comes to the delay valve. Inside, the delay orifice prevents this signal from being immediately transferred to the distributor advance unit. The valve is designed to delay vacuum flow in one direction, while allowing free flow in the other.

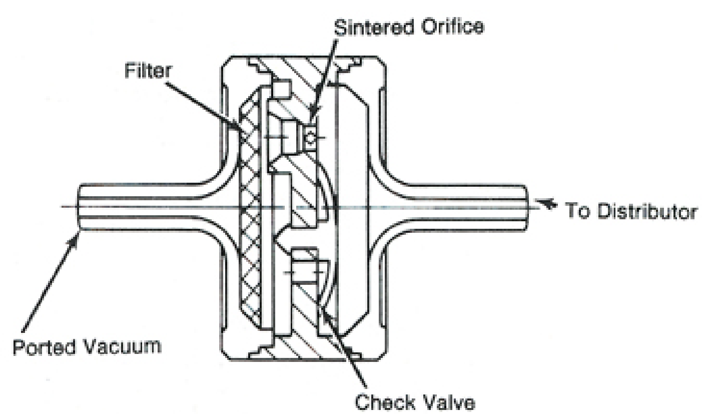


Fig. 9-49: Spark Delay Valve

Therefore, an increase in advance is delayed, while any decrease in the vacuum signal is relayed to the: advance mechanism immediately, thus canceling ignition advance. This prevents full spark advance during low speed acceleration while allowing for completely retarded spark during deceleration and idle. The length of the delay varies from 15 to 30 seconds, depending on the manufacturer of the valve and its application.

OSAC Valve- The Orifice Spark Advance Control (OSAC) valve operates in the same way as the delay valve, but with one additional feature: a temperature sensor. At normal operating temperatures, the valve operates just like any other delay valve. But when ambient air temperature is below about 60°F (15°C); the delay function of the valve is bypassed. This allows normal vacuum advance to occur during cold engine operation.

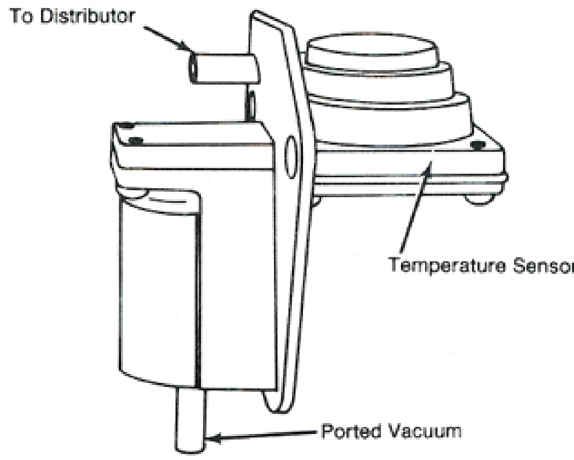


Fig. 9-50: Orifice Spark Advance Control Valve with Temperature Override

NOTE The system tests given here are preliminary samples intended for training purposes. For complete system testing procedures, or to determine where a particular system fault lies, use a current service/repair manual;

Preliminary Checks

Many problems with the spark control system can result from simple faults. To save diagnosis time and effort, perform a visual inspection of the following areas whenever the spark control system is suspected of malfunction or failure:

- Vacuum line connections and hoses. Ensure that all connections are tight and secure. Check that vacuum hoses are in good condition, not dry or cracked.
- Electrical wiring and connections. Check that all connections are clean and tight. Check wiring for frayed ends, chafing, splitting or cracking. Ensure that all connectors are clean and secure.

It is especially important that all system components are present and properly installed. A partial spark control system (with one or more components removed or disconnected) will not operate effectively or correctly:

Overall System Tests

System tests are divided into four categories:

- Vehicles with manual transmissions.
- Vehicles with automatic transmissions which use a speed sensor and amplifier for vehicle speed information.
- Automatic transmission equipped vehicles using a transmission switch for speed information with the switch located in the direct clutch circuit.
- Automatic transmission equipped vehicles using a transmission switch for vehicle speed information, with the switch located in the governor oil pressure circuit.

If the location of the transmission switch cannot be determined, refer to the repair manual for that model.

Manual Transmission - 1) Remove the vacuum line from the vacuum advance unit, and install a vacuum gauge in the line. With engine at normal operating temperature, apply the brakes firmly and bring engine speed to 1500 RPM.

2) With the clutch disengaged, place transmission in 1st gear. Observe the vacuum gauge. Shift up to the next gear and note vacuum reading. Continue upshifting and checking

gauge through all forward gears. A vacuum reading should register in top gear only. With the transmission in high gear, the gauge should show ported vacuum level.
3) If response is as indicated, the system is operating properly. If not, there is a fault in the system. System components should be tested individually. For specific component tests and procedures, refer to a shop manual.

Automatic Transmission with Speed Sensor and Amplifier - 1) Raise the rear wheels until they are off the ground, and support vehicle with safety stands. Remove the vacuum line from the distributor advance unit, and install a vacuum gauge in the line.
2) With air temperature sensor below about 55°F (13^{0}C), put transmission in neutral, and raise engine speed to 1500 RPM. The vacuum gauge should read 6-10 in. Hg. Allow temperature of sensor to rise above about 65°F (18^{0}C) and read vacuum gauge. Reading should be zero.
3) With the transmission in gear and at a speed of about 30 MPH, the vacuum gauge should read about 6 in. Hg. Slowly decelerate and observe gauge. At around 15-20 MPH vacuum reading should drop to zero.
4) If the system responds as described, it is in good condition and operating properly. If not, individual system components should be checked. For specific component tests and procedures, refer to ;a current shop manual.

Automatic Transmission - Switch in Governor Oil Pressure Circuit - 1) Raise the rear wheels until they are off the ground, and support vehicle with safety stands. Remove the vacuum line from the distributor advance unit and install a vacuum gauge in the line.
2) Start the engine and place the transmission in "D". With engine coolant at normal operating temperature, slowly accelerate to about 40 MPH. As speed approaches 40 MPH, ported vacuum should read on the vacuum gauge.
3) Lower speed to normal idle, remove the gauge and reconnect the vacuum line to the advance unit. Connect a timing light to the engine and observe ignition timing while increasing engine speed. Ensure that vacuum advance mechanism is operating properly.
4) If the system responds as described, it is in good condition and operating properly. If not, individual system components should be checked, For specific component tests and procedures, refer to a current shop manual.

Automatic Transmission - Switch in Direct Clutch Circuit - 1) Remove the vacuum line from the distributor vacuum advance unit and install a vacuum gauge in the line. Start the engine, apply brakes firmly and place transmission in reverse.
2) Allow coolant to reach normal operating temperature and increase engine speed to 1500 RPM (transmission still in reverse and brake firmly applied). The vacuum gauge should indicate ported vacuum.
3) If the system responds as described, it is in good condition and operating properly. If not, individual system components should be checked. For specific component tests and procedures, refer to a current shop manual.

Spark Delay Valve

1) Remove the delay valve from the vehicle and connect a hand vacuum pump to the ported vacuum side of the valve. Apply about 10 in. Hg vacuum, and watch pump gauge.
2) Vacuum level should drop slowly to zero. If valve does not hold vacuum, or if signal does not drop, valve is faulty and should' be replaced.
3) Move hand pump to distributor side of valve and try: to apply vacuum. Valve should not hold vacuum. If it does; the-valve is damaged and must be replaced. For specific component tests and procedures, refer to current shop' manual.

OSAC Valve

1) With engine idling and air temperature at valve above 60°F (15^{0}C), remove the vacuum line from the distributor vacuum advance' unit, and install a vacuum gauge in the line.
2) Raise the engine speed to 2000 RPM, and watch vacuum gauge. Reading on gauge should increase slowly, reaching a maximum value in about 20 seconds. If no reading is shown, the valve is defective and should be replaced. Also, the increase in vacuum should occur slowly, indicating proper operation of the delay orifice in the valve. As stated before, for specific component tests and procedures refer to a current shop manual.

MAINTENANCE

Most components in the spark advance system do not need regular maintenance. Check to be sure all vacuum lines are properly routed and not kinked or cracked. Check wiring as well, if a VSV is used.

The vacuum and centrifugal advance mechanisms, inside the distributor, pivot on small pins. These pins are sensitive, and tend to corrode, and cause the advance system to fail or act unpredictably. It is good practice to check these picot pins and lubricate them during any tune-up service

CATALYTIC CONVERTERS

Extensive efforts have been made to reduce exhaust emissions from the engine. However, excessive amounts of the 3 pollutants still leave the engine and enter the exhaust system. To prevent these pollutants from entering the atmosphere, they must be converted to less harmful elements while still in the exhaust system. Since 1975, the single most important device used to meet this challenge has been the Catalytic Converter.

HISTORY & DEVELOPMENT

Domestic automobile manufacturers were aware of catalytic converters long before they were actually used on production vehicles. Early emissions regulations could be met without the complication, expense and questionable reliability of the first converters. In later years, as emissions regulations tightened, these disadvantages were gradually outweighed by the need for stricter engine controls.

In 1974, California regulation. required that hydrocarbon (HC) and carbon monoxide (CO) emissions levels not exceed 32 and 39 grams per mile (g/m), respectively. Grams per mile (g/m) is a measurement of emissions the manufacturer uses to certify vehicles with the Environmental Protection Agency (EPA). In 1975, these regulations tightened to .9 g/m for HC and 9 g/m for CO. The most practical method available to meet these drastic cuts was the addition of a catalytic converter. National emissions levels were reduced as well, though not quite as drastically as in California. And so, most vehicles sold in 1975 were equipped with catalytic converters.

As with other emissions devices, the design and function of the converter has been refined and improved in recent years. Initially, catalytic converters were designed to reduce HC and CO emissions, only. In later years, as restrictions on NO_x emissions levels tightened, converters were redesigned to include NO_x reduction as well.

DESCRIPTION

The catalytic converter is installed in the exhaust system between the exhaust manifold and the muffler so exhaust gases must pass through it. On some early Ford V8 systems, a single converter was used. The system was designed so only half of the exhaust gases were treated by the converter, with the other half by-passing it completely. In 1979 this system was discontinued, due to continued reductions in allowable amounts of HC and CO in vehicle exhaust.

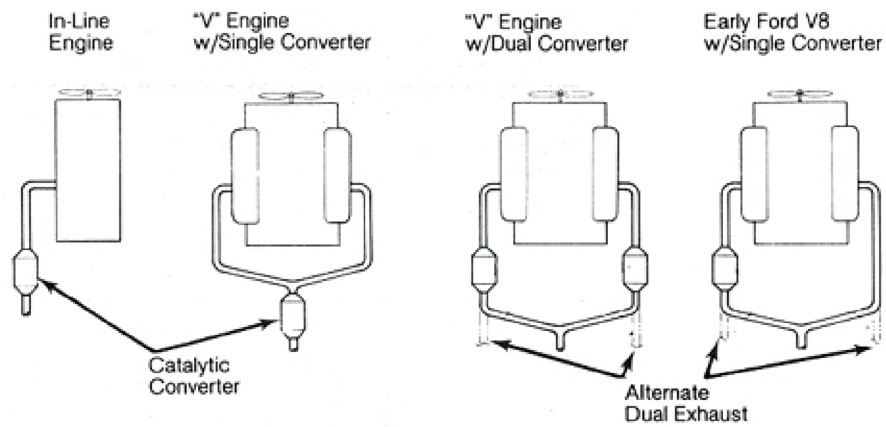


Fig. 9-51: Typical Catalytic Converter Installations

In the converter, platinum (or platinum alone) are used as a "catalyst" to help a chemical reaction convert HC and CO to carbon dioxide and water. The converter contains aluminum oxide pellets, or a ceramic honeycomb "monolith", coated with the catalyst. Systems which reduce NO_x emissions in addition to HC and CO include a converter which uses either rhodium or rhodium and platinum as a catalyst. Because of its ability to reduce all three emissions, it is known as a three way catalyst, or TWC.

OPERATION

Most vehicles equipped, with a catalytic converter also include special heat shielding between the exhaust system and the vehicle underbody, and some type of catalyst protection system.

Catalytic Converters

There are several types of converters in use today. They include conventional, TWC, dual stage (a combination of the first two in one housing) and, on some recent systems, warm-up or mini-oxidation converters. The primary function of any converter, regardless of design, is to reduce exhaust emissions levels. This is accomplished through the use of a catalyst: platinum, palladium or rhodium. The catalyst is present as a coating on either aluminum oxide pellets or a ceramic monolith (single piece ceramic honeycomb). Function of the converter is the same, regardless of the medium used.

Conventional Converter - A conventional converter is the most common type of converter in use. It may use pellets or a monolith medium, depending upon application. Platinum and palladium (or platinum alone) are used as the catalyst in this type of converter. Those using aluminum oxide pellets have built-in baffles which contain the pellets within the converter and force exhaust gases to pass through the pellet "bed". This ensures that the full capacity of the converter is used, and that all exhaust gases are treated.

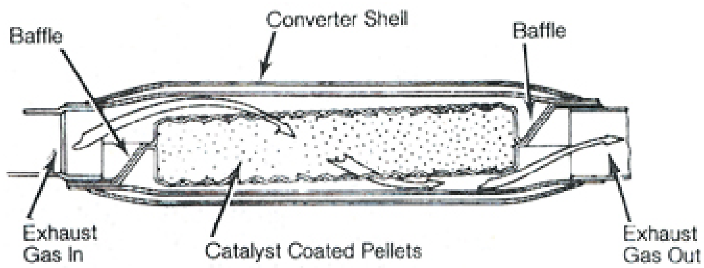


Fig. 9-52: Exhaust Flow Through a Typical Pellet Type Converter

Converters which utilize a ceramic monolithic contain the monolith itself (coated with the catalyst), diffuser plates and a steel mesh blanket. The monolith is a honeycomb-like structure with hundreds of small passages through it. It is superior to the pellet design because it causes less exhaust system back pressure, is smaller (resulting in quicker heating time), and is generally more durable and less susceptible to vibration. However, it also requires more catalyst to manufacture (higher cost) and is not repairable. If the catalyst is destroyed, as would occur if leaded gasoline were used extensively, the entire unit must be replaced. The pellets in a pellet type converter, on the other hand, can be replaced without replacing the, entire assembly. Also, the monolith structure can be damaged by excessive road shock or rapid changes in temperature. The steel mesh blanket is wrapped around the monolith to help protect it from these hazards. It acts as a cushion for the monolith, and insulates if. from rapid temperature changes.

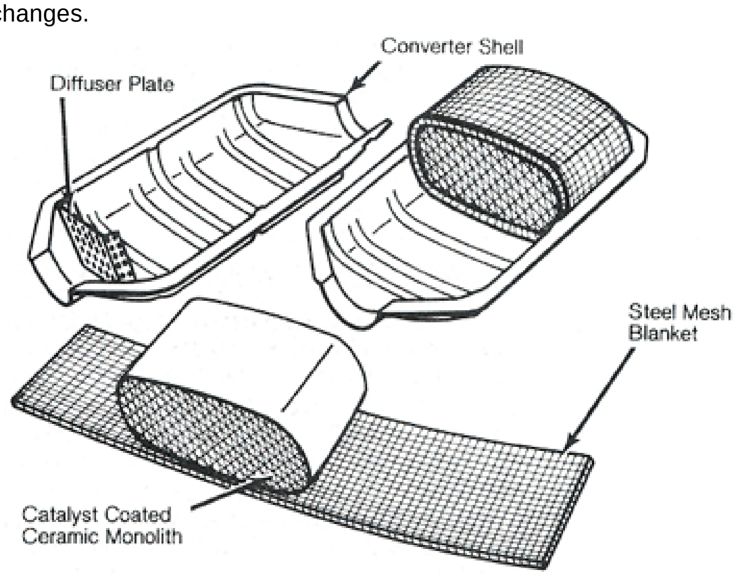


Fig. 9-53: Disassembled View of a Monolith Converter

As exhaust gases enter this type of converter, they encounter a perforated diffuser plate which breaks up and spreads out the flow. This ensures that the gas will be more equally distributed throughout the monolith, and not be concentrated on one small section of it. As the gases pass through the hundreds of passages in the monolith, they are exposed to the catalyst.

TWC Converter - This type of converter is nearly identical to a conventional converter with the exception of the catalyst used. A conventional converter, using platinum and palladium, as a catalyst, reduces emissions of HC and CO only. The TWC converter uses rhodium, with or without platinum, as its catalyst. Rhodium helps reduce NOx emissions, as well as HC and CO. This characteristic, that of reducing emissions of all three major pollutants, is why it is referred to as a three way catalyst, or TWC.

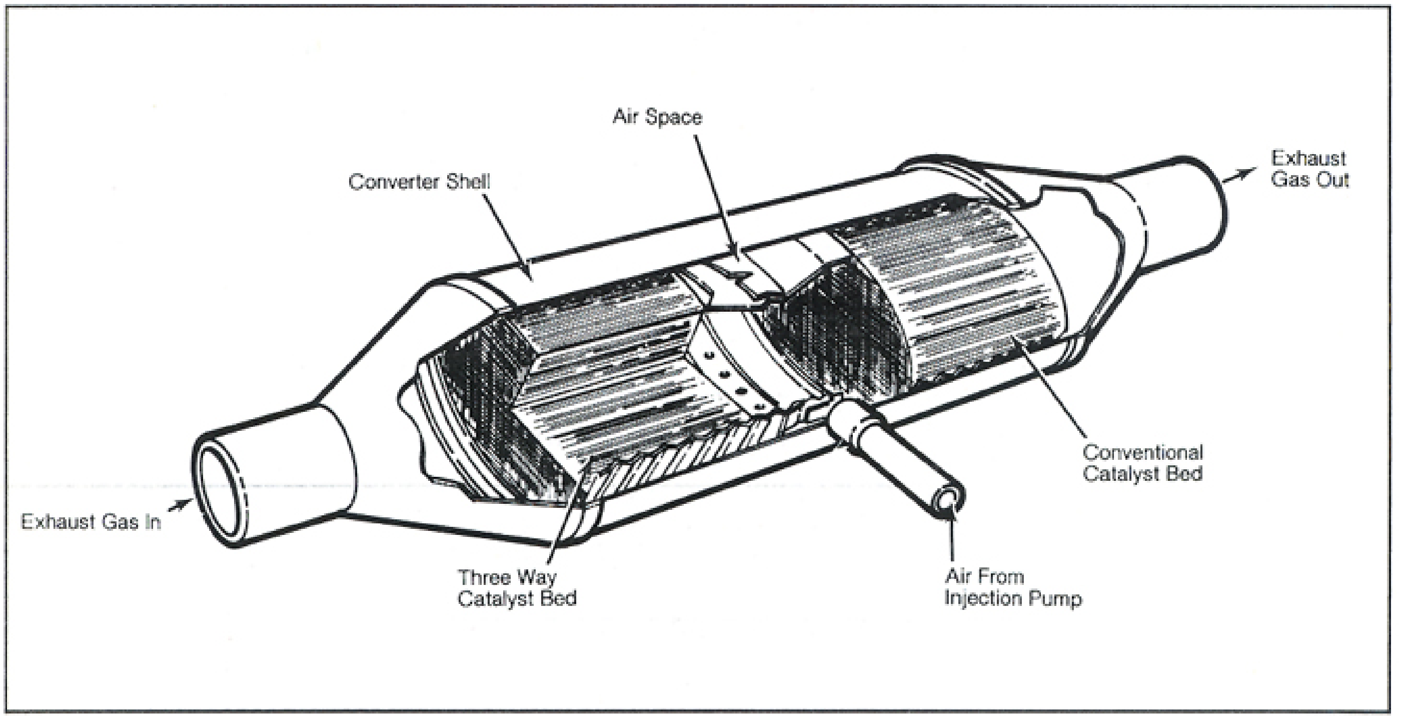


Fig. 9-54: Monolith Type Dual-Stage Converter with Air Injection

TWC converters, when used, are usually included in addition to a conventional converter. The TWC converter is added in one of two ways. As a separate converter assembly, it's located in the exhaust pipe ahead of the conventional converter. It may also be included as part of a single assembly which has the TWC and the conventional converter in common housing. This is called a dual-stage converter.

Dual-Stage Converter - The dual-stage converter contains a TWC converter and a conventional converter in a common housing, separated by a small air space. The two catalysts are referred to as catalyst "beds". Exhaust gases pass through the TWC first. The TWC bed performs the same function as it would as a separate device, reducing all three emissions. As exhaust gases leave this bed, they pass through the air space and into the second, conventional, catalyst bed.
Catalytic converters reduce emissions levels by oxidizing pollutants. This means exhaust gases combine with oxygen to form harmless compounds. The reaction requires lots of oxygen. In a dual stage converter, most of the available oxygen is used up in the first catalyst bed. If oxidation of HC and CO is to continue in the second bed, more oxygen is required. Most dual stage converter systems use the air injection system as the source of this supply. Air is injected into the space between catalyst beds to provide the required oxygen.

Warm-Up Converter - In the past few years, some systems have begun to utilize a small, additional converter, located immediately after the exhaust manifold, know as a "mini" or "warm-up" converter. Usually of the monolithic design, it does two things. First it starts oxidation of emissions before they reach the main converter. Second, and more importantly, it provides for some control of exhaust emissions before the larger converter has warmed up to operating temperature.

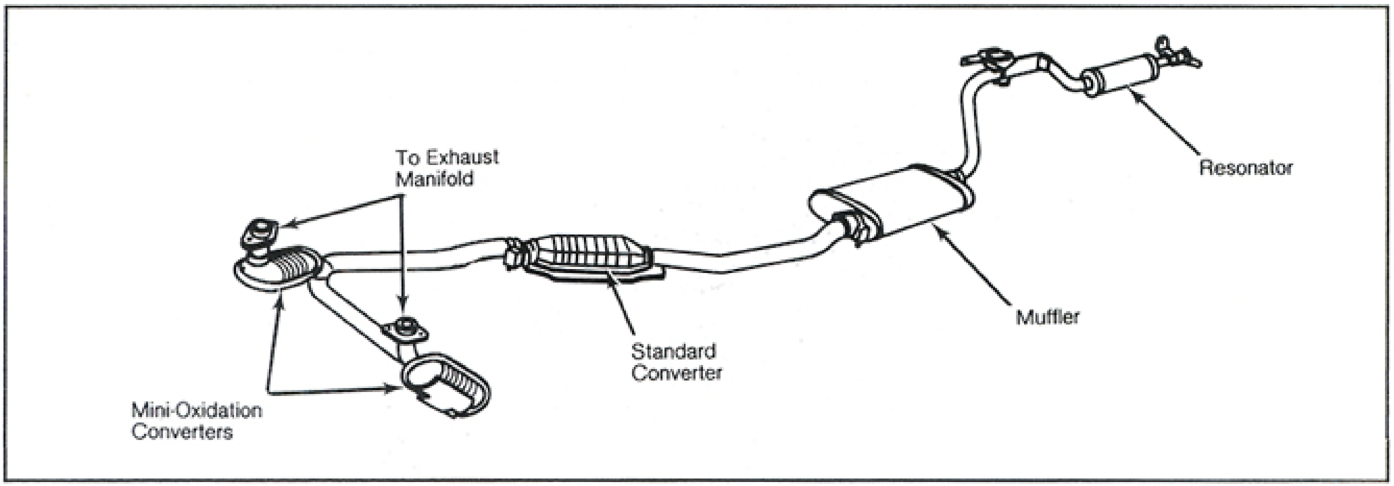


Fig. 9-55: Exhaust System with Warm-Up Converter

Before any converter can begin to reduce emissions, exhaust gas temperatures of at least 500°F (260°C). Due to its location close to the exhaust manifold, and its considerably smaller size, the warm-up converter reaches the required temperatures much more rapidly than the larger, main converter. This reduces the amount of time during which no converter action occurs:

Heat Shields

When functioning properly, catalytic converters produce a great deal of heat. During normal operation, internal temperature of the converter will be about 1400°F (760°C), with skin temperatures of 700°F (370°C) or higher. Special shields are installed to prevent damage to the vehicle underbody, and to keep heat from transferring through the floor and into the engine compartment. Extra heat insulation is added in the passenger compartment to keep the floor from becoming uncomfortably hot:

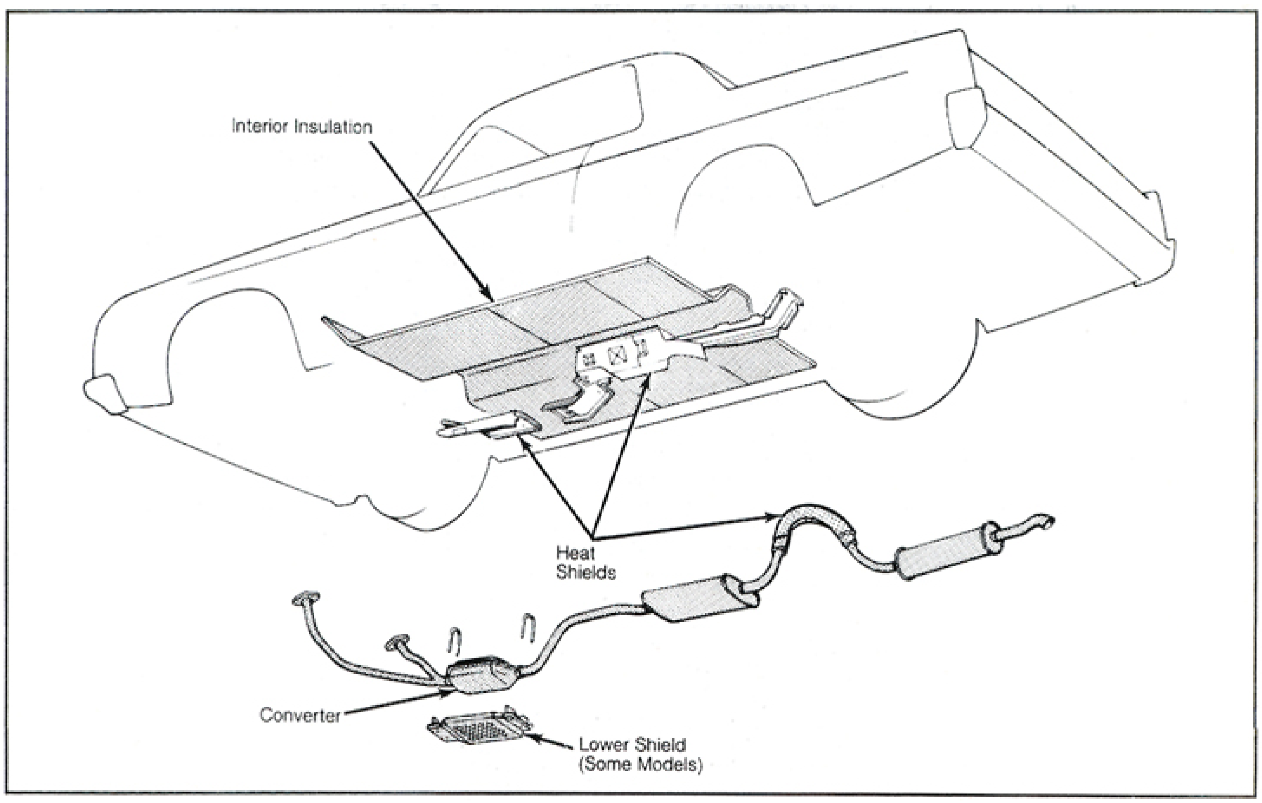


Fig. 9-56: Heat Insulation and Shielding Insulation

Usually of aluminized steel, the shields are located in critical areas above the converter and muffler. They usually extend several inches beyond the borders of these components. Shield application varies with the make and model of vehicle, drivetrain used, and original emission controls (due to differences in converter usage). When replacing a missing or damaged shield, it is very important that the replacement shield be identical to the one being replaced.

Catalyst Warm-Up Systems
On some models, air injection is used to, increase converter efficiency during cold engine operation. In addition to the usual air injection and catalytic converter system components, a thermal switch or valve(s) is included.
The main purpose of a catalyst warm-up system is to improve emissions levels when the converter is cold, and to raise converter temperature to its optimum range as rapidly as possible. This is accomplished by the limited use of air injection. Vehicles which use this system are typically equipped with a feedback-type fuel injection system. This system uses an oxygen sensor to inform an onboard computer of air/fuel ratio. The computer responds to the oxygen sensor signal by adjusting the actual ratio towards the ideal. Since the sensor signal is based upon the oxygen content of exhaust gases, air injection cannot be used during normal engine operating conditions. This is because the high oxygen level in the exhaust would fool the oxygen sensor. During cold engine operation, however, this fact can be used to advantage.
The thermal switch used on warm-up systems allows air injection to occur below a specific coolant temperature. Typically around 110°F (45°C), air injection is prevented once coolant temperature exceeds this level. But when coolant temperature is low enough, air injection occurs. During warm-up periods, a rich air/fuel mixture is needed for smooth engine operation. By injecting air into the exhaust system, several things are accomplished. First, the oxygen sensor detects a high ratio of oxygen in the exhaust gases and signals the computer of this condition. In response, the computer signals a richer air/fuel mixture, eliminating the need for a conventional choke mechanism. Also, the additional air allows for better converter operation while it is still below, optimum operating temperature. Not only does this result in improved emissions levels during cold engine operation, but the improved converter efficiency produces more heat, bringing the converter to that optimum temperature sooner than would occur without air injection.

Catalyst Protection Systems
The catalyst reduces the emissions of HC, CO and NO_x by completing the combustion process in the converter. As noted earlier, this results in very high internal temperatures. If engine conditions result in excessive unburned fuel in the converter, temperatures high enough to destroy the catalyst can be reached. Special systems have been developed to protect the catalyst from these excessively high temperatures.

Throttle Positioner Solenoid - Under deceleration, the closed throttle plates restrict airflow into the engine, resulting in, a rich mixture and unburned fuel in the exhaust. Under normal conditions, this presents no problem. However, high speed deceleration introduces unusually high amounts of unburned fuel into the converter. Excessive heat build-up can result from the converter burning excess fuel and possibly damage the converter assembly. On some early catalytic converter. applications this problem was solved by adding a throttle positioner solenoid to the system.
An electronic engine speed which switch senses ignition signals and calculates engine RPM. The speed switch controls a throttle positioner solenoid. At low RPM, the solenoid is not activated. But when engine speed exceeds-2000 RPM, a signal is sent to the solenoid, It extends outward; holding the throttle plates open at a fast idle position (about 1500 RPM). If the throttle plate is released at high engine speeds, this position keeps the throttle plates from closing and allows airflow into the engine. This balances the air/fuel ratio, providing for more complete combustion in the cylinders.: This prevents unburned fuel from entering the converter and avoids excessive heat build-up. When engine speed drops below 2000 RPM, speed switch cuts off the signal to the solenoid. The solenoid de-energizes and the' throttle returns to its normal position.

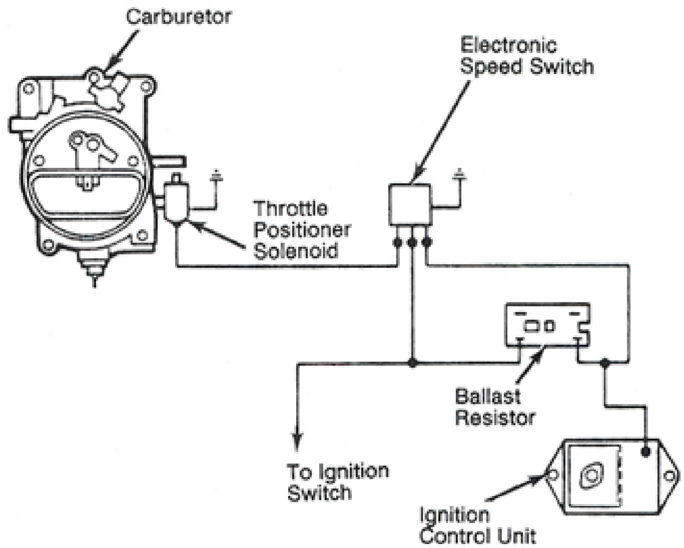


Fig. 9-57: Schematic Drawing of a Throttle Positioner Protection System

Air Injection Diversion - During certain engine operating conditions, the only way to successfully avoid excessive catalyst temperatures is to "turn off" the converter. This is done by diverting air injection away from the converter. Without the additional air supply, oxidation cannot occur. Since it is oxidation which produces heat in the converter, diverting air injection reduces converter temperatures: It also results in higher emissions levels and can only be used under extreme conditions.

The main components of this system are the diverter valve, Vacuum Differential Valve (VDV), vacuum solenoid, ported vacuum switch, air cleaner and floor pan temperature switches. Engine conditions which require diversion are: rich engine warm-up, engine deceleration, overheated engine operation or an overheating catalytic converter (as indicated by the floor pan temperature switch). Normal diverter valve operation is reversed in this system. While most diverter valves operate when a vacuum signal is present, the valve in this system by-passes injection when the manifold vacuum signal is absent.

The vacuum signal to the diverter valve is controlled by the vacuum solenoid. When energized the, vacuum solenoid allows the manifold vacuum signal to reach the diverter valve. Power to the solenoid is provided via the normally closed temperature switches. If engine or floor pan temperatures exceed a preset value, a switch opens, de-energizing the vacuum solenoid. This cuts off the vacuum signal to the diverter valve. In the absence of a vacuum signal, the valve by-passes injection air to the atmosphere.

The vacuum delay valve allows air diversion during engine deceleration. It is located in the vacuum line to the diverter valve, between it and the vacuum solenoid. The delay valve consists of two vacuum chambers separated by a flexible, spring loaded diaphragm; the lower exposed to manifold vacuum. Under normal operating conditions, a small orifice in the diaphragm balances vacuum between the two chambers. When deceleration results in a sudden drop in manifold vacuum, the diaphragm is pulled down against the spring. This opens an air bleed in the valve. This vents the vacuum signal, preventing it from reaching the diverter valve. This condition lasts until the orifice in the diaphragm can balance the vacuum signal between the two chambers. When the chambers are balanced, the air bleed is closed and normal operation is restored.

NOTE Refer to EXHAUST GAS RECIRCULATION and AIR INJECTION articles for detailed descriptions of air injection and EGR operation.

Air Injection/EGR Prevention - The Air Injection/EGR Prevention catalyst protection system is designed to prevent EGR when the engine is cold, and air injection during extended idling. The main components of the system are a thermal vacuum switch (TVS), a vacuum delay valve (VDV) and the diverter valve. When intake air temperature is below 60°F (16°C), the TVS blocks the ported vacuum signal to the EGR and diverter valves. EGR and air injection are prevented until intake air temperature exceeds 60°F (16°C), opening the TVS.

The unusually rich air/fuel mixture which occurs during engine idle can easily cause converter overheating if combined with air injection and continued for an extended period of time. A vacuum delay valve allows air injection to continue during periods of brief engine idle, but cuts off injection if engine idling continues for more than 30-60 seconds. The vacuum delay valve is located in the ported vacuum line to the diverter valve. During normal engine operations, a vacuum signal is present in this line. However, when the throttle is closed and engine speed drops to idle, the ported vacuum signal drops to zero.
The vacuum delay vale contains a diaphragm with a small bleed hold. Under normal operating conditions, the vacuum signal is balanced across the diaphragm by this bleed. When the throttle is closed and ported vacuum drops to zero, the previously high vacuum signal is trapped between the vacuum delay valve, and the diverter valve. Air injection continues until the vacuum in this line is bled down through the valve orifice, usually about 30-60 seconds. Air is then by-passed to the atmosphere until normal engine operation is resumed.

TESTING

No real testing procedures exist for a catalytic converter. As a standard procedure, the complete exhaust system (including converter, muffler, pipes and heat shields) should be visually inspected anytime that the vehicle is on a rack for service. Any serious damage to the converter, i.e. gouges, large dents or tears, means the converter should be replaced. Excessive exhaust system backpressure (as indicated by poor engine performance or overheating) or abnormally high HC and CO levels may be an indication of an improperly operating converter.

Exhaust Backpressure
1) Run engine until warm. Remove a check valve from air injection system to open a port to the exhaust system.

CAUTION - Exhaust system is hot. Wear gloves to avoid serious burns.

2) Connect a fitting and hose to the exhaust manifold port. Connect a fuel pump pressure gauge to the other end of the hose.
3) Start engine and run at 2500 RPM. If the gauge indicates more than 2.75 to 3 psi, there may be a restriction' in the converter or exhaust system.
4) Stop engine and inspect exhaust system carefully,. Be sure to check for dual-layer pipes, where inner layer may collapse. If no evidence of restriction is found, replace converter.

Catalyst Protection Systems
Testing procedures are given here for the Throttle Positioner Solenoid Protection System. For basic air injection and EGR test procedures, refer to the appropriate article in this manual. For specific testing of these systems as they relate to catalyst protection, refer to shop manuals.

Throttle Positioner Solenoid Protection System - 1) Disconnect the throttle position solenoid lead wire and hold throttle, open. Watch the solenoid stem closely while applying battery voltage' to the solenoid lead., The stem should move out of the solenoid to its extended position. If it does not, replace the solenoid assembly.
2) If solenoid reacts as indicated, or with new solenoid in place, connect a tachometer and start the engine. Apply battery voltage to solenoid lead once again. Wait about 30 seconds for engine speed to stabilize, and check engine speed. Slowly raise engine speed until solenoid is just fully extended. Verify that engine idle speed with the solenoid extended is 1450-1550 RPM. Adjust engine speed if not within this range.
3) Disconnect the solenoid wire from the direct battery voltage and reconnect it to the electronic speed switch. Slowly raise engine speed while observing solenoid stem. As engine speed passes about 2000 RPM, the stem should extend and remain extended.
4) Slowly decelerate engine. At about 1800 RPM, the solenoid stem should retract. If the solenoid does not respond correctly in this step or step **3)**, the speed switch is faulty and must be replaced.

MAINTENANCE

No regular maintenance is required on a catalytic converter. Check the air injection or overheat protection. system to be sure all hoses and wires are connected properly. Be sure unleaded fuel is used at all times.

THERMOSTATIC, AIR SYSTEMS

In order for a cold engine to operate smoothly, the air/fuel mixture must be enriched. Unfortunately, when a richer mixture is used and incoming air is cold, HC and CO levels are increased. Until the engine is fully warmed up, or unless a warm air supply is provided, emissions levels of the engine will be too high. Thermostatic Air Systems use air cleaner heat, intake manifold heat and pre-heating grids to provide warmer air.

HISTORY & DEVELOPMENT

If automotive emissions levels were only measured while cruising at 2500 RPM with a warm engine, many of the emissions controls present on today's vehicles would not be necessary. However, automobile engines do not operate under such predictable and steady conditions. They must function at different speeds, temperatures, altitudes and humilities. Emissions standards must be met under all of these conditions. One important operating condition is initial start and warm-up of a c o l d engine.

To obtain smooth operation when the engine is cold, the air/fuel mixture is enriched (choked). This is necessary because cold air does not mix with (atomize) liquid fuel as well as warm air. Since less fuel is in the air, more must be present to begin with to get enough fuel in the combustion chambers. Unfortunately, this results in a greater amount of unburned fuel in the exhaust. So while cold operation improves, HC and CO emissions are increased.

If warm air can be supplied to the carburetor during cold engine operation (warm-up), leaner air/fuel mixtures can be used. The result is more complete combustion and lower emissions. The thermostatic air cleaner provides this warmer air.

INTAKE CHARGE HEATING

In addition to the heating done by the thermostatic air cleaner, most manufacturers also heat the intake charge once it is in the manifold. This is called manifold heat. Fuel tends to drop out of the airstream (condense) when warm air hits a cold manifold wall. To reduce this tendency; either the air or the manifold can be heated. A variety of approaches are used, but most engines are designed to heat the bottom of the intake manifold. This can be done with exhaust gas or engine coolant. Another method is to reheat the mixture with an electric heating grid:

ENGINES WITHOUT INTAKE HEATING

Some cars will not have thermostatic air cleaners or intake heating; usually fuel-injected models with one injector per cylinder. The injection system measures the amount of air entering the engine, and can adjust the mixture for colder, denser air. In addition, since fuel is injected right at the intake valves, no fuel is lost due to condensation in the manifold. Unlike most carbureted models, these engines are capable of controlling mixture without intake air heating.

DESCRIPTION

Thermostatic Air Cleaner

The purpose of a Thermostatic Air Cleaner (TAC) is to supply warm air to the carburetor during cold engine operation. This system is active during cold engine warm-up only, as this is the only time when, special provisions for warm airflow are required. Under all other operating conditions, air cleaner function is the same as any non-thermostatic unit.

Warm air is collected from around the exhaust manifold by an exhaust shroud and carried through a hot air duct, or tube, to the air cleaner snorkel. An air door located in the snorkel controls the amount of hot air that is blended with cooler air from the engine compartment (or outside source). When the engine is cold, the d o o r is positioned so only heated air is allowed into the air cleaner. With the engine fully warmed up, only cooler air is admitted. Air door position is controlled by either a thermostat motor in the snorkel, or by a vacuum motor mounted on top of the snorkel.

Manifold Heating

In most cases, an exhaust gas crossover is designed into the manifold, just under the carburetor: Hot exhaust gases can be routed through it, heating the intake charge, decreasing warm-up time and improving air/fuel mixing to allow leaner mixtures. This system uses an exhaust manifold valve, operated by a thermostatic spring or a vacuum motor. A similar heater system uses a coolant passage under the manifold, so engine block coolant can warm the manifold passages. A third approach heats the intake charge. This system uses a coolant temperature switch and an electric heating grid under the carburetor.

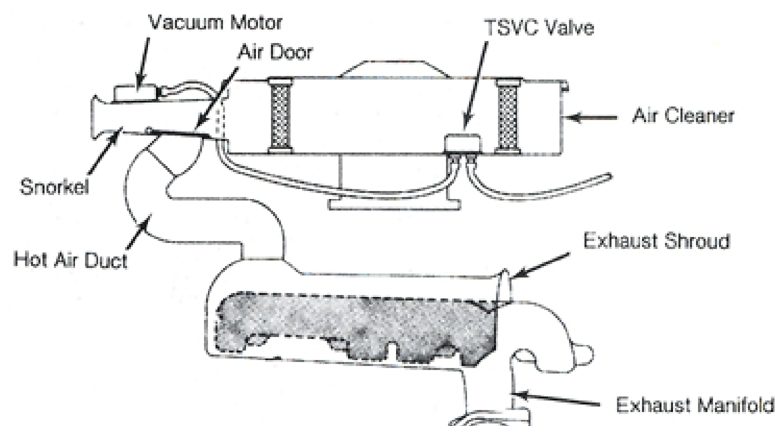


Fig. 9-58: Typical Thermostatic Air Cleaner System
(Vacuum Control Shown; Thermostat Control is Similar

OPERATION

Thermostatic Air Cleaner

The amount of air blending which occurs in a thermostatic air cleaner is controlled by the position of the air door. Most air doors are controlled by a vacuum motor, though function is the same regardless of the control method used. Operation of the two types of TAC (vacuum or thermostat motor) is nearly identical.

The main components of the system are the air cleaner housing and snorkel, the heat shroud around the exhaust manifold, a hot air tube or pipe to carry heated air from the shroud to the snorkel, an air door in the snorkel, and the control motor. See Fig. 9-58. Systems with thermostat controlled air doors may include a vacuum override switch. Those with vacuum motor control include a temperature sensitive vacuum control switch (mounted in the air cleaner housing) and in some cases, a vacuum check valve.

Thermostat Motor Control

Basic Operation - On systems which use a thermostat motor, the air door is spring loaded in the heated air or open position. The thermostat motor is located in the snorkel just ahead (carburetor side) of the air duct opening. The motor is connected to the air door by a linkage rod. When the temperature of incoming air is below a specific point, typically 85-105°F (30-40°C), the linkage rod is retracted. This holds the air door fully open so that heated air from the exhaust shroud is admitted into the air cleaner. As the temperature at the thermostat increases, the control rod is extended. It gradually closes the air door to allow a greater percentage of cooler air to mix with heated air. When air temperature finally rises above a specific level (varies with manufacturer), the control rod is fully extended. It closes off the air door, completely cutting off heated air from the exhaust shroud.

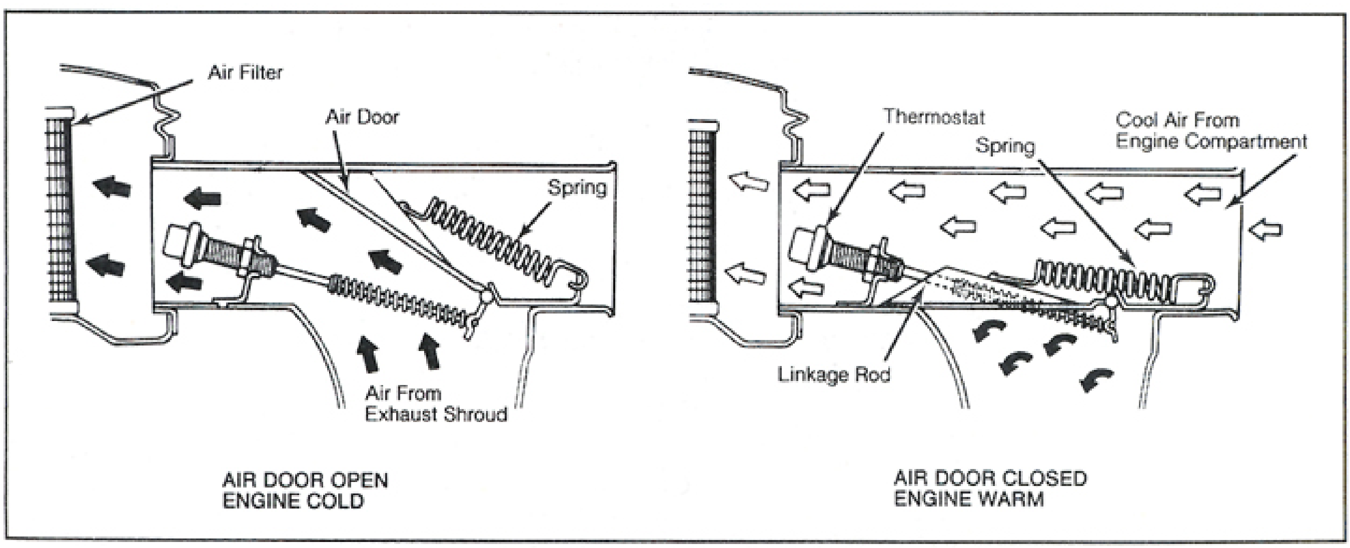


Fig. 9.59: Thermostat Motor Controlled Air Door

Vacuum Override Motor -.When operating at full throttle, an unrestricted cool air supply is required for maximum performance. During cold engine operation, air door in the air cleaner snorkel is open and airflow is restricted by the exhaust shroud. To overcome this and allow full airflow into the air cleaner, a vacuum override motor is added to the system. The motor is attached to the air door on one end and to an intake manifold vacuum line at the other. The vacuum override motor consists of a spring-loaded diaphragm and the linkage rod to the air door.

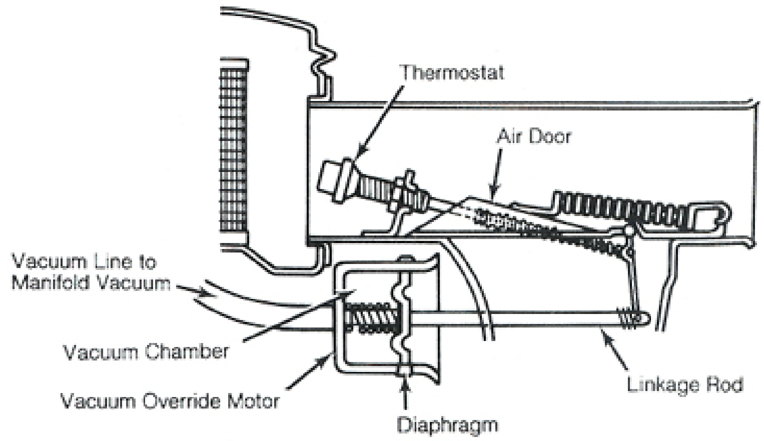


Fig. 9-60: Thermostat Controlled :Air Door with Vacuum Override Motor

Manifold vacuum drops to very low levels at wide open throttle. When this occurs, the spring in the vacuum override motor pushes the linkage rod out. Being stronger than the thermostat motor, this closes the air door regardless of the temperature in the air cleaner snorkel. So at full throttle with a cold engine, the spring in the override motor overcomes thermostat motor strength to close the air-door. Cool, dense air can then enter the air cleaner. When engine operation returns to normal, the vacuum signal to the override motor overcomes spring pressure,, allowing normal thermostat motor control of air door position.

Vacuum Motor Control

Basic Operation - Thermostatic air cleaners of this type use a vacuum motor to control air door position. The motor consists of a spring-loaded vacuum diaphragm and a linkage rod to the air door. The vacuum chamber above the diaphragm is connected to intake manifold vacuum. In contrast to the thermostat motor TAC, the air door in this system is spring-loaded to a closed position, blocking heated airflow to the air cleaner.

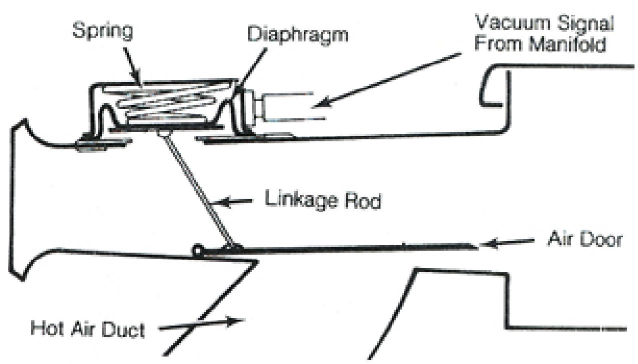


Fig. 9-61: Vacuum Motor Controlled Air Door

As manifold vacuum increases, spring pressure is gradually overcome, opening the air door to allow heated air into the engine. If no other components were added to the system, the flow of heated air would be determined only by this manifold vacuum signal. Since the signal is independent of temperature, this would fail to fulfill the requirements of the system. To provide temperature control, a temperature-sensitive vacuum control valve is included. It is mounted inside the air cleaner housing on the carburetor side of the air filter element, in the vacuum line between the intake manifold and the vacuum motor. The vacuum signal from the manifold to the motor is modified and controlled by this valve.

Temperature-Sensitive Vacuum Control (TSVC) Valve - The TSVC valve is an air bleed mounted to temperature-sensitive bi-metallic strip and two vacuum line connections for the line from the intake manifold to the vacuum motor. At low air temperatures, the air bleed is closed. This permits the full strength of the manifold vacuum signal to pass through the valve to the vacuum motor, overcoming the strength of the diaphragm spring and opening the air door. This allows full heated airflow into the engine.

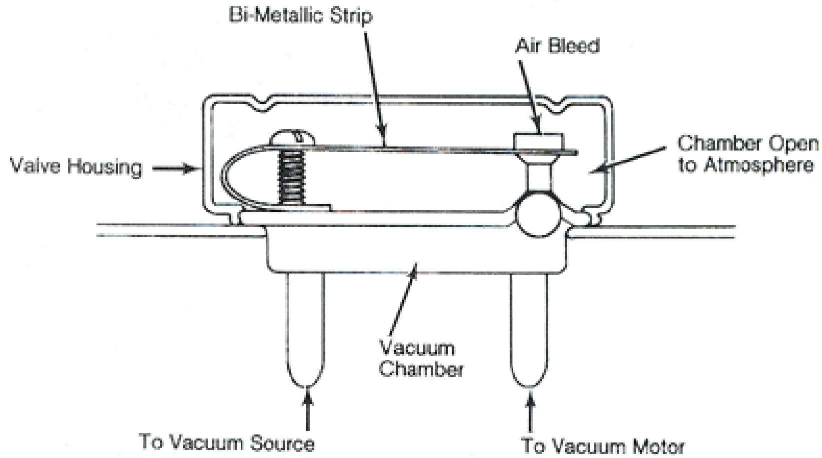


Fig. 9-62: Typical TSVC Valve

As air temperature at the sensor increases, the 'bleed valve begins to open, bleeding air into the vacuum line and reducing the strength of the vacuum signal to the motor. As signal strength decreases, the diaphragm spring begins to lower the air door. Above a specific temperature (depends on manufacturer) the air bleed opens completely, canceling the vacuum signal. With no signal at the vacuum motor; the diaphragm spring lowers the air door completely, blocking heated air to the engine.
Unlike the thermostat-controlled TAC, the vacuum motor requires no vacuum override motor to close the air door during wide open throttle conditions. When manifold vacuum drops during wide open throttle; the signal to the vacuum motor goes to zero. With no vacuum signal, the TSVC valve has nothing to modify and the air door closes.

Vacuum Check Valves - In some cases, poor driveability can result from the combination of low air temperatures and a completely closed air door. Another problem is noise. If engine vacuum is very low (as with throttle wide open), the door will slam shut. Check valves are used to prevent clanging from rapid door movement. The object is to trap vacuum in the line to the door motor, so the air door remains open even if manifold vacuum has dropped.

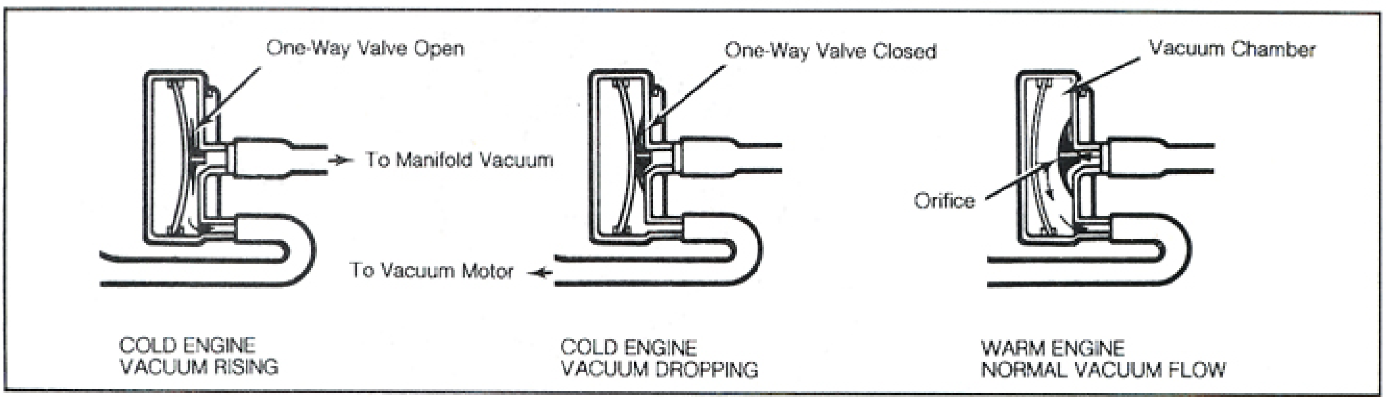


Fig. 9-63: Vacuum Check Valve Operation

One design consists of a check valve located in the vacuum line between the TSVC valve and the vacuum motor. When ambient air temperatures are below about 60°F (15°C), a temperature-sensitive bi-metallic strip blocks an orifice in the valve. The orifice is of a one-way design, allowing signal strength at the vacuum motor to increase with manifold vacuum, while preventing vacuum loss when the manifold signal drops. When temperatures rise above about 60°F (15°C), the metal strip uncovers the orifice and normal operation of the vacuum motor is restored.

The other check valve used is a simpler, less conspicuous design. It is integral with the TSVC valve and consists of a check ball located in the vacuum line connection on the vacuum motor side of the valve. Its function is the same as the other check valve, allowing for increased signal strength while blocking vacuum loss at low air temperatures.

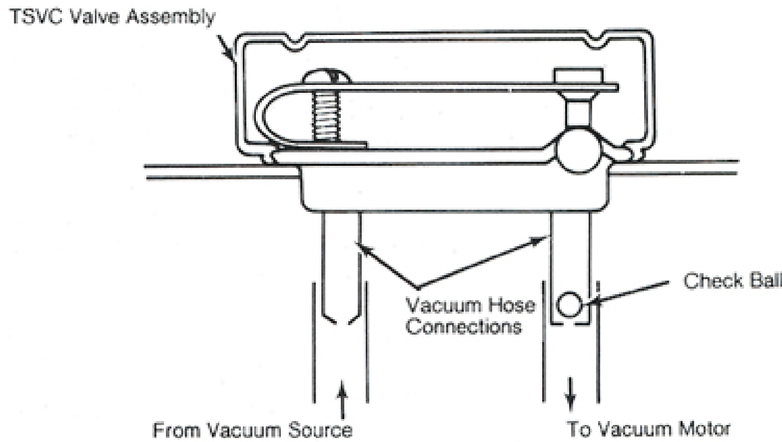


Fig. 9-64: TSVC Valve with Built-In Check Ball

Manifold Heating Exhaust Gas Crossover - A butterfly valve may be mounted in a housing installed between the exhaust manifold and: the header pipe, or it may be mounted in the exhaust manifold itself. When the engine is cold, the valve closes. This forces exhaust gases through the intake manifold: passage, heating the manifold. When the engine reaches proper operating temperature, the valve opens to allow normal exhaust flow.

Two types of valve control are used. Most models use wheat-sensitive spring and a counterweight. The counterweight is usually on the outside of the manifold, connected to the valve by a linkage rod which. Passes through the exhaust manifold. When the engine is cold, the spring holds: the valve closed. As exhaust gases increase in temperature the spring gradually releases tension, allowing the counterweight to open the manifold to full exhaust flow.

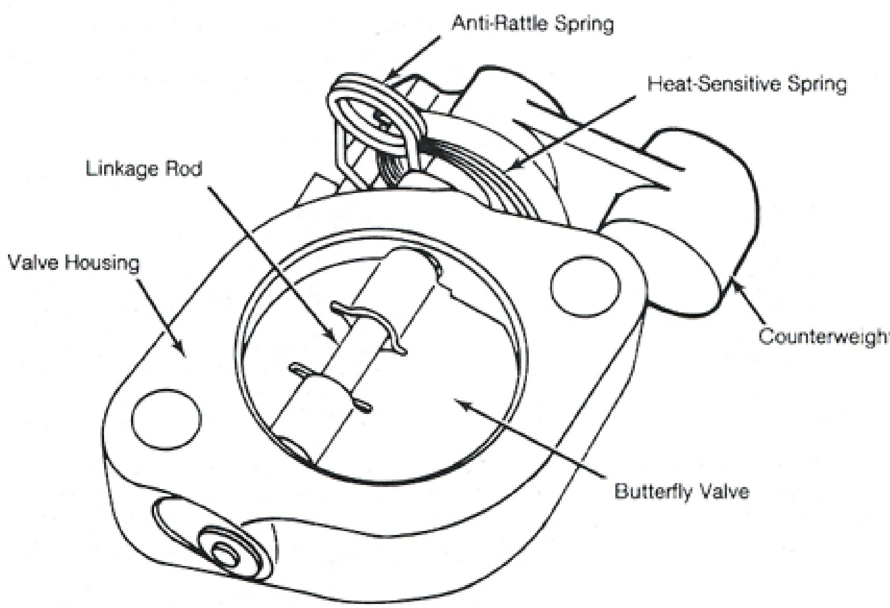


Fig. 9-65: Valve Housing with Counter-Balanced Butterfly Valve

The other system in use is. found on many General Motors vehicles. Valve operation is controlled by manifold vacuum rather than the heat-sensitive spring. Valve operation is tied to engine temperature by the use of a Thermal Vacuum Switch (TVS). At low coolant temperatures, the switch is open. This allows the vacuum signal to reach the valve and hold it closed. As coolant temperature increases, the switch closes, blocking the vacuum signal to the valve. In the absence of a vacuum signal, the valve opens, allowing normal exhaust flow. This method of control is more accurate and reliable than the spring-type system.

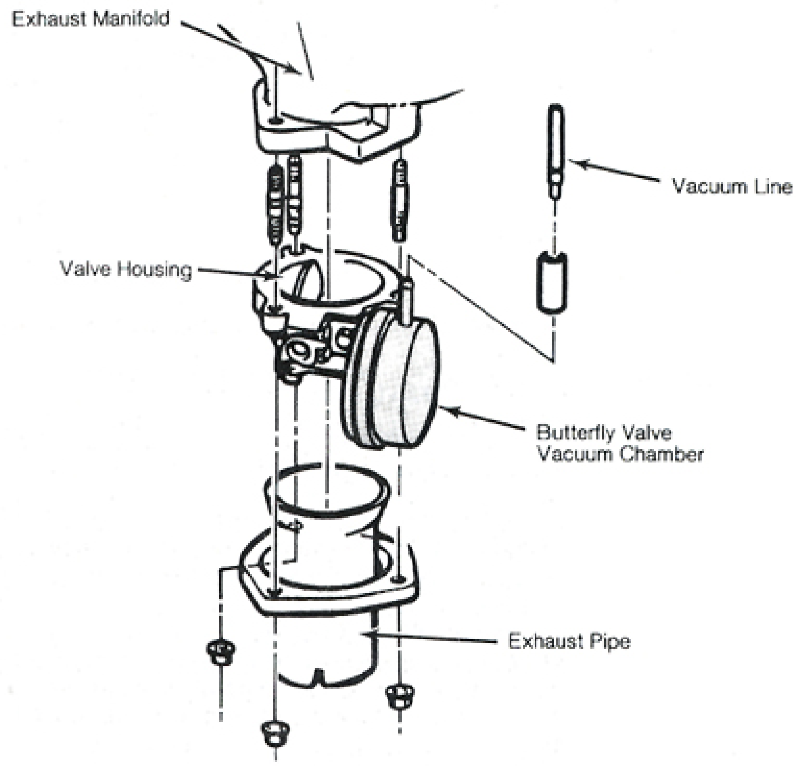


Fig. 9-66: Manifold Vacuum Controlled Butterfly Valve

Coolant Heat - Many imported and some domestic cars have coolant passages inside the intake manifold. The passages allow hot coolant from the engine to heat the manifold so incoming fuel will not condense. The coolant maybe circulated through holes in the cylinder head or through separate hoses.

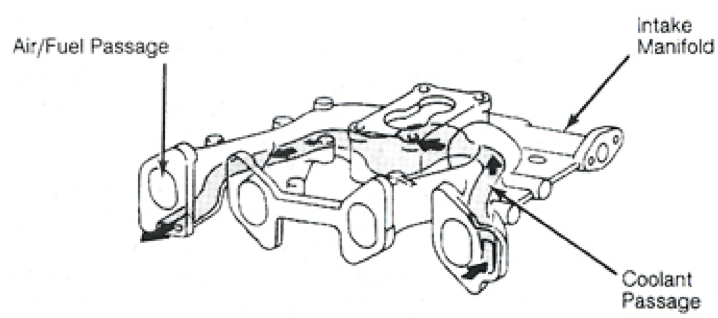


Fig. 9-67: Coolant Heat Passages in Intake Manifold

Pre-Heating Grid - On some General Motors and Ford models, a pre-heating ceramic grid is used instead of the exhaust manifold valve. This grid is placed below the primary throttle bore(s) of the carburetor as an integral part of the insulator and gasket. At low coolant temperatures, electrical current is applied to the grid. This heats the air/fuel mixture as it passes through the grid, promoting fuel vaporization.

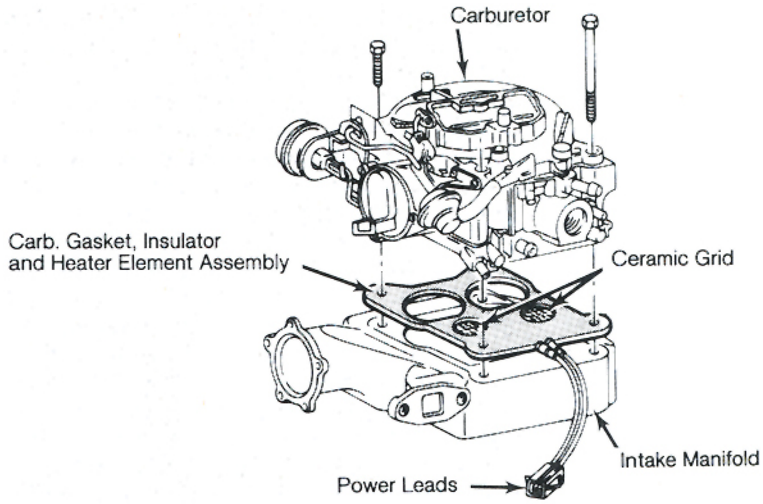


Fig. 9-68: Ceramic Grid Heating Element Installation

TESTING Before testing the TAC system, a visual inspection of the following components should be made:

- Air cleaner assembly. Must be in proper position and open to airflow with no modifications (such as, upside-down lid or removed snorkel), damage or alteration to the air cleaner housing.
- Air filter element. Must be clean and in proper position.
- Exhaust manifold heat shroud and air duct. Properly positioned and securely mounted.
- Vacuum hoses. Check for correct routing, tight connections and pinched or cracked hoses.

Thermostat Motor Control
Air Door Operation - 1) Inspect air door linkage and spring for proper operation. Remove the air cleaner assembly from the engine, then remove the air filter and top from the assembly. Place the snorkel and thermostat in a pan of water.
2) Allow the thermostat to cool and check that the air door is in the fully open (heated air) position. Gradually raise water temperature to about 130°F (54°C) while observing the air door. The thermostat should be fully extended, putting the air door in its fully closed position. If the thermostat does not react as indicated, it should be replaced.

Vacuum Override Motor Test - If the system is equipped with a vacuum override motor, use the following testing procedure to check its operation.
1) With the engine off, air cleaner assembly installed and thermostat temperature below 85°F (29°C) the air door should be closed. If not, check for possible interference with the air door which could be holding it partially open. Correct as needed.
2) Start the engine. With thermostat temperature still below 85°F (29°C), the air door should be fully open. If not, check for proper door and linkage alignment. If the air door remains closed, remove the vacuum hose from the override motor and attach a vacuum gauge to the line.
3) Check with engine idling to ensure full manifold vacuum is present at this line. If not, check for vacuum leaks in the line or its connections. If the vacuum signal is correct, disconnect the vacuum motor from the air door and perform the same testing procedure used for a thermostat-controlled system without an override valve.
4) If thermostat operation is correct with the vacuum motor disconnected, the motor is faulty and should be replaced.

Vacuum Motor Control
Preparation For Testing - Place a thermometer next to the TSVC valve in the air cleaner housing to monitor air temperature. Install a T fitting in 'the vacuum line between the vacuum motor and the TSVC valve. Attach a vacuum gauge to the T.

Testing Procedure - 1) Observe air door position with the engine off. It should be fully closed, regardless of temperature. With air temperature below 85°F (29°C), start the engine and let it idle. The air door should open and the vacuum gauge should read full manifold vacuum.

2) If the vacuum reading is correct but the door does not open, check for binding or disconnected linkage. Check for proper air door alignment. Ensure that vacuum lines are in good condition and not leaking.
3) With thermometer and vacuum gauge installed and air cleaner lid in place, observe the air door as engine idles. When the door first starts to close, remove the air cleaner lid and note thermometer temperature reading. Replace the lid.
4) When the air door reaches the fully closed position, remove the lid and note temperature and vacuum gauge readings once more. If the door has not moved after several minutes, check temperature reading. Continue to allow engine to idle and temperature to increase until the air door is either completely closed or temperature exceeds 145°F (63°C). Turn off engine.
5) First door movement should occur at a temperature of about 85°F (30°C). The temperature at the sensor should be 105-130°F (41-54°C) when the door is completely closed. The vacuum reading should have dropped from full manifold vacuum to about 5-9 in. Hg.
6) If the vacuum reading does not decrease with an increase in temperature, or vacuum readings change but temperature is outside of the indicated range when the door reaches a fully closed position, the TSVC valve is faulty and should be replaced. If the door does not close, but temperature and vacuum readings are correct, the vacuum motor is faulty and must be replaced.

Check Valve Test - If the system is equipped with a vacuum check valve, perform this test. With the engine cold and idling, ensure that the air door is fully open to heated air. Disconnect the vacuum line at the intake manifold. The air door should not move. If it does, the check valve is not operating properly and should be replaced.

Manifold Heaters

Vacuum Motor Test - Disconnect the vacuum hose at the manifold valve motor. Connect a hand vacuum pump and draw vacuum. The rod from the motor should move, closing the manifold heat valve. Hold vacuum. The vacuum level should not drop if the vacuum motor is good.

NOTE The engine computer controls the vacuum motor or heating grid on some models. Check a shop manual for testing procedures.

MAINTENANCE

Thermostatic Air Cleaner

There are several common maintenance problems with heated air systems. On the thermostatic air cleaner, the vacuum hoses become disconnected or torn. The intake tube almost always falls off or becomes torn or crushed. Check the vacuum hose routing and replace the intake tube if necessary to ensure good operation.

Manifold Heat

Spring-loaded butterfly valves tend to become stuck in one position. Special manifold heat lubricant is available which will loosen most valves. Spray the valve and spring well, then work the counterweight up and down until the valve operates freely. On models with vacuum motor valves, spray the valve with manifold heat lubricant. Make sure the hoses are properly hooked up to the vacuum motor. No maintenance is required on heated grid systems.

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Answer the following questions using the reading material in the article titled "Emission Control Systems" (pp. 13 – 70).

Crankcase:

1. What. percentage of the emissions are produced from the crankcase of an uncontrolled vehicle?

Answer: ______________________________

2. Why is a crankcase ventilation control required?

Answer: ______________________________

3. When does maximum PCV flow rate occur?

Answer: ______________________________

4. What two diagnostic tests can be performed on a PCV system?

Answer: ______________________________

Evaporative Emissions:

1. What percentage of fuel vapor emissions were vented to the atmosphere from the fuel tank and carburetor before the initiation of evaporative emission control systems?

Answer: ______________________________

2. What pollutant will be increased without an evaporative emission system?

Answer: ______________________________

3. Why is an evaporative emission system required?

Answer: ______________________________

4. What is eventually done with the vapors that are collected by the evaporative emission system?

Answer: ______________________________

5. What are the main components of a typical evaporative emission control system?

Answer: ______________________________

6. Why do manufacturers use a purge valve?

Answer: ______________________________

Air Injection:

l. Air injection is designed to reduce what two pollutants?

Answer: ____

2. What are the two basic types of air injection systems?

Answer: ____

3. What is the purpose of connecting the air injection system to the catalytic converter?

Answer: ____

4. Why is a diverter valve used?

Answer: ____

5. The what type of vacuum operates the diverter valve?

Answer: ____

6. What is the purpose of the check valve?

Answer: ____

7. What two types of check valves does a pulse air system use?

Answer: ____

Exhaust Gas Recirculation:

1. EGR systems are used to **mainly** reduce what pollutant?

Answer: ____

2. At what combustion temperatures are high/unacceptable levels of NOx emissions created?

Answer: ____

3. Approximately how much exhaust gas is re-circulated back into the intake manifold?

Answer: ____

4. What two vacuum sources are mainly used to control a vacuum operated EGR valve?

Answer: ____

5. On a computer controlled (pulse width modulated) EGR valve, how is the strength of the vacuum signal controlled?

Answer: ____

6. Name two types of backpressure EGR valves that might be used?

Answer: ____

Exhaust Gas Recirculation (con't):

7. All EGR valves can be tested by applying vacuum (via a hand vacuum pump) to the valve and watching for the engine to run rough or stall. True or False?

Answer: ____

8. What typical basic computer inputs are needed to control the operation of a digital EGR valve?

Answer: ____

Spark Timing & Control:

1. What is the main purpose of a spark control system?

Answer: ____

2. The correct spark advance is proportional to what two factors?

Answer: ____

3. What is the purpose of the Coolant Temperature Override (CTO) switch?

Answer: ____

Catalytic Converters:

l. A two way catalytic converter reduces what pollutants?

Answer: ____

2. A three way catalytic converter reduces what pollutants?

Answer: ____

3. What is the purpose of rhodium in a TWC?

Answer: ____

4. What vehicle condition needs to exist before a catalytic converter can reduce emissions?

Answer: ____

5. What is the normal internal operating temperature of a catalytic converter?

Answer: ____

Induction Preheating:

1. What is the main purpose of pre-heating the incoming air on an air induction system?

Answer: ____

2. What type of system(s) might be used to warm the incoming air?

Answer: ____

Induction Preheating (con't):

3. What is the purpose of the TAC systems?

Answer: ____

4. What is the purpose of manifold heating?

Answer: ____

5. Where is the preheating grid located?

Answer: ____

FOUR-GAS ANALYZERS

This section deals with the four-gas analyzer that is part of the BAR 97 EIS. If used properly, this analyzer is a powerful diagnostic tool.

To successfully complete this section the student must demonstrate knowledge of:

1. Components and operation of a basic four-gas analyzer.
2. Hydrocarbon (HC) emissions and its relationship to engine performance.
3. Carbon monoxide (CO) emissions and its relationship to engine performance.
4. Carbon dioxide (CO_2) emissions and its relationship to engine performance.
5. Oxygen (O_2) content in engine exhaust and its relationship to engine performance.
6. Relationship of the four-gases to each other and stoichiometric air/fuel ratio.
7. Ability to troubleshoot engine performance problems using four-gas analyzer.

FOUR-GAS ANALYZERS

By measuring the end products of combustion, an exhaust gas analyzer can quickly indicate possible problem areas and check the overall condition of the engine. Two-gas analyzers measure Carbon Monoxide (CO) and Hydrocarbon (HC). The measurement of these two gasses was sufficient for testing and diagnosing pre-catalytic converter vehicles. Adjustments to ignition timing, idle speed and carburetor air/fuel mixture were usually the only adjustments required to lower the vehicle's emission levels.

As vehicle emission standards became stricter with the addition of catalytic converters and computerized engine controls, a more precise way of analyzing the exhaust gasses was required. The four-gas analyzer provides this accuracy as well as the ability to measure two additional gasses for more precise diagnosis. The four-gas analyzer can measure Hydrocarbon (HC), Carbon Monoxide (CO), Carbon Dioxide (CO_2) and Oxygen (O_2).

The most accurate way to diagnose a catalytic converter equipped engine is to use a four-gas analyzer. With a four-gas analyzer, CO_2 and O_2 are measured along with HC and CO. Catalytic converters do not affect the amount of CO_2 and O_2 present in the exhaust. Therefore, by measuring these gasses in addition to HC and CO, an accurate look at the engine's efficiency can be made. Some engines are equipped with an air pump or pulse air injection system, which feeds fresh air into the converter. These systems should be disconnected or plugged prior to testing the exhaust.

Both CO_2 and O_2 are measured in percentages. The exhaust of a normally running engine will contain 13.8-15% CO2 and 1.0- 2.0% 0, Oxygen (O_2) is an excellent indicator of the air/fuel mixture. If the engine is running rich, the O_2 reading will be low and the CO reading high. If the engine is running lean, O_2 will increase and CO will be low. Carbon Dioxide (CO_2) is a by-product of combustion. Therefore the amount of CO_2 percent depends upon those factors that affect combustion efficiency including air/fuel ratios. The amount of CO_2 will only be within the desired range when the air/fuel ratio at idle is stoichiometric, The percentage of CO_2 decreases as the air/fuel mixture becomes more rich or lean.

Carbon Monoxide (CO) is measured in a percentage. High carbon monoxide readings indicate a rich air/fuel mixture, caused by excessive fuel or insufficient air. Anything that causes the air/fuel mixture to be too rich will increase CO. Possible problem areas leading to high carbon monoxide are:

- Stuck choke plate
- Dirty air filter
- Incorrect air/fuel mixture
- Low idle speed
- Plugged PCV valve
- Advanced ignition timing
- High carburetor float
- Leaking carburetor needle and seat or power valve
- Canister purge control valve
- Excessive fuel pump pressure
- Dripping injectors
- Faulty oxygen sensor
- Plugged oxygen sensor vent
- Inoperative air pump

Hydrocarbon (HC) content in the exhaust gasses is measured in Parts Per Million (ppm) by volume. Hydrocarbon (HC) is a by-product of incomplete combustion (unburned gasses). Even a properly maintained engine produces some HC. High HC readings are caused by incomplete combustion. The readings result from unburned fuel leaving the combustion chamber, typically caused by a defective ignition system or a lean air/fuel mixture. A lean mixture can be caused by a vacuum leak or a malfunctioning vacuum control valve. Poor cylinder sealing will also cause incomplete combustion.

Measuring the exhaust quantity from the tailpipe of a vehicle equipped with a catalytic converter does not accurately describe the condition of the engine. If the catalyst is working properly, it will reduce the amount of Hydrocarbon (HC) and Carbon Monoxide (CO) in the exhaust before it is released into the tailpipe. Therefore, in order to use an exhaust analyzer as a diagnostic tool, the analyzer should measure exhaust gas unaltered by the catalytic converter. To do this, some service facilities disconnect the air injection pump or plug the pulse air injection system to reduce the effect of the catalytic converter. Other technicians measure the exhaust before it flows into the converter by inserting the exhaust probe into the front of the converter through an access hole provided by the manufacturer or by inserting the probe into the exhaust opening of the EGR valve.

Most manufacturers attempt to maintain an air/fuel ratio at approximately 14.7 parts of air to 1 part fuel. This 14.7:1 air/fuel ratio is called the stoichiometric ratio. A proper running computer controlled vehicle will emit very low levels of HC and CO, and an efficient catalytic converter will further reduce these emissions to a level that can be difficult to measure.

A properly tuned computer controlled vehicle will emit approximately 50 ppm of HC, less than 0.5% CO, 1.0-2.0% O_2, and 13.8-15.0% CO_2.

Operation:
When a beam of infrared light passes through a gas sampler, some light gets through and some of it is absorbed by the exhaust gases. The more gas in the sample, the more light is absorbed. The light that gets through the exhaust gasses is focused on a light-intensity detector. The exhaust gas analyzer measures this light intensity to determine how much gas is present in the sample, either in Parts Per Million (ppm) or as a percentage. Each gas measured absorbs a different wave length of infrared light.

Testing:
Always perform a visual inspection on the vehicle being tested. Ensure that all electrical connections and vacuum hoses are in good condition and properly connected. Check the vehicles exhaust system. Repair any leaks that would dilute the exhaust gas sample. Set the parking brake and block the drive wheels. Ensure that the area you are testing in is properly ventilated. Ensure the four-gas analyzer is warmed up and calibrated. Always refer to the manufacturers operating instructions for complete testing preparation and analyzer maintenance.

In most cases, the vehicles air pump or pulse air injection system should be disabled so that the true exhaust emission content can be measured without the catalytic converter masking the emission levels. Run the engine to be tested until normal operating temperature is reached. If a computer controlled vehicle is being tested, engine must be in closed loop for accurate testing. Insert the exhaust gas analyzers probe in the tailpipe far enough to obtain an accurate sample of exhaust emissions. Allow the analyzer to stabilize and record the readings. Do not allow the vehicle to idle for long periods before taking analyzer readings. This will load the engine with hydrocarbons. To purge a loaded engine, increase engine speed to 2,000-2,500 RPM for 10 seconds. Slowly return engine to idle. Take analyzer readings when tail pipe emissions stabilize.

DIAGNOSING WITH THE FOUR-GAS ANALYZER

By applying your understanding of the different gasses in the exhaust and their relationship to each other, you are ready to diagnose the vehicles exhaust gasses using a four-gas analyzer.

Remember, high Hydrocarbon (HC) and high Oxygen (O_2) readings are caused by misfires and/or a too lean mixture. If the spark plug does not fire or the air/fuel mixture is too lean to support combustion, raw fuel (HC) and the Oxygen (O_2) from the cylinders will pass through the engine unchanged. The following graph illustrates the relationship of the four-gasses and where the rich/lean side of the air/fuel ration begins. See Fig. 5-17.

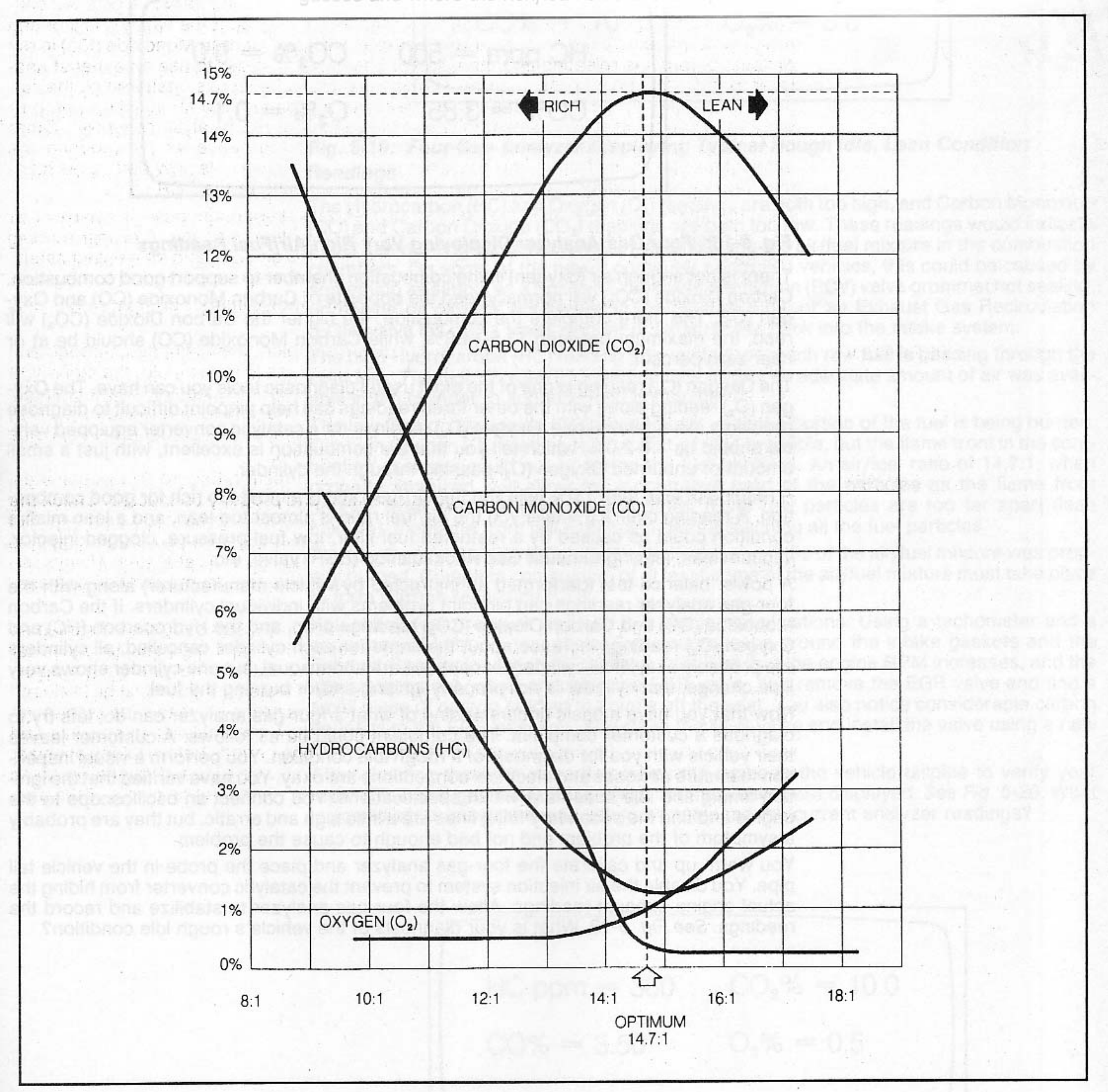

Fig. 5-17: Air/Fuel Ratio Comparison Chart

An engine operating condition that produces high Carbon Monoxide (CO), high Hydrocarbon (HC) readings, with low Carbon Dioxide (CO_2) and Oxygen (O_2) readings indicates a very rich mixture. See *Fig. 5-18.*

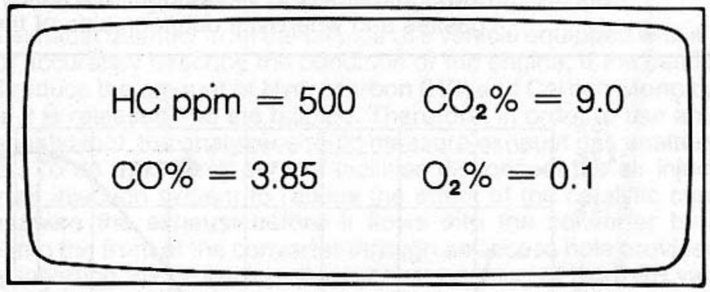

Fig. 5-18: Four-Gas Analyzer Displaying Very Rich Air/Fuel Readings

There is not enough air (oxygen) in the combustion chamber to support good combustion Carbon Dioxide (CO_2) will normally read the opposite of Carbon Monoxide (CO) and Oxygen (O_2). The more complete the combustion, the higher the Carbon Dioxide (CO_2) will read, the maximum between 13.5-14.8%, while Carbon Monoxide (CO) should be at or near zero percent.

The Oxygen (O_2) reading is one of the most useful diagnostic tools you can have. The Oxygen (O_2 reading along with the other three readings can help pinpoint difficult to diagnose problems. As a general rule, Oxygen (O_2) readings for a catalytic converter equipped vehicle should be 1.0-2.0%, which tell you that the combustion is excellent, with just a small amount of unburned Oxygen (O_2) passing through the cylinder.

A reading of less than 1.0% tells you the air/fuel ratio is almost too rich for good combustion. A reading over 2.0% tells you the air/fuel ratio is almost too lean, and a lean misfire condition could be caused by a restricted fuel filter, low fuel pressure, clogged injector, vacuum leak, leaking Exhaust Gas Recirculation (EGR) valve, etc.

A power balance test (performed as instructed by vehicle manufacturer) along with the four-gas analyzer readings can pinpoint problems with individual cylinders. If the Carbon Monoxide (CO) and Carbon Dioxide (CO_2) readings drop, and the Hydrocarbon (HC) and Oxygen (O_2) readings increase about the same for each cylinder cancelled, all cylinders are probably okay. If all cylinders except one are about equal, but one cylinder shows very little change, that cylinder is not properly igniting and/or burning the fuel.

Now that you have a basic understanding of what a four-gas analyzer can do, lets try to diagnose a customer complaint. The complaint could be as follows: A customer leaves their vehicle with you for diagnosis of a rough idle condition. You perform a visual inspection to ensure all hoses and electrical connections are okay. You have verified that the ignition timing and idle speed are within specifications. You connect an oscilloscope to the engine and find the secondary firing lines are a little high and erratic, but they are probably a symptom of the problem and not bad enough to cause the problem.

You warm up and calibrate the four-gas analyzer and place the probe in the vehicle tail pipe. You disable the air injection system to prevent the catalytic converter from hiding the actual engine exhaust readings. Allow the four-gas analyzer to stabilize and record the readings. See *Fig. 5-19.* What is your diagnosis of the vehicle's rough idle condition?

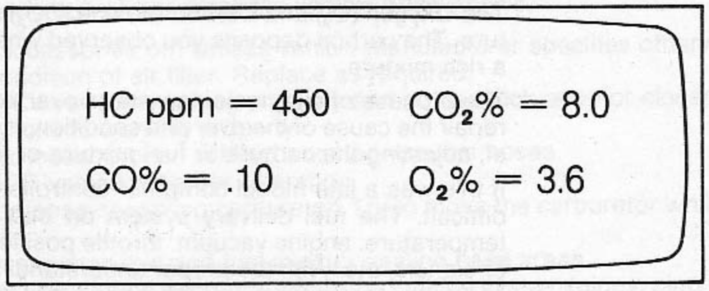

Fig. 5-19: Four-Gas Analyzer Displaying Typical Rough Idle, Lean Condition Readings

The Hydrocarbon (HC) and Oxygen(O_2) readings are both too high, and Carbon Monoxide (CO) and Carbon Dioxide (CO_2) readings are both too low. These readings would indicate a fuel starved engine or vacuum (air) leaks diluting the air/fuel mixture in the combustion chambers. On some of the newer computer controlled vehicles, this could be caused by something as simple as a Positive Crankcase Ventilation (PCV) valve grommet not sealing, an engine oil dipstick not seated in the dipstick tube, or an Exhaust Gas Recirculation (EGR) valve leaking a small amount of exhaust gas back into the intake system.

The high Hydrocarbon (HC) reading tells us that too much raw fuel is passing through the cylinders. The high Oxygen (O_2) reading tells us that an adequate amount of air was available in the cylinder to support good combustion.

The low Carbon Monoxide (CO) reading tells us that a portion of the fuel is being burned. Our high Oxygen (O_2) reading tells us that air was available, but the flame front in the combustion chamber could not bridge to the fuel particles. An air/fuel ratio of 14.7:1, when properly atomized, will allow for a controlled burn of the particles as the flame front bridges from one fuel particle to another. If the fuel particles are too far apart (lean mixture), the flame front will extinguish before reaching all the fuel particles.

The low Carbon Dioxide(CO_2) reading indicates very little of the air/fuel mixture was properly burned. Complete combustion of at least some of the air/fuel mixture must take place to form Carbon Monoxide (CO).

You check fuel pressure and find it is within specifications. Using a tachometer and a spray can of light oil, you check for vacuum leaks around the intake gaskets and the Exhaust Gas Recirculation (EGR) valve. You find that the engine RPM increases, and the idle smoothes out, when checking the EGR valve. You remove the EGR valve and find a small piece of carbon holding the pintle off the seat. You also notice considerable carbon deposits in the EGR passage. You clean the EGR valve and install the valve using a new EGR base gasket.

After cleaning the EGR valve you insert the probe in the vehicle tailpipe to verify your repair. The four-gas analyzer readings for this vehicle are displayed. See Fig. 5-20. What is your diagnosis of the repair you just made, and the current analyzer readings?

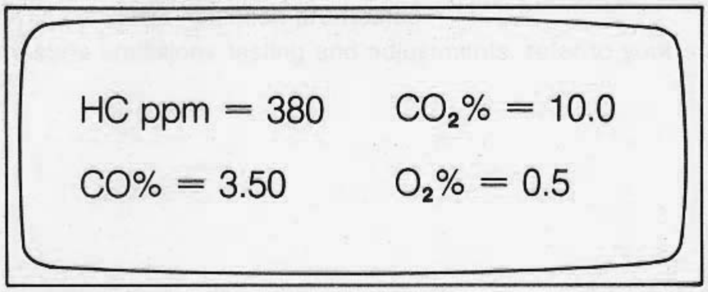

Fig. 5-20: Four-Gas Analyzer Display After EGR Valve Cleaning

Now that you have corrected the air leaks, the analyzer displays an air/fuel mixture that is to rich. The Carbon Monoxide (CO) and Hydrocarbon (HC) readings are both too high. The Oxygen (O_2) and Carbon Dioxide (CO_2) readings are low, indicating an over rich mixture. The carbon deposits you observed when cleaning the EGR valve would also confirm a rich mixture.

The process of diagnosis now starts over again. Your challenge now is to determine and repair the cause of the over rich condition. If this vehicle is not a computer controlled model, adjusting the carburetor fuel mixture or float level could correct the problem.

If this was a late model computer controlled fuel injected model, your job is a little more difficult. The fuel delivery system on this vehicle is controlled by the engine coolant temperature, engine vacuum, throttle position, engine RPM signal, fuel injectors, computer signals, etc. With the proper understanding of how these computerized systems work, and a few test meters, you might find that this rich condition is caused by a coolant temperature sensor that is reading out of specifications or an O_2 sensor that is responding slowly. Or maybe a throttle position sensor that is out of adjustment.

This problem could also be caused by a leaking fuel injector. When the fuel injector is clean, the fuel spray pattern atomizes properly with the incoming air. A leaking fuel injector will not spray the fuel properly, and will cause excess fuel at all times or a rich mixture will occur. Each of these possible problems needs further testing and appropriate remedial action taken. A final check of the emission levels after repair will ensure that an effective service operation has been carried out.

As you can see, your job as an automotive technician will be challenging, and hopefully very rewarding. An ongoing learning process is very important if you are to stay abreast of the new technology and succeed in your career. Additionally, the right tools will be necessary to perform the job correctly.

Diagnostic Procedures Using Four-Gas Analyzer:
We want to stress the importance of properly setting up a vehicle before performing four-gas diagnosis. Always review the manufacturer's emission label. It will be important to disable the air pump or pulse air injection system where applicable, to ensure exhaust emission readings are not diluted. Remember, diagnostic information is meant to provide a quick reference of possible vehicle problems, and will in some cases require you to perform further diagnosis to pinpoint certain components or vehicle sub-system problems. Care should be taken to check air filters, PCV valves, vacuum hoses, and EGR valve for operation; carburetor base for tightness, and your ignition related systems for proper operation.

Emission System Safety:
Always follow these emission system safety precautions when working on a vehicle:

- Never run the vehicle in an enclosed area. Exhaust system leaks should always be
- The catalytic converter housing will get very hot. DO NOT park a catalytic converter equipped vehicle over any flammable material. DO NOT touch a catalytic converter.
- Any condition that allows unburned fuel vapors to enter a catalytic converter can be dangerous. Correct any over-rich condition or ignition problem immediately. DO NOT try to push-start a catalytic converter equipped vehicle.

(above article reprinted with permission from Mitchell 1)

Clarification:

Although this article has many valuable points, some clarification needs to be noted:
The above article states:

"A properly tuned computer controlled vehicle will emit approximately 50 ppm of HC, less than 0.5% CO, ***1.0-2.0% O_2****, and 13.8-15.0% CO_2."*

The 3-way catalytic converter needs oxygen to complete the oxidation process to lower HC and CO. *In general*, when sampling the tailpipe emissions after the catalytic converter, it is not unusual to see O_2 content down to almost zero. A good catalytic converter (with the engine under load) will use almost all the remaining oxygen left over from the combustion process to oxidize the HC and CO emissions. The oxygen content can go higher when the engine is idling or in a no load condition. This higher oxygen content is due to the reduced amounts of HC and CO produced by the engine. Due to the small amounts of HC and CO, the catalytic converter will not use all the oxygen to perform the reduction operation – thus, some oxygen will be left over.

REVIEW QUESTIONS

Answer the following questions from the four gas analyzer reading material:

1. Why was it necessary to utilize a four-gas analyzer (instead of a two gas analyzer) with the advent of catalytic converters?

Answer: ____

2. What are the percentages of CO_2 and O_2 of a normal running engine (per this article)?

Answer: ____

3. If the engine is running rich, the CO will be high , and the O_2 will be?

Answer: ____

4. For CO_2 to be within a desired range, the air/fuel ratio should be what?

Answer: ____

5. Hydrocarbons (HC) in the exhaust gases is the result of what?

Answer: ____

6. Why is it a good idea (in most cases) to disable the air injection or pulse air system when using a four-gas analyzer?

Answer: ____

7. High HC and O_2 readings may be caused by what?

Answer: ____

8. A very rich air/fuel mixture would show what kind of readings on the four-gas analyzer (e.g., high or Low for: HC, CO, O_2, CO_2)?

Answer: ____

9. The four-gas analyzer readings noted in Fig. 5-20 show an engine operating condition that is rich or lean?

Answer: ____

ADMINISTRATIVE REQUIREMENTS

Student Reading Assignment: Read the Smog Check Reference Guide and the DRAFT copy of the Smog Check Inspection Procedures Manual.

REVIEW QUESTIONS

Answer the following questions using the material you have just read:

1. What are the names of the three main inspection program areas in California?

Answer: 1.) ____________________2.)____________________3.)____________________

Section where answer was found: ______________________________________

2. What type of emission inspection (tailpipe) test is required of a vehicle that is registered in a "Basic Area" program?

Answer: ____

Section where answer was found: ______________________________________

3. How many Smog Check technician(s) are required to be at a licensed Smog Check station during the hours the station is open to perform testing/repairing?

Answer: ____

Section where answer was found: ______________________________________

4. Can a registered Automotive Repair Dealer (ARD) contract with a customer to perform Smog Check repairs on vehicles that fail a Smog Check inspection without being a licensed Smog Check Test and Repair station?

Answer: ____

Section where answer was found: ______________________________________

5. What vehicle identification label must be affixed to a specially constructed vehicle for a Test-Only or Test and Repair station to inspect the vehicle?

Answer: ____

Section where answer was found: ______________________________________

6. May a Test and Repair station sublet a Smog Check inspection to a Test-Only station? If not, why?

Answer: ____

Section where answer was found: ______________________________________

7. May a licensed Smog Check technician working at a Test-Only station perform minor adjustments to ignition timing? If not, why?

Answer: ____

Section where answer was found: _____________________________________

8. List three reasons that a Smog Check technician may reject a vehicle from an inspection:

Answer:

1.) ____

2.) ____

3.) ____

Section where answer was found: _____________________________________

9. A consumer's vehicle failed a Smog Check inspection (high emissions) at a Test-Only station. The consumer had the vehicle repaired at a non-licensed repair facility at a cost of $487.00. An "after repairs" Smog Check inspection was performed, and the vehicle still fails for high emissions. Does this vehicle now qualify for a ($450.00) cost wavier? If not, why?

Answer: ____

Section where answer was found: _____________________________________

10. A Test and Repair station does not have the appropriate tools/equipment to repair a particular vehicle they are about to inspect. What obligation (if any) to the customer does a station have, prior to performing the Smog Check inspection?

Answer: ____

Section where answer was found: _____________________________________

11. Where should a customer be directed if they feel their Smog Check inspection and or repairs were performed incorrectly?

Answer: ____

Section where answer was found: _____________________________________

12. What should a technician do if the VIN noted on the DMV registration document does not match the VIN on the vehicle being tested?

Answer: ____

Section where answer was found: _____________________________________

13. A vehicle's ignition timing specification (per the underhood label) indicates timing needs to be set at 12 degree BTDC at 750 RPM. The technician performs the ignition timing functional test and measures 15 degrees BTDC at 750 RPM. Should this vehicle pass or fail the functional ignition timing test? What is the BAR allowed timing variance?

Answer: ____

Section where answer was found: _____________________________________

14. When performing an ASM emissions test, what gear selection should be used if the vehicle is equipped with a manual transmission?

Answer: ____

Section where answer was found: ____________________________________

15. During a visual inspection, a technician notices that a light duty truck has dual fuel tanks – one OEM and the other is an aftermarket tank. What action should be taken by the technician as a result of this discovery?

Answer: ____

Section where answer was found: ____________________________________

16. During a visual inspection, the technician notices that an OEM air cleaner is missing, and a non-approved aftermarket air cleaner is installed. What action should be taken by the technician as a result of this discovery?

Answer: ____

Section where answer was found: ____________________________________

17. During a visual inspection, an OEM Catalytic Converter is noted as missing, and in its place is a small aftermarket catalytic converter. What action should be taken by the technician as a result of this discovery?

Answer: ____

Section where answer was found: ____________________________________

18. When inspecting a kit car (SPCNS), a grey market vehicle, or a vehicle with an engine change, the technician should look for a BAR Referee Label. What is the primary purpose of the BAR Referee Label?

Answer: ____

Section where answer was found: ____________________________________

19. Some vehicles may experience difficulties conducting the OBD II Functional test. BAR provides technical information about these vehicles. What is the name of this document, and where can it be found?

Answer: ____

Section where answer was found: ____________________________________

20. During an ASM test, the maintenance reminder lamp illuminates. Should the technician fail the vehicle for the MIL functional test? Or should this item be entry coded as "defective" in the "other related emission components"?

Answer: ____

Section where answer was found: ____________________________________

21. An independent repair dealer may replace a defective emission control part that may be covered under warranty. True or False?

Answer: ____

Section where answer was found: ____________________________________

22. The owner of a 2006 vehicle has purposely used leaded fuel in a vehicle requiring unleaded fuel. As a result of this action, the catalytic converter has failed. Under normal circumstances, would this vehicle qualify for a replacement catalytic converter under the emission controls warranty in California? Why or why not?

Answer: ____

Section where answer was found: ____________________________________

23. Where should a customer be directed, when repairs for emission failures were unsuccessful and the cost limit has been reached? What additional information/documentation does the customer need when being referred?

Answer: ____

Section where answer was found: ____________________________________

24. When entering parts cost for an after repairs test, what customer paid costs are to be entered?

Answer: ____

Section where answer was found: ____________________________________

25. The law prohibits owners of vehicles to repair their own vehicle's emission failures. True or false?

Answer: ____

Section where answer was found: ____________________________________

NOTE: Answer questions number 26 - 32 using one of the following answers: *Pass, Missing, Modified, Disconnected, Defective, or Non-Applicable.*

26. All or part of an emission control system has been removed from the vehicle. How should this be entered into the BAR 97 EIS under visual inspection?

Answer: ____

27. During an inspection, you notice that the air pump has been removed. How should this be entered into the BAR 97 EIS under visual inspection?

Answer: ____

28. An add-on part has been installed, which has not been approved by the State Air Resources Board (ARB) or is an OEM replacement part. How should this be entered into the BAR 97 EIS under visual inspection?

Answer: ____

29. An OEM emission control device has been physically altered to a non-factory configuration, but all devices and hoses are connected. How should this be entered into the BAR 97 EIS under visual inspection?

Answer: ____

30. A vacuum hose has been re-routed, bypassing a TVS valve, and is connected directly to intake manifold vacuum. How should this be entered into the BAR 97 EIS under visual inspection?

Answer: ____

31. An air injection system is present, but the belt is missing; and there are no signs of tampering. How should this be entered into the BAR 97 EIS under visual inspection?

Answer: ____

32. A vacuum hose to the EGR valve is attached correctly, but is split in the middle due to age. How should this be entered into the BAR 97 EIS under visual inspection?

Answer: ____

Visual Inspection:

33. Are all required emission control systems identified on the underhood label?

Answer: ____

Section where answer was found:____________

34. When performing an inspection, what on the vehicle's registration needs to be matched with the vehicle?

Answer: ____

Section where answer was found:_____________

35. When performing an inspection, how do you enter a 19 character VIN into the BAR 97 EIS?

Answer:: ____

Section where answer was found:____________

36. In what two locations will you usually find the VIN?

Answer: ____

Section where answer was found:____________

37. When inspecting a vehicle with a BAR referee label, what information should you enter into the BAR 97 EIS regarding this vehicle?

Answer: ____

Section where answer was found:____________

38. What type of certificate of compliance should be issued to a military person **not** seeking California registration?

Answer: ____

Section where answer was found:____________

Functional Testing:

39. What action should be taken during an ignition functional timing test if the vehicle has a coil-on-plug (non-adjustable) ignition system?

Answer:

____

Section where answer was found:___________

40. During a functional test of the OBD II system, what does the analyzer assess when it interrogates the system?

Answer:

____

Section where answer was found:___________

41. Where are most DLCs located on OBD II equipped vehicles?

Answer: ____

Section where answer was found:____________

42. What entry should be made during the functional gas cap test in the BAR 97 EIS, if no adapter is available from the manufacturer?

Answer: ____

Section where answer was found:____________

43. Is it a failed functional timing test if the manufacturer's timing specifications call for 8 degrees BTDC at 750 RPM and the actual timing is 4 degress BTDC at 750 RPM?

Answer: ____

Section where answer was found:____________

44. Is it a failed functional timing test if the manufacturer's timing specifications call for 4-8 degrees BTDC at 750 RPM and the actual timing is 11 degrees BTDC at 750 RPM?

Answer: ____

45. If the engine is computer controlled and the timing is not adjustable, how would you enter this situation into the BAR 97 EIS?

Answer: ____

46. What action shall be taken if the vehicle cannot have the timing checked because of a defective condition (e.g., slipped balancer)?

Answer: ____

47. What is the most important procedure to follow when performing a functional test on an EGR system?

Answer: ____

48. Since January, 1992 the sale of leaded gasoline in California has stopped. Does this mean that you no longer have to perform a fillpipe restrictor test?

Answer: ____

LABORATORY EXAMINATIONS

LABORATORY EXAMINATION # 1:

Using an emission control system (ECS) applications guide, electronic database, or manufacturer manual locate the ECS equipment and ignition timing specifications required for each of the vehicles listed below:

Special Instructions: Enter "N/A" for the timing specification, when the system is identified as a computer controlled system, and there is no timing adjustment. All vehicles below are to be considered California certified. For required ECS, use ECS abbreviations (e.g., exhaust gas recirculation = EGR).

1.

VEHICLE YEAR MODEL:	VEHICLE MANUFACTURER:	MODEL INFORMATION:	ENGINE SIZE:
2002	General Motors	Light duty truck, GVW: 8599 lbs. or less, SCPI fuel injection, auto. Trans.	5.7 L

ECS Required:____

Timing Specification:__________ degrees (BTDC or ATDC, circle one) at ________ RPM

2.

VEHICLE YEAR MODEL:	VEHICLE MANUFACTURER:	MODEL INFORMATION:	ENGINE SIZE:
1988	Isuzu	Pick Up Truck , 2 bbl carburetor, man. trans.	2.3L

ECS Required:____

Timing Specification:__________ degrees (BTDC or ATDC, circle one) at ________ RPM

3.

VEHICLE YEAR MODEL:	VEHICLE MANUFACTURER:	MODEL INFORMATION:	ENGINE SIZE:
1991	Ford	SHO, SFI fuel Inj., man. trans.	3.0L

ECS Required:____

Timing Specification:__________ degrees (BTDC or ATDC, circle one) at ________ RPM

4.

VEHICLE YEAR MODEL:	VEHICLE MANUFACTURER:	MODEL INFORMATION:	ENGINE SIZE:
1983	Volkswagen	MFI fuel Inj., auto. Trans.	2.1L

ECS Required:____

Timing Specification:__________ degrees (BTDC or ATDC, circle one) at ________ RPM

5.

VEHICLE YEAR MODEL:	VEHICLE MANUFACTURER:	MODEL INFORMATION:	ENGINE SIZE:
2000	DaimlerChrysler	SFI fuel Inj., man. trans.	8.0L

ECS Required:____

Timing Specification:__________ degrees (BTDC or ATDC, circle one) at ________ RPM

LABORATORY EXAMINATION # 2:

Using demonstration or volunteer vehicles and this lab exam sheet, conduct a **visual** inspection on **three** vehicles. Follow procedures noted in the Smog Check Inspection Manual. After performing a visual inspection, note the correct BAR 97 EIS code input (e.g., pass, missing , modified, etc.) for each ECS device listed below.

Note: Use the following abbreviations: Pass = **P**, Disconnected = **D**, Modified = **M**, Missing = **S**, Non-applicable = **N**, and Defective = **F**

Fill in the information below:

Vehicle #1:

VEHICLE YEAR MODEL:	VEHICLE MANUFACTURER:	MODEL INFORMATION:	ENGINE SIZE:

CA or Fed?_____ PCV:____ TAC/ACL:_____ AIS:_____ EGR:_____

Liquid Fuel Leak:_____ EVAP:_____ CAT:_____ Ignition Spark Control:_____

Fuel Restrictor:_____ Fuel Metering System:_____

Sensors, Switches, and Computers:_____ Other:_____

Vehicle #2:

VEHICLE YEAR MODEL:	VEHICLE MANUFACTURER:	MODEL INFORMATION:	ENGINE SIZE:

CA or Fed?_____ PCV:____ TAC/ACL:_____ AIS:_____ EGR:_____

Liquid Fuel Leak:_____ EVAP:_____ CAT:_____ Ignition Spark Control:_____

Fuel Restrictor:_____ Fuel Metering System:_____

Sensors, Switches, and Computers:_____ Other:_____

Vehicle #3:

VEHICLE YEAR MODEL:	VEHICLE MANUFACTURER:	MODEL INFORMATION:	ENGINE SIZE:

CA or Fed?_____ PCV:____ TAC/ACL:_____ AIS:_____ EGR:_____

Liquid Fuel Leak:_____ EVAP:_____ CAT:_____ Ignition Spark Control:_____

Fuel Restrictor:_____ Fuel Metering System:_____

Sensors, Switches, and Computers:_____ Other:_____

LABORATORY EXAMINATION # 3:

Using demonstration or volunteer vehicles, and this lab exam sheet, conduct functional tests on **three** vehicles, and record your results. Follow the procedures noted in the Smog Check Inspection Manual for functional testing. Identify the correct BAR 97 EIS code input (e.g., pass, missing , modified, etc.) for each functional test listed below:

Fill in the information below:

Vehicle #1:

VEHICLE YEAR MODEL:	VEHICLE MANUFACTURER:	MODEL INFORMATION:	ENGINE SIZE:

Functional Tests:

Timing Specification:______ degrees (BTDC or ATDC, circle one) at **________** RPM

Measured Timing:______ degrees (BTDC or ATDC, circle one) at **________** RPM

Timing test results:_____ (pass/fail/NA?)

OBD II Results:_____ MIL Results:_____ EGR Results:_____ LPFET Results:____

Fillpipe Restrictor Results:_____ Fuel Cap Integrity Results:_____

Vehicle #2:

VEHICLE YEAR MODEL:	VEHICLE MANUFACTURER:	MODEL INFORMATION:	ENGINE SIZE:

Functional Tests:

Timing Specification:______ degrees (BTDC or ATDC, circle one) at **________** RPM

Measured Timing:______ degrees (BTDC or ATDC, circle one) at **________** RPM

Timing test results:_____ (pass/fail/N?)

OBD II Results:_____ MIL Results:_____ EGR Results:_____ LPFET Results:____

Fillpipe Restrictor Results:_____ Fuel Cap Integrity Results:_____

LABORATORY EXAMINATION # 3 (con't):

Vehicle #3:

VEHICLE YEAR MODEL:	VEHICLE MANUFACTURER:	MODEL INFORMATION:	ENGINE SIZE:

Functional Tests:

Timing Specification:______ degrees (BTDC or ATDC, circle one) at ________ RPM

Measured Timing:______ degrees (BTDC or ATDC, circle one) at ________ RPM

Timing test results:_____ (pass/fail/N?)

OBD II Results:_____ MIL Results:_____ EGR Results:_____ LPFET Results:____

Fillpipe Restrictor Results:_____ Fuel Cap Integrity Results:_____

LABORATORY EXAMINATION # 4

Using demonstration or volunteer vehicles, and this lab exam sheet, conduct a "Two Speed Idle" (TSI) emissions test on **three** vehicles, and record your results. Follow the procedures noted in the Smog Check Inspection Manual for TSI testing. Use the BAR 97 EIS in the "Training Mode" to conduct this lab exam. Using the Rules and Regulations book, find Section 3340.42 - **Table III** "Emission Standards, Gross Polluter Standards, Dilution Thresholds, and Maximum Idle RPM Limits for the Two Speed Idle Test." Apply these standards to the vehicles you are testing.

Fill in the information below:

Vehicle #1:

VEHICLE YEAR MODEL:	VEHICLE MANUFACTURER:	MODEL INFORMATION:	ENGINE SIZE:

2500 RPM Test:

HC Pass/Fail Standards = _______PPM CO Pass/Fail Standards = _______%

HC Measured = _______PPM CO Measured = _______%

O2 Measured = _______% CO2 Measured = _______%

Did vehicle Pass or Fail the above test? _______ If it failed, what emission(s) did it fail for?_______

Idle Test:

HC Pass/Fail Standards = _______PPM CO Pass/Fail Standards = _______%

HC Measured = _______PPM CO Measured = _______%

O2 Measured = _______% CO2 Measured = _______%

Did vehicle Pass or Fail the above test? _______

If it failed, what emission(s) did it fail for?__________

Vehicle #2:

VEHICLE YEAR MODEL:	VEHICLE MANUFACTURER:	MODEL INFORMATION:	ENGINE SIZE:

2500 RPM Test:

HC Pass/Fail Standards = _______PPM CO Pass/Fail Standards = _______%

HC Measured = _______PPM CO Measured = _______%

O2 Measured = _______% CO2 Measured = _______%

Did vehicle Pass or Fail the above test? _______ If it failed, what emission(s) did it fail for?_______

Idle Test:

HC Pass/Fail Standards = _______PPM CO Pass/Fail Standards = _______%

HC Measured = _______PPM CO Measured = _______%

O2 Measured = _______% CO2 Measured = _______%

Did vehicle Pass or Fail the above test? _______

If it failed, what emission(s) did it fail for?__________

Vehicle #3:

VEHICLE YEAR MODEL:	VEHICLE MANUFACTURER:	MODEL INFORMATION:	ENGINE SIZE:

2500 RPM Test:

HC Pass/Fail Standards = _______PPM CO Pass/Fail Standards = _______%

HC Measured = _______PPM CO Measured = _______%

O2 Measured = _______% CO2 Measured = _______%

Did vehicle Pass or Fail the above test? _______ , If it failed what emission(s) did it fail for?______

Idle Test:

HC Pass/Fail Standards = _______PPM CO Pass/Fail Standards = _______%

HC Measured = _______PPM CO Measured = _______%

O2 Measured = _______% CO2 Measured = _______%

Did vehicle Pass or Fail the above test? _______

If it failed, what emission(s) did it fail for?__________

BASIC CLEAN AIR CAR COURSE
INSTRUCTOR LESSON PLAN

This lesson plan replaces the Basic Clean Air Car Course (BCACC) lesson plan noted in the BAR Instructor Procedures Manual. Instructors shall incorporate into their curriculum the course materials and laboratory examinations in this document, along with the appropriate certified vendor/BAR supplied materials.

The BCACC is three phase course (Phase I, II, & III), students must successfully complete **each** phase to pass the BCACC:

Phase I: **C**overs: BAR rules and regulation, emission control system (ECS) theory and operation, cause and effect of mobile source air pollution, and operation of the BAR 97 EIS in performing a "Basic Area" vehicle emissions inspection.

Phase II: Covers: Advanced Scan Tool Diagnostics.

Phase III: Covers: BAR's OBD II training - System theory and operation course.

Phase I Course and Exam Materials:

- **BCACC Student workbook**: The new BCACC Student Workbook can be downloaded from the S & T website.
- **Automotive Repair – Laws and Regulations book:** Available from BAR's mail room.
- **Smog Check Inspection Manual and Smog Check Inspection Guide:** Can be downloaded from the S and T website.
- **2003 Update Course Video**: Available from BAR's mail room.
- **2005 Update Course Lambda (PowerPoint) Presentation:** Download from S and T website.
- **Low Pressure Fuel EVAP Testing (LPFET) and Smoke Inspection Videos:** Available from BAR's mail room.
- **Phase I Final Examination:** Available from BAR's Standards and Training Unit, by sending an email request to Roger Becker Jr. at: **roger_beckerjr@dca.ca.gov**.

NOTICE: BAR secured permission to reprint training materials from a previously used BCACC training manual. As part of the reprint agreement, BAR was required to ensure that the material incorporated into this training package would only be used for educational purposes, and that no one would profit from the sale of these materials. In light of this commitment, BAR schools are instructed to **only charge students the cost of reprinting the material** in this package.

PHASE I

The BCACC is a <u>minimum</u> of 68 hours in length. Instructors may exceed this time allotment, to ensure students grasp the theory and content of the course materials. Below is a *suggested* timeline for instructing *Phase I* of the Basic Clean Air Car Course. Instructors may alter the order of subject areas and/or time appropriations to suit the classroom situation.

Phase I - Instructor Lesson plan:

<table>
<tr>
<td rowspan="2">30 minutes</td>
<td>1.) Hand out the student course materials package. Ask students to read page 2 titled “Important Notice to Students Taking the Basic Clean Air Car Course,” and page 3 “Notice.”

2.) While they are reading the above page, ask to see each student’s California Driver’s License/ID. Write down each student’s date of birth (DOB), and their name as it appears on that ID. DO NOT use the student’s name as it appears on a list provided to you. Advise students that if they do not have a valid ID, that they must obtain the correct ID (and display it to you) within 60 days of the course completion date, for them to get BAR credit for this course (reference the Certified Instructor Procedures Manual, page 2).</td>
</tr>
<tr>
<td>Discuss with students:
• That this course is not a beginner’s course. That they should have a good working knowledge of basic automotive electrical systems and engine performance systems to be successful in this course (reference the Certified Instructor Procedures Manual, page 2).
• The three phases of the course (emission inspection procedures, OBD II systems, advanced scan tool diagnostics).
• What is required of them to pass this course: full attendance (reference the Certified Instructor Procedures Manual, page 9), successful completion of all lab examinations, passing written examinations with a score of 70% or better, full completion of all homework assignments. Advise them that they cannot be given BAR credit for this course unless they meet all of the above criteria.
• Your school’s policy on second chance examinations (reference the Certified Instructor Procedures Manual, page 12).
• Your school’s policy on making up missed class time (reference the Certified Instructor Procedures Manual, page 9).
• BAR’s policy on exam security (reference the Certified Instructor Procedures Manual, page 10).
• Your school’s policy on the use of shop student vehicles to perform the laboratory examinations (reference the Certified Instructor Procedures Manual, page 9).</td>
</tr>
</table>

<table>
<tr><td>1 Hour</td><td>Review the Laws and Regulations Manual with students and explain statute and regulations using the manual entitled Laws and Regulations Relating to Automotive Repair Dealers, Licensed Official Stations, and Licensed Smog Check Stations dated 2007. Review with students the hierarchy of regulations [e.g., small (a) is more important than a (1), which is more important than an (A), etc.] so they may be able to answer the review questions on the following assignment. Randomly pick a couple of regulations and ask the students to describe how that specific regulation should be written (use whiteboard to write out regulation). If you do not understand this hierarchy, contact Wayne Brumett at (916) 255-1391 or Marty Gunn at (916) 255-3157.

Homework Assignment:
• Using the Laws and Regs. book noted above, answer the questions on page 4 – 5 in the BCACC student workbook. Emphasize that they must be able to provide the correct regulatory section when answering the question.
• Read pages 5 – 11 in the BCACC Student Workbook, and answer the questions on page 12.</td></tr>
<tr><td>3 Hour</td><td>Collect the two homework assignments for student course credit. Give those students who have answered all the questions, credit for this task.

Note: Students may not get BAR credit for passing this course, unless they provide an answer to all review question assignments.

Review the answers in class to the homework assignment on pages 4 – 5.

Emissions – Cause and Effect:
Review the cause and effect of exhaust emissions to include carbon monoxide, hydrocarbons, and oxides of nitrogen. Discussion should also include the combustion process and flame propagation, health impacts, and environmental impacts.

Review the answers in class to the homework assignment on page 12.

Homework Assignment:
Read pages 13 – 70 in the BCACC Student Workbook and answer all questions on pages 71 - 74.</td></tr>
</table>

6 Hours	Collect the homework assignment for student course credit. **Emission Controls – Operation and Identification**: Explain the operation and function of each of the emissions control devices. Discussion should include the definitions of missing, modified disconnected and defective as these terms apply to emission control systems and the visual inspection. Explain the required functional tests. Review the answers in class to the homework assignment on pages 71 - 74. Show LPFET and Smoke inspection videos. **Homework Assignment:** Read pages 75 – 82 in the BCACC Student Workbook and answer all questions on page 83.
3 Hours	Collect the homework assignment for student course credit. **Gas Analyzers and Gas Analysis:** Explain the use and calibration of the BAR 97 analyzer and give the students a demonstration of the 3-day calibration procedure. Discuss how exhaust emissions are affected by the following: stoichiometry, detonation, pre-ignition, and quench areas. Discuss sample dilution. Use the 2005 Update Course Lambda PowerPoint presentation to explain the Lambda calculator and the benefits of its use. Review the answers in class to the homework assignment on page 83.
3.5 Hours	Discuss proper testing procedures for ignition timing, EGR functional testing, and LPFET testing. **Instructor Led Demonstration**: Perform visual inspection and functional tests on a vehicle as they apply to a two-speed idle test. **Student Lab Examination:** Students perform a "Two-Speed" **tailpipe test** on **at least** 3 different vehicles. **Homework Assignment**: Read The Smog Check Inspection Manual and Smog Check Inspection Guide. Answer the questions in the BCACC Student Workbook on pages 84 – 90.

Phase I – (con't)

3 Hours	Collect the homework assignment for student course credit. Review the answers in class to the homework assignment on pages 84 – 90. **Smog Check Manual and Guide Review:** Conduct an in-depth review of the Smog Check Inspection Procedures Manual Dated June 2008 and the Smog Check Reference Guide. Ensure that students understand that the Procedures Manual is *proposed* to be codified into law and therefore enforceable, whereas the Guide is not a legal document. Show 2003 Update course training video, and discuss with class.
10 Hours	**Student Lab Examination:** Using ECS Application manuals, the students shall perform Laboratory Examination #1 on pages 91 – 92. Review the answers in class to the homework assignment on pages 91 – 92. **Student Lab Examination:** Using the appropriate vehicles, perform Laboratory Examination #2 on pages 93 – 96. Using the appropriate manuals, the students shall perform a smog check inspection (i.e., visual, functional, and tailpipe tests) on **3** vehicles, per the Basic Area Program (two speed idle) inspection procedure.
2 hours	**Final Exam for Phase I:** Students must score 70% or better to pass this exam.

Phase II Course and Exam Materials:

- **BCACC OBD II (PowerPoint)Program 9-2008:** Download from S and T website.
- **2005 Update Training Course Laboratory Assignments:** Download from S and T website.
- **A-F Sensor (PowerPoint) Program**: Download from S and T website.
- **Aspire's Oxygen Sensor PowerPoint Program:** To obtain this PowerPoint presentation, see instructions on page 8 of the "Certified Instructor Procedures Manual."
- **Phase II Final Examination:** Available from BAR's Standards and Training Unit, by sending an email request to Roger Becker Jr. at: **roger_beckerjr@dca.ca.gov**.

Phase II - Instructor Lesson plan:

1.5 hours	**OBD Data Acquisition and Interpretation Lecture:** Briefly review with the students the hierarchy of sensors (e.g., RPM, MAF, TPS, etc.) that have the most effect on the engine performance system. Discuss the exercises on pages 1 – 20 of the "2005 Update Training Course Laboratory Assignments." Ensure the students understand that as RPM/load conditions change during a scan tool snap shoot/movie, there is an expected sensor/actuator value that should be displayed. If the value(s) displayed are not what is expected under a given condition, then that may be an area that may require further exploration.
30 Minutes	**Instructor Lead Demonstration:** Demonstrate the snap-shot/movie record functions of a scan tool. Discuss how to select relevant sensors/actuators for the drivability/emission failure issues manifested in the vehicle's operation. In addition, demonstrate how to clear codes, and use the bi-directional control features of the scan tool.
1 hour	**Student Lab Examination:** Using the appropriate vehicles, the students shall practice using the snap shot/movie record functions of a scan tool. Have the students set up the scan tool to record: RPM, MAP/MAF, TPS, ECT, IAT, ECT, $O_{2,}$ Injector pulse, as they increase the RPM from idle to 1500 RPM. Have the students record the values on page 7 of the "2005 Update Training Course Laboratory Assignments" document.
2.5 hours	**Zirconium and A/F Ratio Sensors Lecture:** Review the operation and function of zirconium and titanium type oxygen sensors using both the BAR 2005 Update Course PowerPoint presentation and the Aspire PowerPoint presentation. Make sure students understand the proper O_2 testing (mapping) procedures, and the correct voltage/time specifications. Review the operation and function of A/F ratio sensors using BAR's A-F Sensor and Aspire PowerPoint presentations.
30 minutes	**Fuel Trim Lecture:** Review advanced fuel-trim theory and diagnostics, using BAR's 2007 Update Course PowerPoint presentation - slides #: 9 – 31.
1 hour	**Student Lab Examination:** Using scan tools and the appropriate vehicles, student should capture the Short Term and Long Term fuel trim values of the demo vehicle. In addition, they should demonstrate that they can clear codes, and use the bi-directional control features of the scan tool.
2 hours	**Phase II Final Exam:** Students must score 70% or better to pass this exam

PHASE III

Phase III Course and Exam Materials:

- **Student OBD II Textbook**: Available from BAR approved textbook vendors.(see BAR Instructor Procedures Manual for list of vendors).
- **BCACC 2007 Update Course Program 9-2008:** Download from S and T website.
- **BCACC Phase III Labs 9-2008:** Download from S and T website.
- **Phase III Final Examination:** Available from BAR's Standards and Training Unit, by sending an email request to Roger Becker Jr. at: **roger_beckerjr@dca.ca.gov**.

Phase III - Instructor Lesson plan:

10 hours	**Student Reading Assignment:** Assign students to read the entire OBD II course textbook prior to the first class (if possible). **Lecture**: Provide a lecture on OBD II using the PowerPoint presentation titled "BCACC OBD II 9-2008." Be sure you are familiar with this presentation before giving your first class.
5 hours	**Student Lab Examination**: Using OBD II equipped vehicles and the appropriate scan tools, assign students the BCACC Phase III labs #: 1 – 5.
2 hours	**Lecture**: Brief Overview the operation, function, and application of OBD Mode 6, using the BCACC 2007 Update Course Program 9-2008 - slides #: 104 – 118.
2 hours	**Student Lab Examination**: Using the appropriate scan tools and vehicles, assign students the BCACC Phase III labs #: 6 – 8.
2 hours	**Lecture**: Brief Overview of OBD II fuel evaporative systems using the BCACC 2007 Update Course Program 9-2008 - slides #: 55 – 103.
2 hours	**Student Lab Examination**: Using the appropriate scan tools and vehicles, assign students the BCACC Phase III labs #: 9 – 13.
1 hour	**Lecture**: Brief Overview of Control Area Networks and multiplexing using the BAR 2007 Update Course PowerPoint presentation using the BCACC 2007 Update Course Program 9-2008 - slides #: 55 – 103.
1 hour	**Lecture**: Brief Overview of PCM Reprogramming procedures, Technical Services Bulletins using the BCACC 2007 Update Course Program 9-2008 - slides #: 119 – 126.
2 hours	**Phase III Final Exam:** Students must score 70% or better to pass this exam.