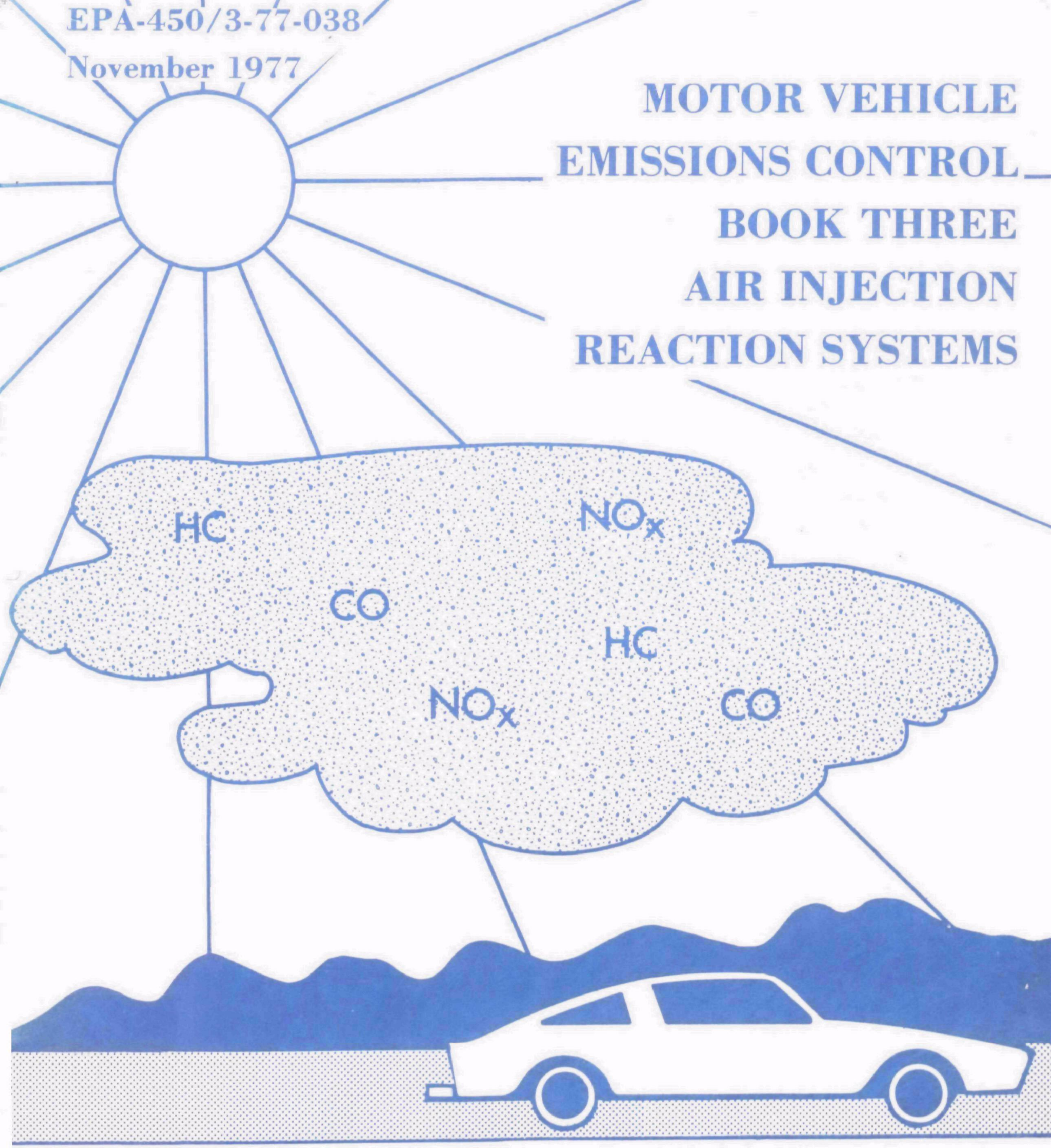
EPA-450/3-77-038

November 1977

MOTOR VEHICLE EMISSIONS CONTROL BOOK THREE AIR INJECTION REACTION SYSTEMS



U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

EPA-450/3-77-038

MOTOR VEHICLE EMISSIONS CONTROL
BOOK THREE
AIR INJECTION REACTION SYSTEMS

by

B.D. Hayes, Project Director
M.T. Maness, Associate Project Director
R.A. Ragazzi, Principal Investigator
R.A. Barrett, Graduate Research Assistant

Department of Industrial Sciences
Colorado State University
Fort Collins, Colorado 80523

EPA Grants No. T008135-01-0 and T900621-01-0

EPA Region VIII Project Officer: Elmer M. Chenault

EPA Project Officer: Bruce Hogarth

Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Control Programs Development Division
Research Triangle Park, North Carolina 27711

November 1977

Copies of this publication are available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - as supplies permit - from the Library Services Office (MD-35), Environmental Protection Agency, Research Triangle Park, North Carolina 27711; or, for a fee, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

This report was furnished to the Environmental Protection Agency by the Department of Industrial Sciences, Colorado State University, Fort Collins, Colorado, 80523, through Grants No. T008135-01-0 and No. T900621-01-0. The contents of this report are reproduced herein as received from Colorado State University. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the Environmental Protection Agency. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

Publication No. EPA-450/3-77-038

MOTOR VEHICLE EMISSIONS CONTROL

-- SERIES OF SEVEN BOOKS --

MOTOR VEHICLE EMISSIONS STAFF, COLORADO STATE UNIVERSITY

BOOK ONE - POSITIVE CRANKCASE VENTILATION SYSTEMS

BOOK TWO - THERMOSTATIC AIR CLEANER SYSTEMS

BOOK THREE - AIR INJECTION REACTION SYSTEMS

BOOK FOUR - FUEL EVAPORATION CONTROL SYSTEMS

BOOK FIVE - EXHAUST GAS RECIRCULATION SYSTEMS

BOOK SIX - SPARK CONTROL SYSTEMS

BOOK SEVEN - CATALYTIC CONVERTER SYSTEMS

ACKNOWLEDGMENTS

The Motor Vehicle Emissions Control Staff of the Department of Industrial Sciences at Colorado State University would like to acknowledge the efforts extended by the Environmental Protection Agency, Research Triangle Park, and Region VIII Environmental Protection Agency, Manpower Development Division.

A special thanks must be extended to the automotive vehicle equipment and parts manufacturers for their cooperation and assistance in the development of this training material.

INSTRUCTIONS FOR THE USE OF THIS BOOK

This book is one of a series designed specifically to teach the concepts of automobile emissions control systems. Each book is designed to be used as self-instructional material. Therefore, it is important that you follow the step-by-step procedure format so that you may realize the full value of the emissions system which is being presented. The topics are taught in incremental steps and each topic treatment prepares the student for the next topic. Each book is divided into sections which include the introduction, purpose, function, inspection and testing of the emissions system presented.

As you proceed through this series, please begin with book one and read the following books in sequence. This is important because there are several instances where material covered in a given book relies on previously covered material in another book.

To receive the full benefits of the book, please answer the self-evaluation statements related to the material. These statements are separated from the text by solid lines crossing the page. The answers to the statement can be found at the end of the book as identified by the table of contents. You should check for the correct answer after you respond to each statement. If you find that you have made a mistake, go back through the material which relates to the statement or statements.

Fill-in-the-blank statements are utilized for self-evaluation purposes throughout the material. An example statement would appear like this:

The American flag is red, white, and ______.

You would write "blue" in the blank and immediately check your answer at the end of the book.

The material, statements and illustrations should be easy to follow and understand. In several illustrations a small ghost named "VEC" (Vehicle Emissions Control) has been used to make the picture easier to understand.

Upon completion of this series, you should be able to better understand the emissions control systems and devices which are an integral part of automobiles today. Your increased knowledge should help you keep these "emissions controlled" vehicles operating as they were designed to operate. Respectable fuel economy, performance and driveability, as well as cleaner air, can be obtained from the automobile engine that has all of its emissions systems functioning properly.

CONTENTS

INTRODUCTION TO EMISSIONS CONTROL

As we all know emissions systems and devices have been installed on the automobile engine because of the air pollution problem. In order for you to understand these emissions systems and devices you should have a background of the problem. All of the emissions control systems were installed on the engine to reduce just three specific exhaust products. These are known as products of combustion. The three products which the emissions systems are designed to reduce are hydrocarbons, carbon monoxide and oxides of nitrogen.

HYDROCARBONS

Gasoline, like all petroleum products, is made up of hundreds of hydrocarbon compounds. The name "hydrocarbon" has been given to these compounds because they are made up of hydrogen and carbon atoms. This is also the reason hydrocarbons have the abbreviation (HC).

Hydrocarbons are gasoline vapors or raw gasoline itself. One reason hydrocarbon emissions must be controlled is because it is one of the major components of photochemical smog. Photochemical or "Los Angeles" smog forms when hydrocarbons and oxides of nitrogen combine in the presence of sunlight. In order to avoid this smog condition the hydrocarbon emissions from automobiles must be controlled. Hydrocarbons also act as an irritant to our eyes and some are suspected of causing cancer and other health problems.

CARBON MONOXIDE

Another product of combustion that must be controlled is carbon monoxide. Carbon monoxide has the abbreviation (CO). CO is also hazardous to our health when it is mixed with the air we breathe. It can cause headaches, reduce mental alertness and even cause death if enough of it is in the air. Carbon monoxide is also a problem in that it speeds the formation of photochemical smog. For these reasons CO emissions must be controlled.

OXIDES OF NITROGEN

Oxides of nitrogen are the last harmful products of combustion we will discuss. Nitrogen oxides have been given the abbreviation (NO_x). As you already know, oxides of nitrogen and hydrocarbons combine to form photochemical smog. The sunlight which triggers the formation of photochemical smog has another effect on oxides of nitrogen. Some of the oxides of nitrogen are broken down and a gas called ozone is formed. Ozone is a lung and eye irritant and it also deteriorates rubber and affects the growth of vegetation. Since the nitrogen oxides have these effects they must also be controlled.

Now that you are familiar with the emissions which must be controlled let's find out where they originate.

FORMATION OF HYDROCARBONS

Hydrocarbons, you will recall, are fuel vapors or raw fuel. For this reason hydrocarbon emissions will result from any uncontained supply of gasoline. Hydrocarbon emissions also come from the tailpipe. If the automobile engine could achieve "complete combustion," all of the unburned fuel or hydrocarbons would be used up. However, it is impossible for today's automobile engines to achieve "complete combustion." Any time the fuel mixture in the combustion chamber is not completely burned, some hydrocarbons will be emitted from the tailpipe. The two main reasons why hydrocarbons are not completely burned are because of engine misfire and "quench areas." When an engine misfire occurs, none of the raw fuel or hydrocarbons are burned. When this happens they are simply exhausted directly to the atmosphere. Quench areas are places in the combustion chamber where the flame goes out before the fuel is completely burned. Small cavities such as where the head gasket seals the cylinder head to the block is a quench area. Another quench area is located between the top of the piston and the first compression ring. These areas are sources of hydrocarbon emissions.

FORMATION OF CARBON MONOXIDE

Carbon monoxide is partially burned fuel. Carbon monoxide is formed in the combustion chamber whenever there is not enough air to burn all the fuel. This means that whenever a "rich" air/fuel mixture is pulled into the combustion chamber carbon monoxide will be formed. After the flame goes out the carbon monoxide is exhausted through the tailpipe and into the air.

FORMATION OF OXIDES OF NITROGEN

Oxides of nitrogen are also formed in the combustion chamber. These oxides result from the nitrogen which is contained in our air. In some cases combustion temperatures in the automobile engine can exceed 4500°F. At temperatures above approximately 2500°F, nitrogen oxides will start forming. Therefore, if combustion chamber temperatures exceed 2500°F, oxides of nitrogen will be produced and then exhausted to our atmosphere.

Now that you understand how these emissions are formed in the automobile engine, we will see how changes in ignition timing and carburetor adjustment affect the amount of these pollutants.

As you know, changes in timing and carburetion can have a large effect on how an engine performs. These changes in timing and carburetion also can have drastic effects on the amount of pollutants which are present in the automobile's exhaust. The amount of hydrocarbons, carbon monoxide and oxides of nitrogen which are present in the exhaust gases will vary as timing and carburetion adjustments are changed.

IGNITION TIMING

Prior to emissions controlled automobiles, advancing the spark timing was a common practice. Setting the spark timing this way caused the spark plug to fire before the piston reached top dead center. This advanced spark timing allowed the maximum amount of heat energy to be exerted on the piston. As a result the best performance and fuel economy could be obtained. Unfortunately, this also produced high hydrocarbon and nitrogen oxide emissions levels.

In order to reduce emissions levels, ignition spark timing was retarded. By firing the spark plug after the piston reaches top dead center, not as much of the heat energy is converted to work on the piston. The extra heat energy which is not used on the piston now passes through the exhaust valve and into the exhaust manifold. This keeps the exhaust gas temperatures higher. These higher exhaust temperatures allow burning of the air/fuel mixture to continue in the exhaust manifold. This further oxidation or burning in the exhaust manifold helps to reduce HC and CO emissions.

Another advantage of retarded timing from an emissions standpoint is that combustion temperatures are not as high. This is due to the fact that the maximum combustion pressure will be lower. Since the combustion temperatures will be lower and the formation of oxides of nitrogen depends on temperature, a smaller amount of these pollutants will be exhausted to the atmosphere.

There is one more advantage to using retarded spark timing. As you know, when ignition timing is retarded the engine's idle speed will drop. This decrease in idle speed occurs because less heat energy is applied to the combustion chamber and more heat energy is being supplied to continue the burning process in the exhaust manifold. In order to regain an acceptable idle speed, the throttle plates must be opened wider. This wider throttle plate opening allows more air to pass through the carburetor. This increase in air flow will reduce the amount of residual exhaust gases in the cylinder. This in turn will allow a more burnable mixture which can be made leaner. Since the mixture can be leaner there will be more air in the combustion chamber. As you know, the more air that is made available during combustion the lower will be the HC and CO emissions.

CARBURETION

Adjustments made to the carburetor air/fuel ratio can also have a large effect on the amount of pollutants which come from the automobile engine. When idle mixture settings become richer there is less air present for the combustion process. This lack of air results in an increase in hydrocarbon and carbon monoxide emissions.

When idle mixture screws are turned in, the amount of fuel is reduced and the mixture becomes leaner. This leaner mixture contains more air and therefore more oxygen is available for more complete burning of the fuel. This results in lower HC and CO emissions levels.

As the idle mixture screws are turned in, the idle air/fuel mixture becomes leaner. If this mixture becomes too lean a "lean misfire" will occur. A "lean misfire" will occur because the fuel is so diluted or thinned out by the air that the mixture will not ignite. This leads to a very large increase in hydrocarbon emissions. This happens because the failure of the mixture to ignite results in that amount of raw fuel being emitted to the atmosphere.

The carbon monoxide emissions decrease when a lean misfire condition is present. Carbon monoxide is partially burned fuel. Since no combustion takes place during a lean misfire condition no CO is formed and the total amount of CO produced by the engine will be less.

A lean misfire usually occurs in one or more cylinders. This condition may also move from cylinder to cylinder while the engine is running. This is caused by the uneven distribution of the air/fuel mixture delivered to each cylinder. This condition occurs mainly because of problems with intake manifold design.

Now you should understand how changes in timing and carburetion adjustment can affect emissions levels. With this knowledge you will be able to understand how each emissions control system we will discuss helps to reduce the air pollution caused by the automobile.

SYSTEM INTRODUCTION

The next system we are going to discuss is the AIR system. As you remember from the introduction of this book, hydrocarbons and carbon monoxide emissions must be controlled. The AIR system greatly helps reduce these two emissions. Before we go any further with this system let's briefly review what happens after the exhaust gases leave the combustion chamber.

As you recall when ignition spark timing is retarded the exhaust gas temperatures will be hotter. Using retarded timing helped to continue the burning or "oxidizing" of the unburned hydrocarbons and carbon monoxide. This takes place because there is a small amount of air in the exhaust manifold and when the hot exhaust gases come in contact with this air they can continue to burn. The amount of burning which takes place in the exhaust manifold depends on just how much air is availalbe. Unfortunately, there is not enough air in the manifold to burn all the hydrocarbons and carbon monoxide which are present in the exhaust gases.

The AIR system is designed to supply more air to the exhaust manifold and actually burn the unburned portion of the exhaust gases. This reduces the harmful hydrocarbon, HC, and carbon monoxide, CO, emissions. These exhaust gases should be further oxidized before they go out the tailpipe. Because of the incomplete combustion taking place in the cylinders, carbon monoxide and hydrocarbons are pushed out of the cylinders during the exhaust stroke. If the hydrocarbons and carbon monoxide in the exhaust manifold continued to burn, the harmful gas, carbon monoxide, would change to the harmless gas, carbon dioxide which has a symbol CO_2. The HC that is burned in the exhaust manifold because of the AIR system, is reduced to water vapors which have a symbol H_2O.

The AIR system injects air into the exhaust manifold. This is how this system got its name. AIR stands for air injection reaction. However, different manufacturers have their own name for this system. Figure 3-1 shows the different names which are used for this system. Even though

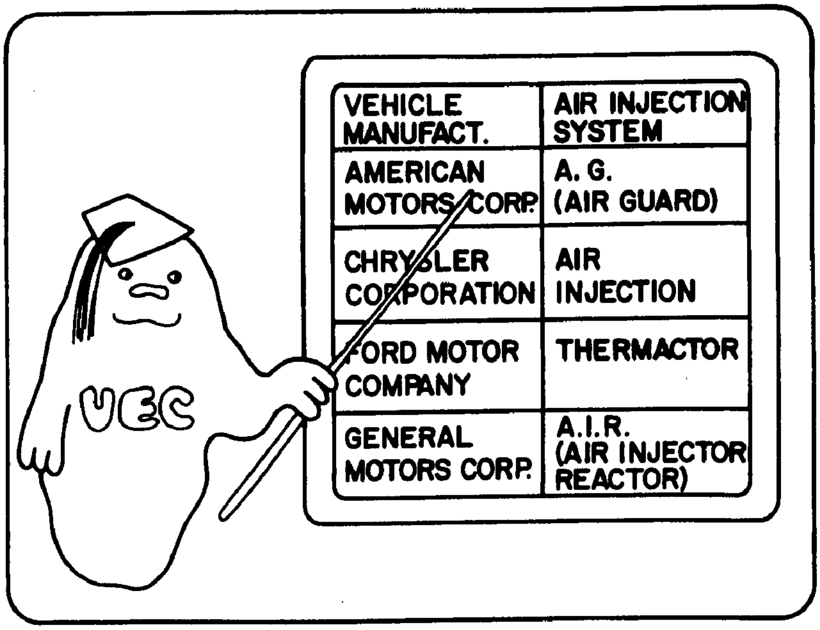


FIGURE 3-1

each manufacturer uses a different name for this system they all have the same purpose and all function in the same way.

The AIR system was first used on automobile engines in 1966. During 1966 and 1967 most of the automobiles which were equipped with an AIR system were sold in California. Starting in 1968 AIR systems were installed on many engines throughout the country. Many of the foreign automobiles which are imported into this country also have air injection systems.

Since the AIR system does its job after the combustion takes place in the cylinder, the system is very beneficial. It does an effective job of reducing HC and CO from the exhaust. It also allows the manufacturers to change carburetion and ignition timing to give better driveability.

---

1. The amount of secondary burning or oxidizing which takes place in the exhaust manifold depends on how much ______ is available.

---

2. The AIR system injects fresh air into the ______________ ________________.

---

3. AIR is the abbreviation for ______ __________________ ________________

---

4. The AIR system does its job after ____________________ takes place in the cylinders.

---

5. ________________________ and ____________ ________________ are effectively reduced by the AIR system.

---

6. By using the AIR system manufacturers could change ______________________ and ignition timing to give us better driveability.

SYSTEM/COMPONENT PURPOSE

Now that you are familiar with how the AIR system helps control the emissions of hydrocarbons and carbon monoxide it is time to take a closer look at the components of this system. First you will look at each component separately to find out what part it plays in the AIR system.

The components of the AIR system are shown in figure 3-2. As you can see this system is composed of an air pump, a diverter valve, a check

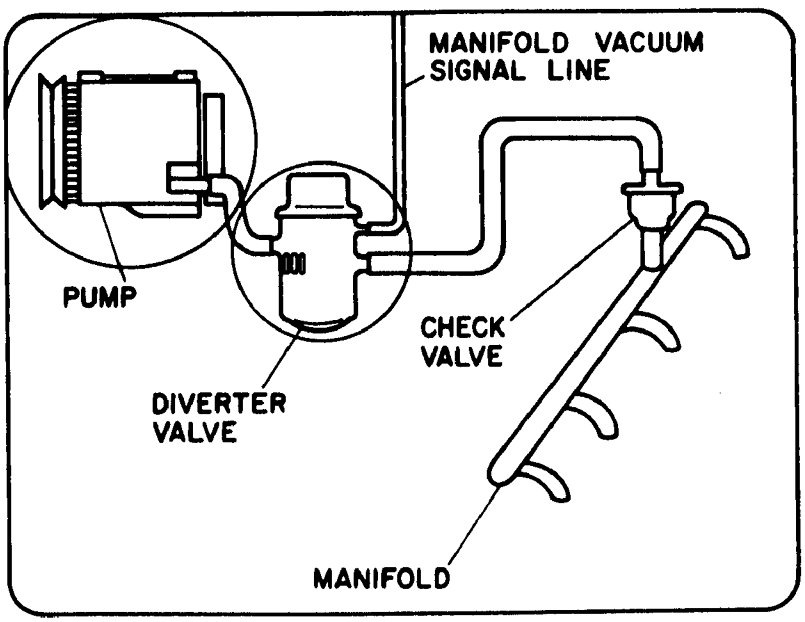


FIGURE 3-2

valve, an air injection or distribution manifold and the connecting hoses and vacuum lines. V8 engines use two check valves and two injection manifolds.

Figure 3-3 shows where these components are usually located on a V8 engine.

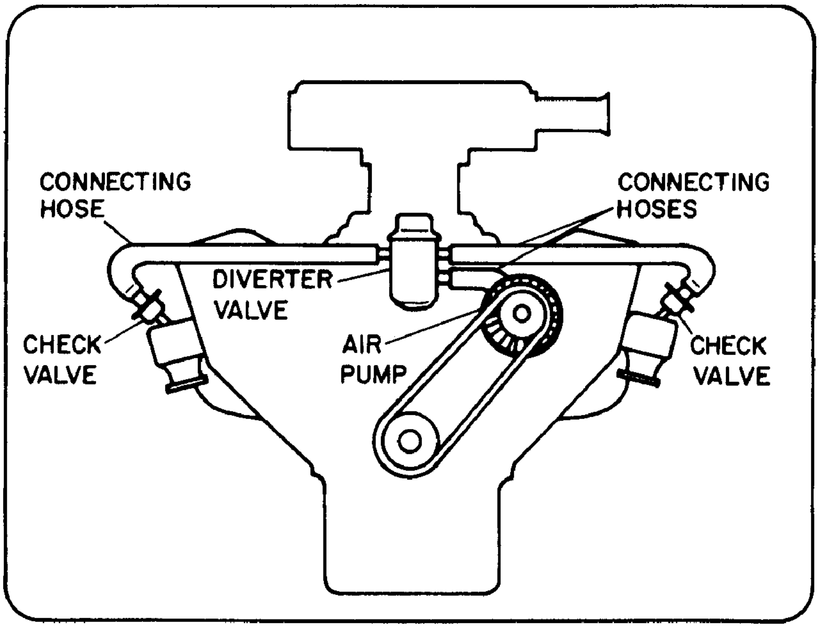


FIGURE 3-3

AIR PUMP

Since the AIR system supplies the exhaust manifold(s) with additional air to oxidize or burn the hydrocarbons and carbon monoxide, a means of "pumping" outside air into the exhaust manifold must be used. This is the job of the air pump. The air pump is a belt driven pump and as you can see in figure 3-4, it is located much like other belt driven engine components.

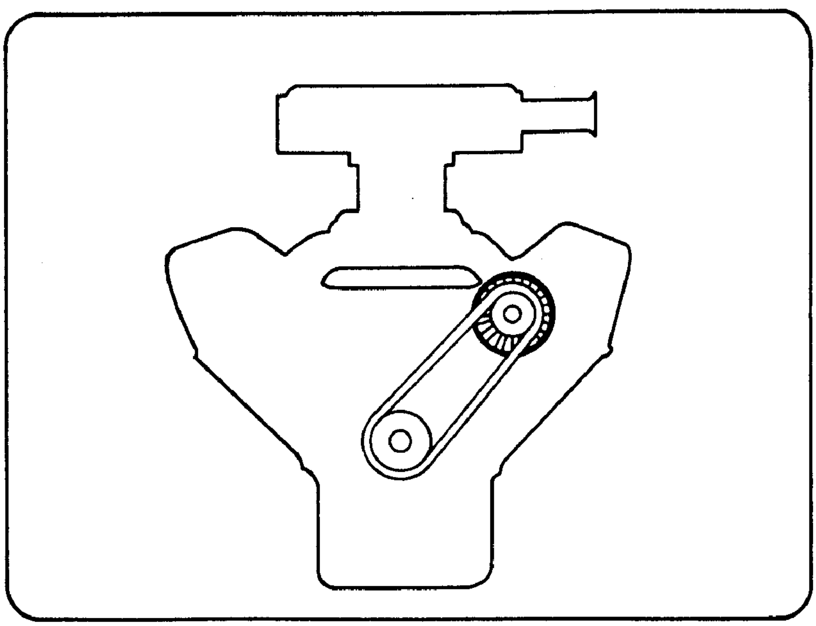


FIGURE 3-4

The air pump draws fresh air from the engine compartment through an inlet, usually located in the pump itself. Part of this air inlet serves as a filter to remove any foreign matter from the air. If dirt or dust is allowed into the air pump it could possibly damage the pump and render the system useless.

INLET FILTERS

The most popular air pump inlet and filter arrangement is shown in figure 3-5.

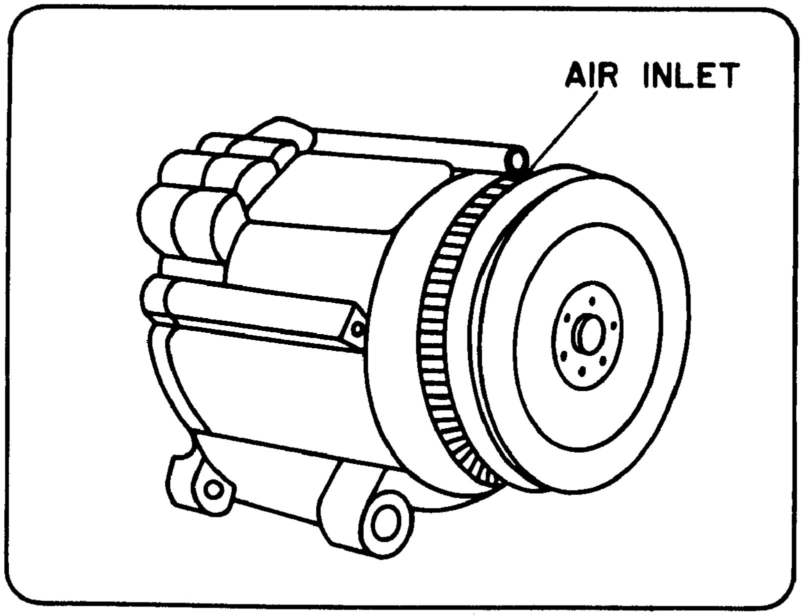


FIGURE 3-5

The air enters the pump and is filtered by a centrifugal fan filter. This filter is actually part of the pump itself.

The second method which can be used is the external filter shown in figure 3-6.

As you can see the filter and air inlet are separated from the pump itself. A hose is used to connect the filter to the pump.

Figure 3-7 shows the location of the pump discharge or outlet.

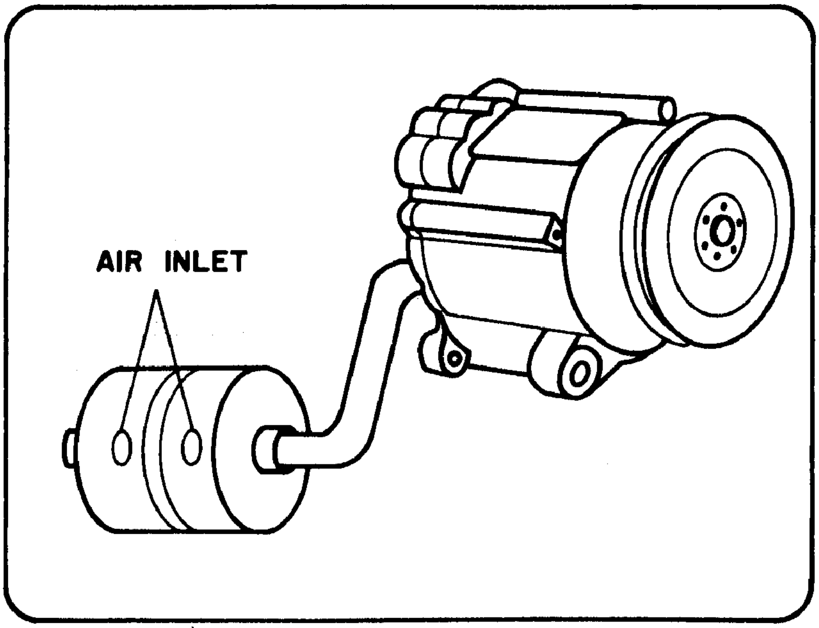


FIGURE 3-6

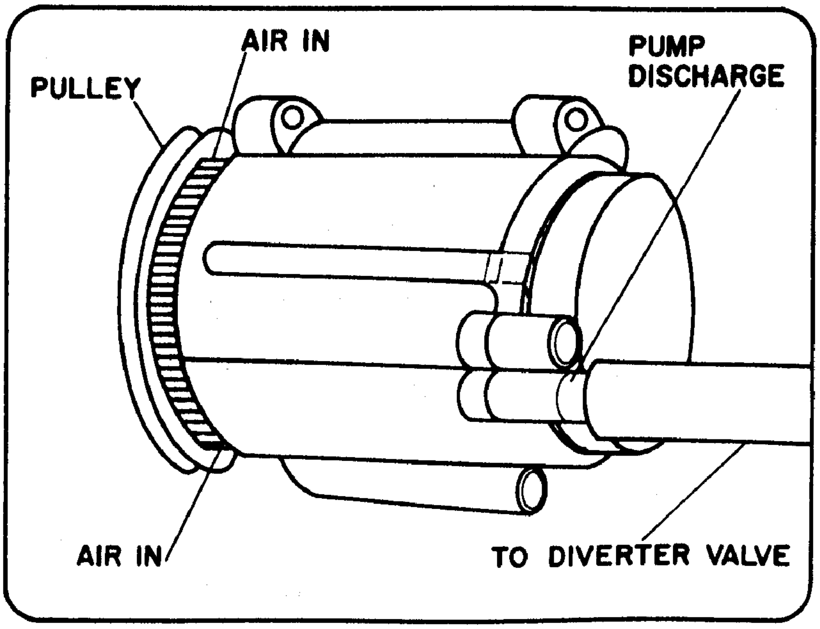


FIGURE 3-7

A hose is connected to the pump outlet so the supply air can move on to the diverter valve and injection manifolds.

---

7. An ______ ________ supplies the air for the air injection system.

---

8. Before air enters the pump it passes through an __________ ____________ to remove any dust particles.

---

9. The AIR system uses a ________ driven pump.

PRESSURE RELIEF VALVE

The air pump is usually equipped with a pressure relief valve. This valve is shown in figure 3-8. This pressure relief valve limits the maximum pressure from the pump. This is done to prevent exhaust system

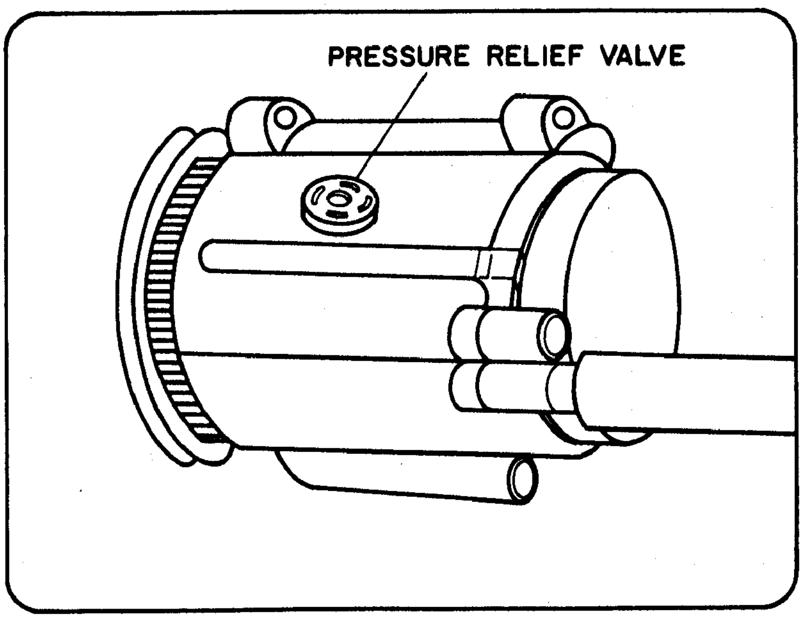


FIGURE 3-8

overheating at high engine speeds. Limiting the maximum pump pressure can also be done at the diverter valve. For this reason, not all air pumps will have a built-in pressure relief valve.

DIVERTER VALVE

A diverter or anti-backfire valve and its various connections is shown in figure 3-9.

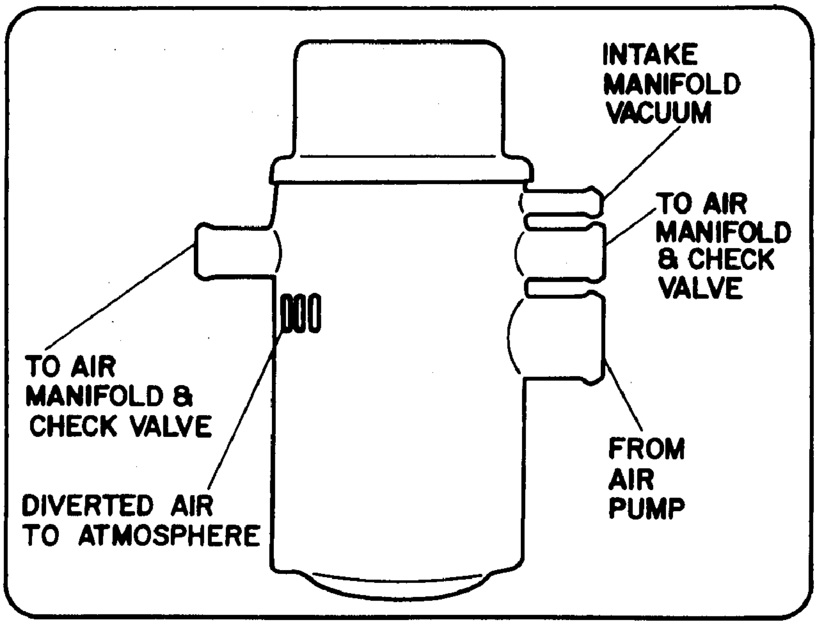


FIGURE 3-9

This valve has been called several different names. The purpose of the valve, regardless of its name, is the same. The valve's job is to prevent backfire by momentarily diverting the air pump's output. This is done so that air does not reach the exhaust valve area during the initial stages of engine deceleration. Engine deceleration takes place when you take your foot off the gas pedal. When this occurs the throttle plates in the carburetor close creating a high vacuum condition just beneath the throttle plates. Because of this vacuum condition rich air/fuel mixture is drawn into the cylinders. This rich mixture cannot burn completely during the power stroke so much of the mixture is pushed out past the exhaust valves and into the exhaust manifold. If the AIR system was allowed to inject fresh air into the exhaust ports under this condition, an undesirable backfire would occur. This backfire would take place as soon as the fresh air mixed with the overly rich exhaust gases. This valve is called a diverter valve because it diverts the air from the air pump away from the exhaust manifold and out to the atmosphere. It's called an anti-backfire valve because it prevents backfiring during deceleration.

A muffler was installed on the diverter valve to prevent the loud noise when the valve diverts the air to the atmosphere. On newer engines, the muffler is internal and you cannot see it. The older type diverter valves had an external muffler. Figure 3-10 shows both types of diverter valves.

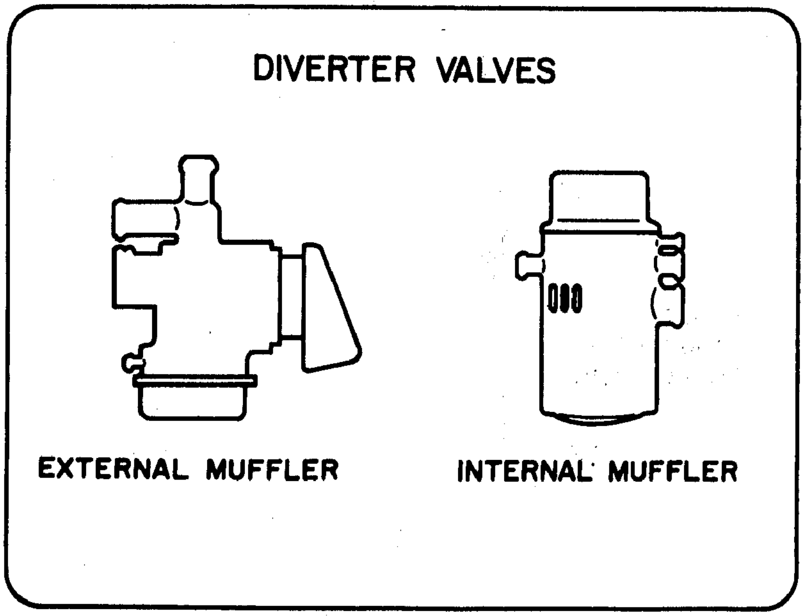


FIGURE 3-10

---

10. Most air pumps are equipped with a ________________ ____________ valve.

---

11. Maximum pump pressure is limited by the pressure relief valve. This is done to prevent exhaust system ______________________ at high speeds.

---

12. In order to prevent a ________________ in the exhaust system during deceleration, the AIR system uses a diverter valve.

---

13. The diverter valve is usually very noisy when it diverts air to the atmosphere. To prevent this noise a _______________ was installed.

GULP VALVE

Some manufacturers use another type of anti-backfire valve which is called a gulp valve. This valve allows air from the air pump to be sent to the intake manifold when the engine decelerates. This air will dilute the rich fuel mixture before it goes into the cylinder, thus preventing a backfire. Figure 3-11 shows a gulp valve.

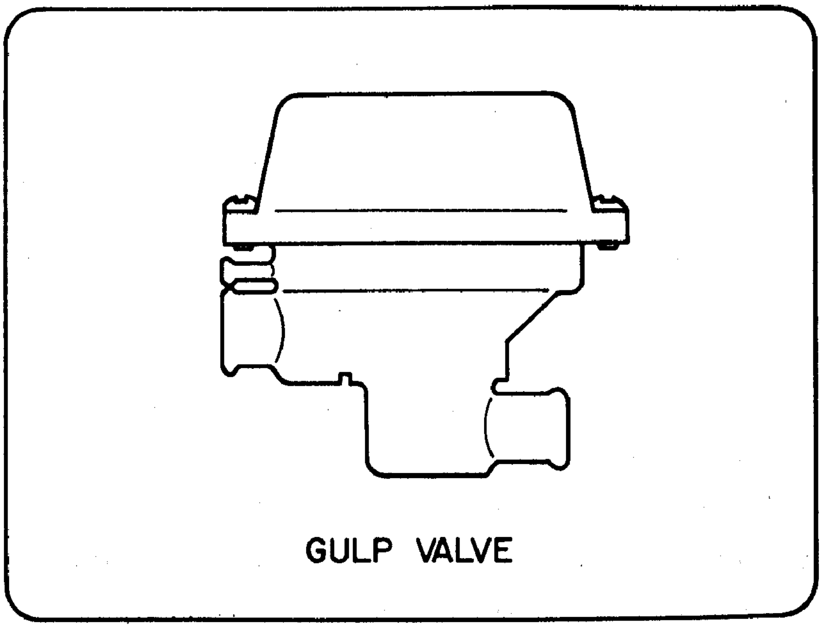


FIGURE 3-11

CHECK VALVE

The next component of the AIR system we shall discuss is the check valve. A check valve is used to prevent exhaust gases from reaching the hoses, pump or anti-backfire valve.

The air pump has enough pressure to keep the air flowing toward the air pipe assemblies. But what would happen if the pump stopped pumping air for some reason or if an air hose would break? Exhaust gases would go into the air pipe assembly instead of the tailpipe. It is the check valve's job to prevent this from occuring. The check valve prevents hot exhaust gases from backing up into the hoses and pump. A check valve is shown in figure 3-12. The check valve is a one-way valve. This means

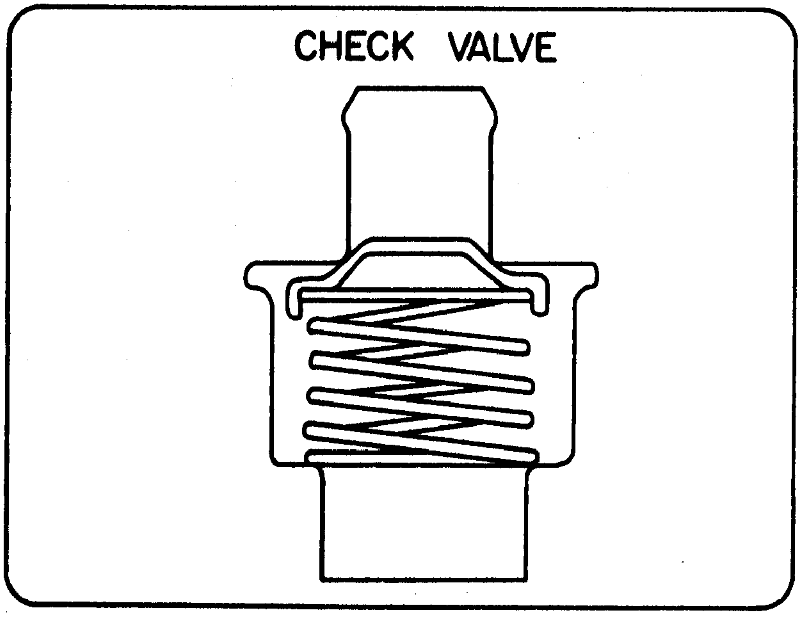


FIGURE 3-12

that it will permit air to flow in only one direction or one way. On an in-line engine there is only one check valve, because there is only one air injection manifold. There are two air injection manifolds on V8 engines and therefore two check valves. Check valves are usually mounted on the air injection manifold and connect to the diverter valve with a rubber hose.

---

14. The gulp valve used by some manufacturers diverts air from the air pump to the ____________ ________________ during the first few seconds of deceleration.

---

15. During the first few seconds of deceleration the gulp valve will dilute the rich fuel mixture before it goes into the cylinder, thus preventing a ______________.

16. When exhaust pressure is higher than the system air pressure, the __________ valve prevents the back flow of exhaust gas into the air supply hoses.

AIR INJECTION MANIFOLD

The last component of the AIR system we shall discuss is the air injection manifold. Some manufacturers call their injection manifold an air distribution manifold. The purpose of the air injection manifold is to distribute the pump air to the exhaust ports of each cylinder. As you can see in figure 3-13, only one manifold is used for an in-line engine.

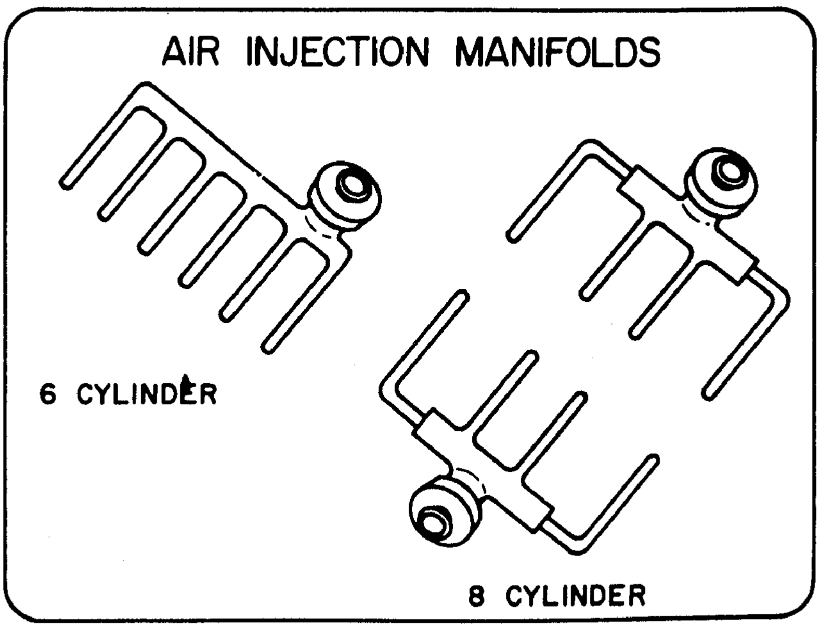


FIGURE 3-13

A V8 engine will use two injection manifolds. These manifolds usually have one outlet or nozzle for each cylinder. In some applications, however, this may not be the case. Because of design limitations some V8 engines have only seven nozzles. These nozzles are usually located very near the exhaust valves. Figure 3-14 shows the exhaust valve and air injection nozzle location usually found on an AIR equipped automobile.

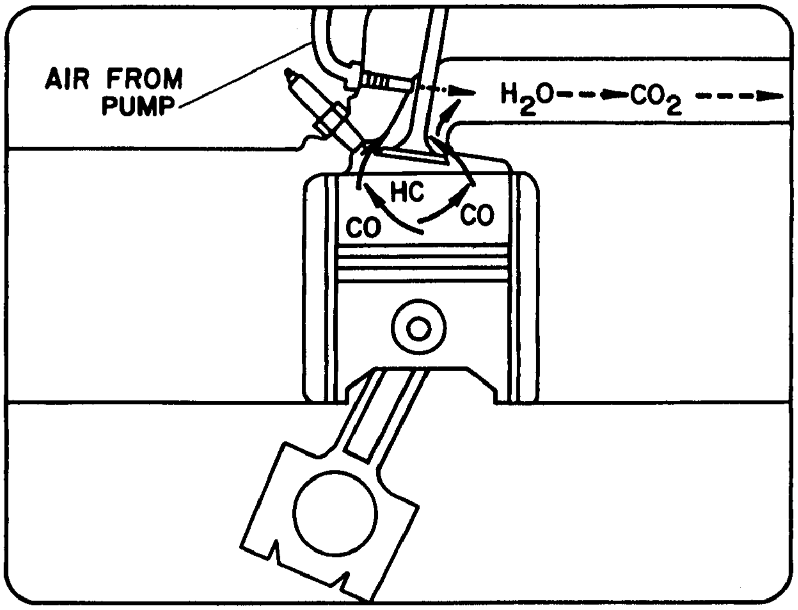


FIGURE 3-14

---

17. The air injection manifold distributes the pump air to the ______________ ports of each cylinder.

---

18. Some V8 engines have only __________ nozzles because of design limitations.

Now that you are familiar with all of the AIR system components it is time to take a closer look at how they function.

SYSTEM/COMPONENT FUNCTION

You will recall from the last section of this chapter that an AIR system has four basic components. These are the air pump, anti-backfire valve, check valve and the air injection manifold. Now we shall look more closely at each of these components so you can understand how they do their job.

AIR PUMP

As you remember the belt driven air pump supplies the system with air to be injected into the exhaust manifold. This pump is a rotary vane type pump. The air pump is made up of a pump housing, a rotor, and vanes. Most air pumps have between 2 and 5 vanes. Figure 3-15 shows a simplified view of the inside of the air pump. After the air is filtered to remove

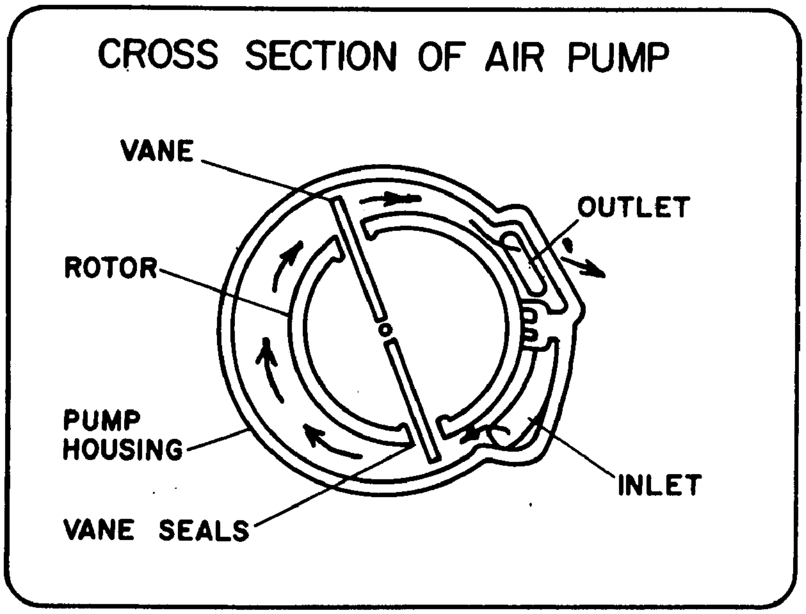


FIGURE 3-15

any dirt or dust it enters the inlet of the pump. As the vanes move around the pump housing they pull air through the inlet and push it out through the outlet. The arrows in figure 3-15 show the flow direction of air through the pump.

PRESSURE RELIEF VALVE

A spring loaded valve is used as a pressure relief valve on those air pumps which have a built-in relief valve. As you recall, maximum pump pressure must be limited to prevent exhaust system overheating at high engine speeds. When pressure in the pump exceeds a maximum pressure level the relief valve spring will be compressed, opening the valve. With this condition the excess air will pass through the valve to the atmosphere. When the pump pressure drops back to a safe level the relief valve will close and the pump will operate normally again.

---

19. Maximum pump pressure is limited by the pressure relief valve to prevent exhaust system overheating at ________ engine speeds.

---

20. When pump pressure exceeds its preset maximum pressure level, the relief valve will vent the excess pressure to the ____________________.

DIVERTER VALVE

The purpose of the diverter or anti-backfire valve is to divert pump air to the atmosphere during the first few seconds of engine deceleration. Now let's see how this valve accomplishes this. A combination diverter and pressure regulator valve is shown in figure 3-16. This diverter valve is made up of two valve plates, a spring loaded stem, a diaphragm and a diaphragm spring. The diverter valve has an inlet connection for the air supply from the pump, an outlet for air to reach the injection manifold, and a signal line from the intake manifold. This manifold vacuum line provides the signal which tells the diverter valve when to "dump" its air to the atmosphere.

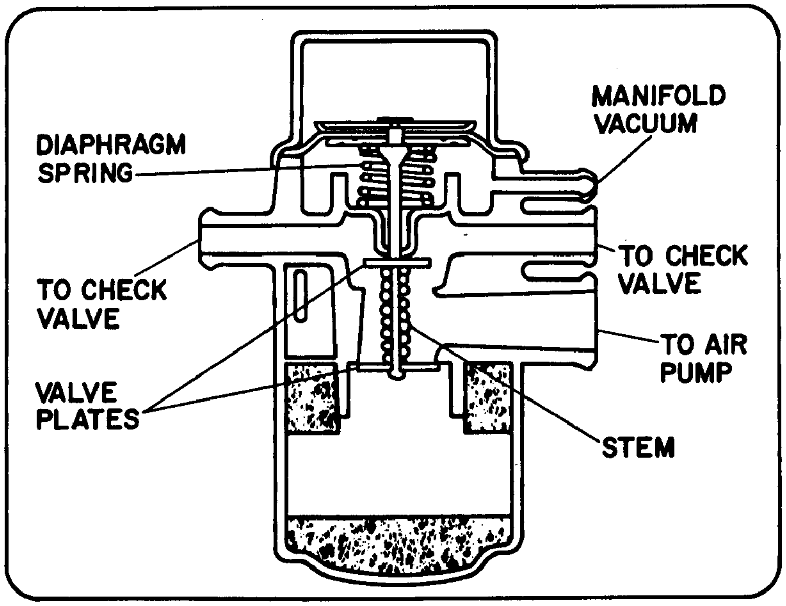


FIGURE 3-16

When the engine is operating vacuum will be applied to both the upper and lower sides of the diaphragm. This is accomplished by the use of a timing orifice located in the diaphragm itself. Figure 3-17 shows the location of this orifice. In this position the diaphragm spring will raise the stem and unseat the upper valve plate. When the diverter valve

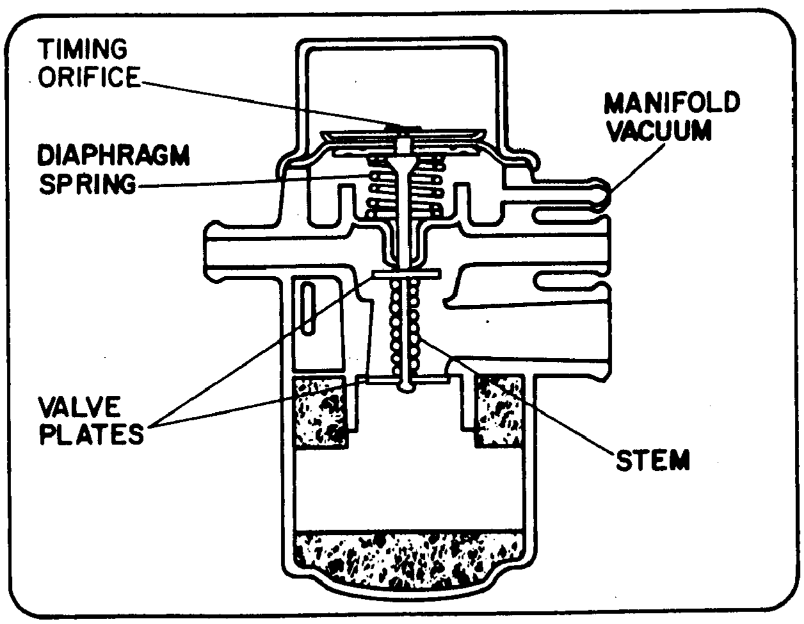


FIGURE 3-17

is operating in this manner, air will flow from the valve inlet past the upper valve plate and out through the valve outlet. This flow of air through the diverter valve is shown in figure 3-18.

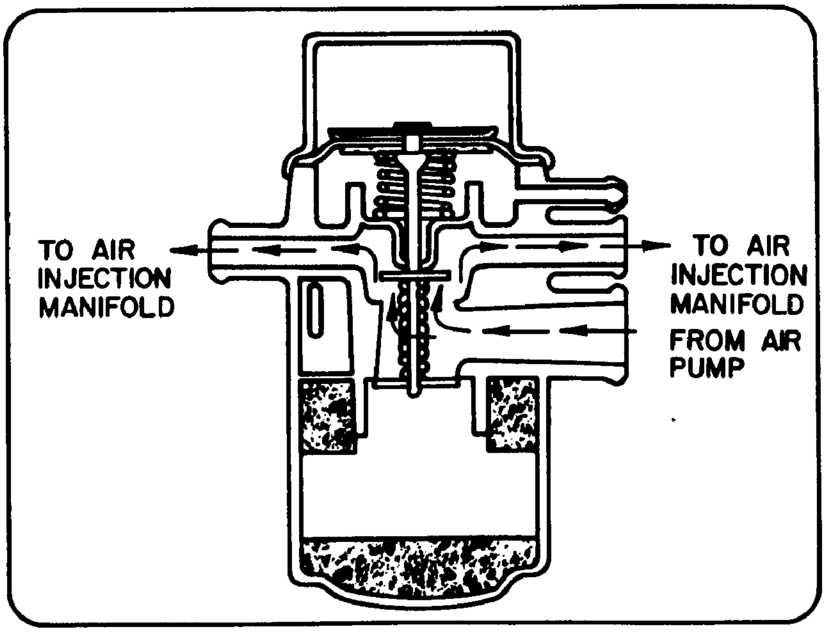


FIGURE 3-18

A high intake manifold vacuum will result when the carburetor throttle plates close during deceleration. This high vacuum condition will act on the diaphragm in the diverter valve pulling it downward. The diaphragm spring will compress, thus moving the stem downward. When this happens the lower valve plate will be unseated and the air will be diverted through a muffler to the atmosphere. Figure 3-19 shows how the air will flow through the diverter valve when it is in the dump position.

Since the diaphragm has a timing orifice built into it which connects the upper and lower sides of the diaphragm the unequal vacuum conditions will stabilize. When the vacuum on both sides of the diaphragm becomes equal the diaphragm spring will push the stem up again and unseat the upper valve plate. When this happens the air will again flow to the injection manifold(s). This equalizing of the two vacuum chambers will usually take approximately 2 to 3 seconds. Thus the air will only be diverted to the atmosphere for the first few seconds of deceleration when the excessively rich mixture is liable to cause a backfire.

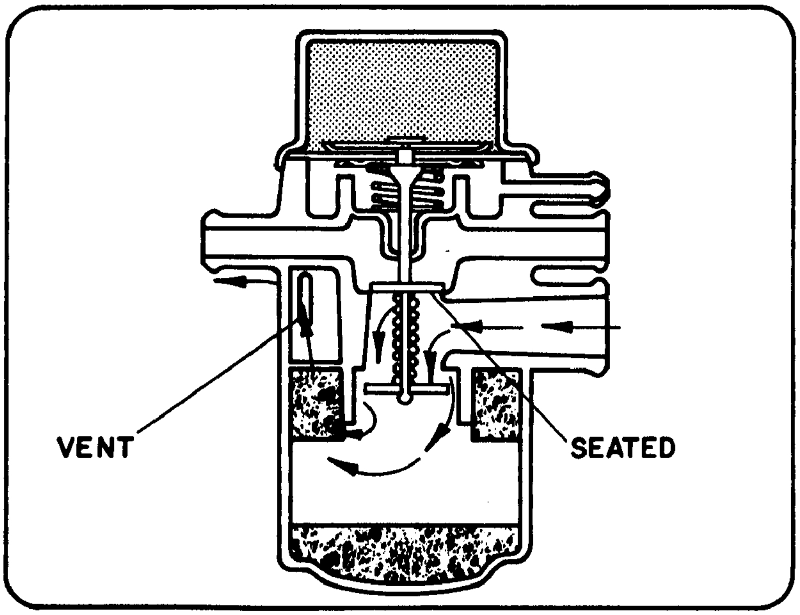


FIGURE 3-19

When the engine is turning at a high RPM excessive pump pressure will be produced. It is the diverter pressure regulator valve's job to limit this pressure. As you can see in figure 3-20, when the excessive pump pressure acts upon the diverter pressure regulator valve, the lower valve

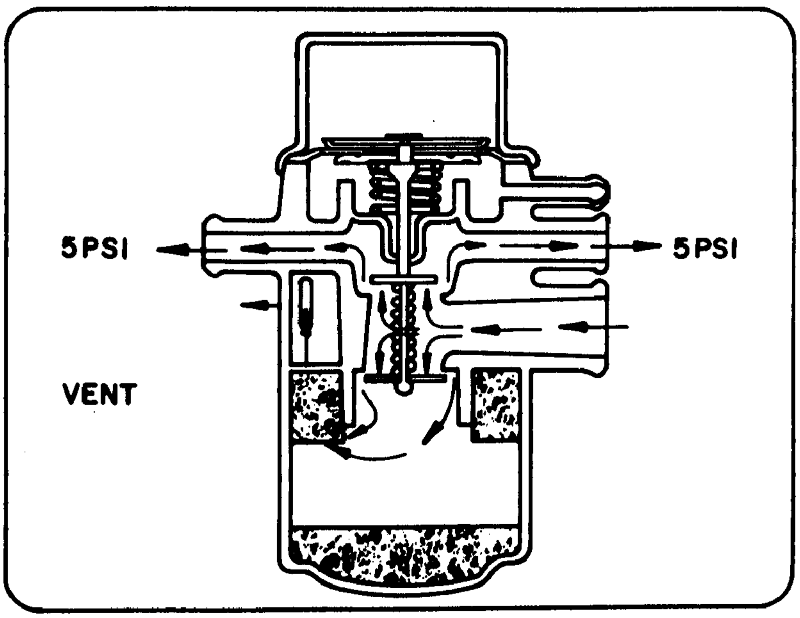


FIGURE 3-20

plate will unseat. This will vent pump air to the atmosphere to hold the pressure to a pre-determined maximum.

---

21. The purpose of the anti-backfire valve is to divert pump air to the atmosphere during the first few seconds of engine ______________________.

---

22. The vacuum signal which tells the diverter valve when to "dump" its air to the ____________________ is provided by the intake manifold.

---

23. The unequal vacuum conditions created in the diverter valve diaphragm chambers will equalize through the built-in ____________ ______________ during deceleration.

---

24. When the vacuum on both sides of the diverter valve diaphragm becomes equal the air will again flow to the _____________ __________.

---

25. It usually takes approximately two to three ____________ for the two vacuum chambers in the diverter valve to equalize.

GULP VALVE

This second type of anti-backfire valve is known as a gulp valve. As you can see in figure 3-21, this valve is teed into the supply line between the air pump and the injection manifold. In order to prevent backfire on deceleration the gulp valve diverts pump air to the intake manifold.

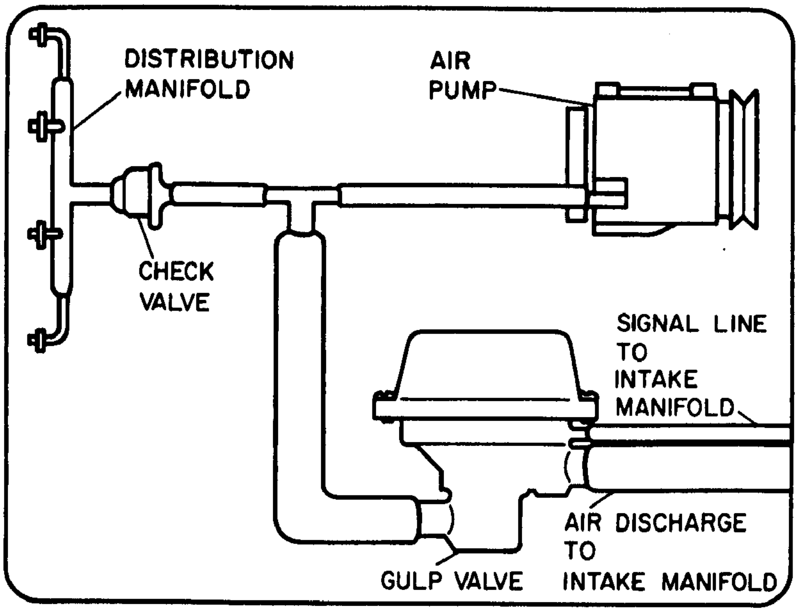


FIGURE 3-21

Figure 3-22 shows an inside view of the gulp valve. You will notice that the upper diaphragm chamber and valve stem are much the same as the

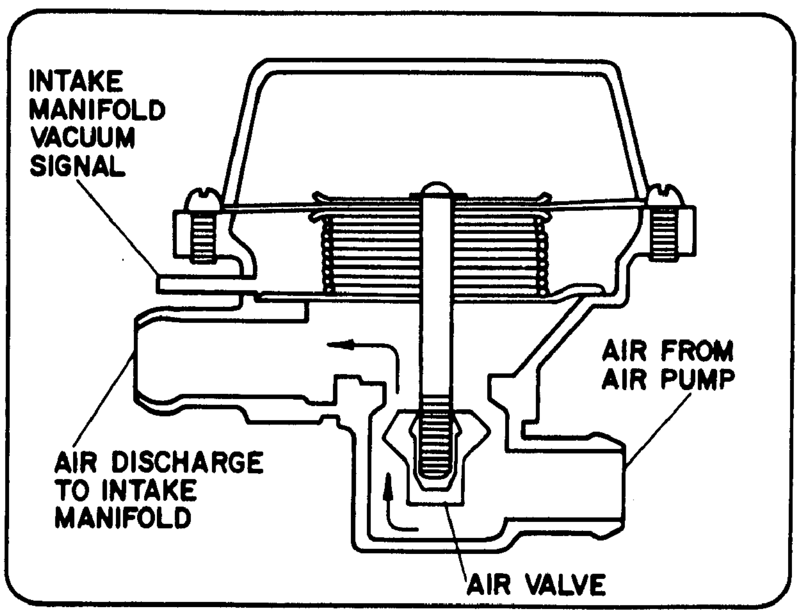


FIGURE 3-22

diverter valve. An intake manifold vacuum signal is used to dump the gulp valve in the same manner as the diverter valve. When a high intake manifold vacuum occurs the diaphragm will be pulled down against spring force. This will open the valve and pump air will pass through the gulp valve to the intake manifold. A small timing orifice in the diaphragm will slowly equalize the vacuum on both sides of the diaphragm returning the valve to a closed position. This will take only a few seconds as does a diverter valve. After the gulp valve closes the air will again flow to the injection manifold.

CHECK VALVE

The check valve which is usually mounted on the air injection manifold is a one-way valve. This valve will allow air to pass from the pump side to the injection manifold side. It will not allow air flow from the injection manifold side to the air pump side.

This valve, as you can see in figure 3-23, is a simple spring loaded device. When the air pump pressure exceeds the exhaust system pressure

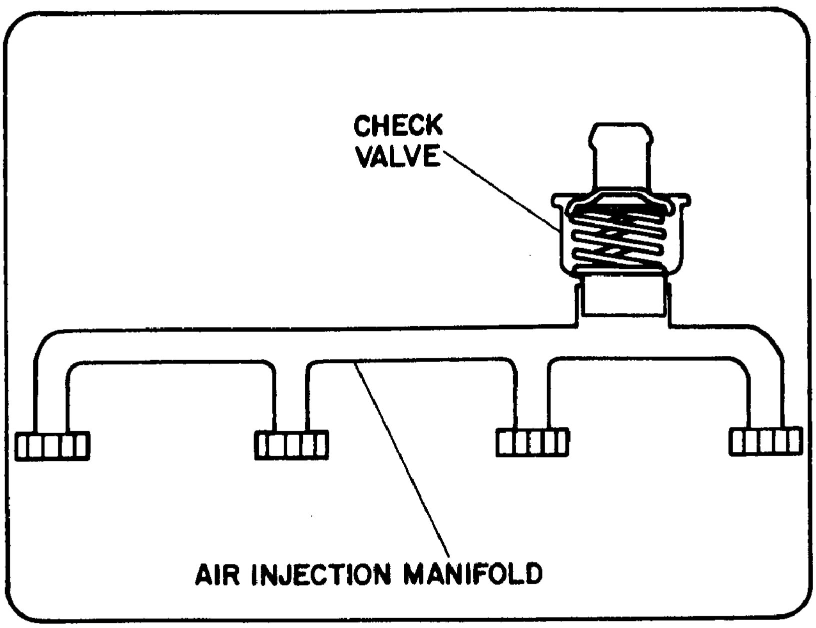


FIGURE 3-23

the air will flow through the check valve as shown in figure 3-24. The check valve spring will be compressed and the air will flow around the

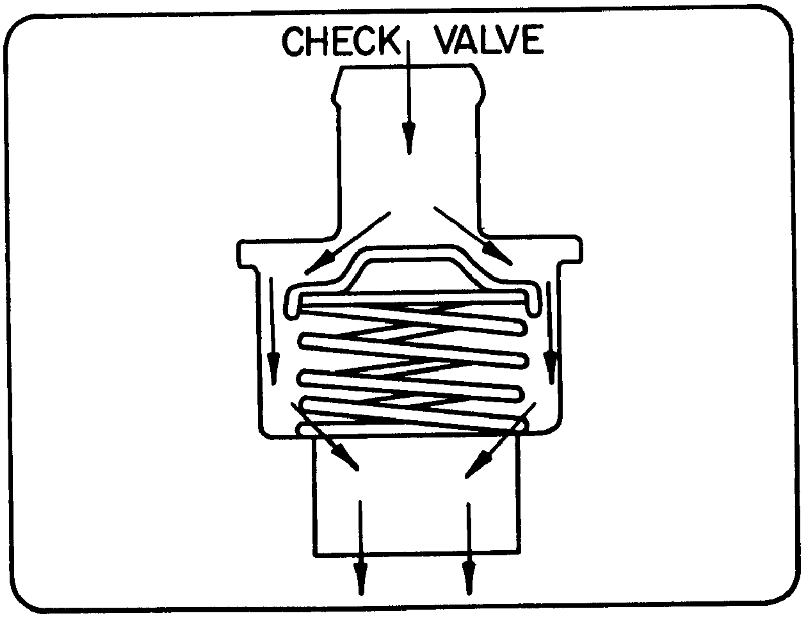


FIGURE 3-24

valve plate and through the valve to the air injection manifold. If for any reason the exhaust system pressure is greater than the air pump pressure the valve plate will seat preventing flow through the valve. This condition is shown in figure 3-25.

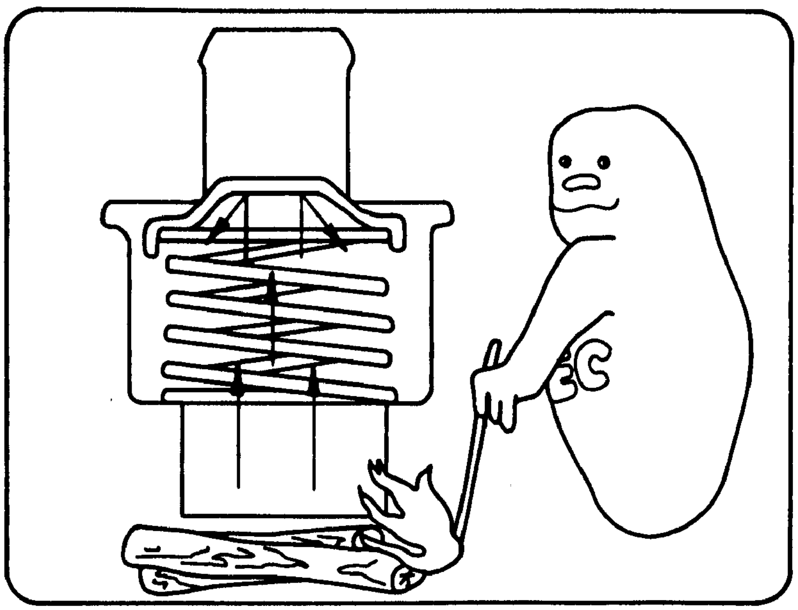


FIGURE 3-25

26. Another type of anti-backfire valve is known as a ________ valve.

27. Gulp valves are teed into the supply line between the __________ ______________ and the air pump.

28. The gulp valve diverts pump air to the __________ ______________ to prevent backfire on deceleration.

29. Usually mounted on the injection manifold is a check valve. A check valve will allow flow in _____ direction.

30. The check valve used in the AIR system will allow air to pass through it from the _______ side to the injection manifold side.

AIR INJECTION MANIFOLD

As you recall the purpose of the air injection or distribution manifold is to distribute the pump air to each cylinder. This manifold is made of tubing with the cylinder nozzles all connected to a common line. With this arrangement all the cylinders will receive air. Some engines may have passageways cut in the cylinder head instead of using an injection manifold. These passageways distribute and inject air in the same manner as an injection manifold.

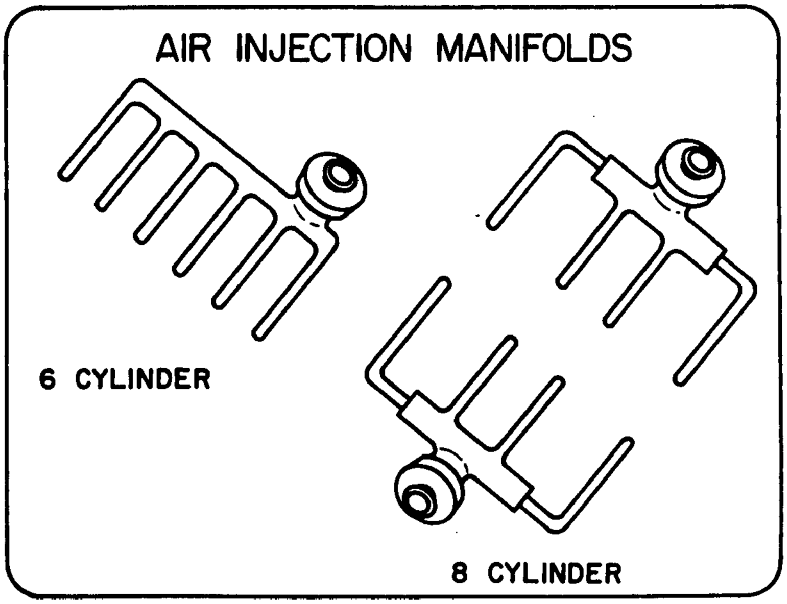


FIGURE 3-26

---

31. To complete the AIR system the air pump, diverter valve, check valve, and ________________ manifold are connected with hoses and pipes.

Now you should understand the AIR system. It is now time to look at the maintenance procedures required to keep this system operating properly.

SYSTEM INSPECTION

An inspection of the AIR system should be made periodically and previous to any testing of the system. This inspection will require only simple tools and takes only a few minutes. Many problems may be avoided or corrected by these steps.

1. Check to see that all components are properly installed on the engine and no modifications have been made. Air pump, drive belt, anti-backfire valve, check valve, manifold and all connecting hoses should be in place.

   In order for the AIR system to function as it was designed all components must be installed correctly.

2. Inspect the air inlet filter if the system is so equipped. If the filter is excessively dirty it should be replaced.

   If the air inlet filter is dirty the air supply for the pump may be restricted. This will result in reduced effectiveness of the entire system.

3. The air pump drive belt should be inspected for excessive wear. If the belt condition is unacceptable it should be replaced. In addition, this belt must be tightened according to manufacturer's specifications.

   If the drive belt is worn or too loose, the pump efficiency will be reduced and the effectiveness of the entire system will suffer.

4. Check the system connecting hoses for cracks, deterioration and loose connections.

Any air leaks in the system will reduce the AIR system's effectiveness. In addition, if air leaks into the anti-backfire valve's signal line, a backfire condition on deceleration may occur.

---

32. The AIR system should be inspected periodically and before ______________ the system.

---

33. All ____________________ of the AIR system must be installed correctly in order for the system to function as it was designed.

SYSTEM TESTING

The AIR system should be tested periodically or anytime it is suspected to be working improperly. The components of the AIR system which require testing are the air pump, anti-backfire valve and the check valve(s).

AIR PUMP TEST

Manufacturer's specifications should be consulted when testing the air pump as with all other test procedures. Figure 3-27 shows the procedure recommended by one manufacturer. They recommended the pump be tested

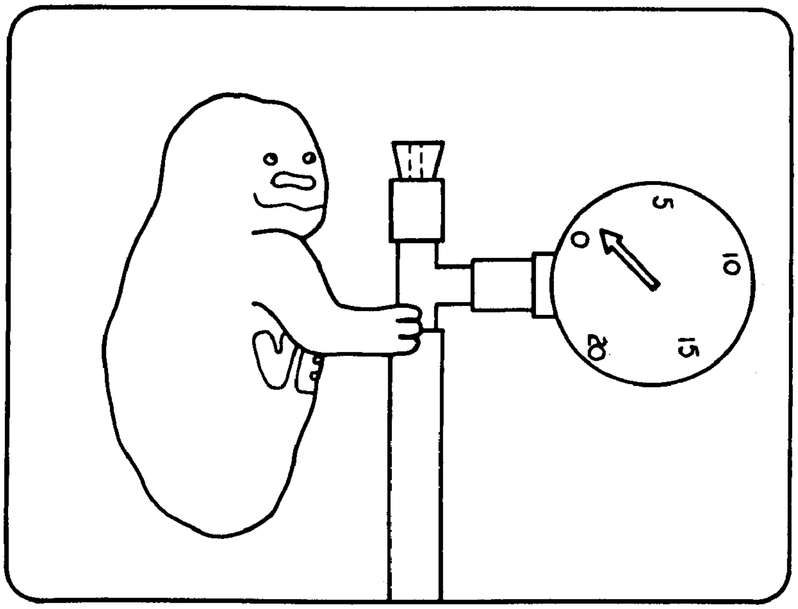


FIGURE 3-27

using a special test tee and pressure gauge connected into the outlet hose of the pump. The pump air pressure is then measured at a specified engine speed.

GULP VALVE TEST

The anti-backfire valve must also be tested to see that it is operating correctly. The gulp valve, if used, can be tested as shown in figure 3-28. With the engine idling the by-pass hose should be pinched shut somewhere between the valve and the intake manifold. If the valve is operating properly the idle RPM should not change. Now the vacuum signal line should

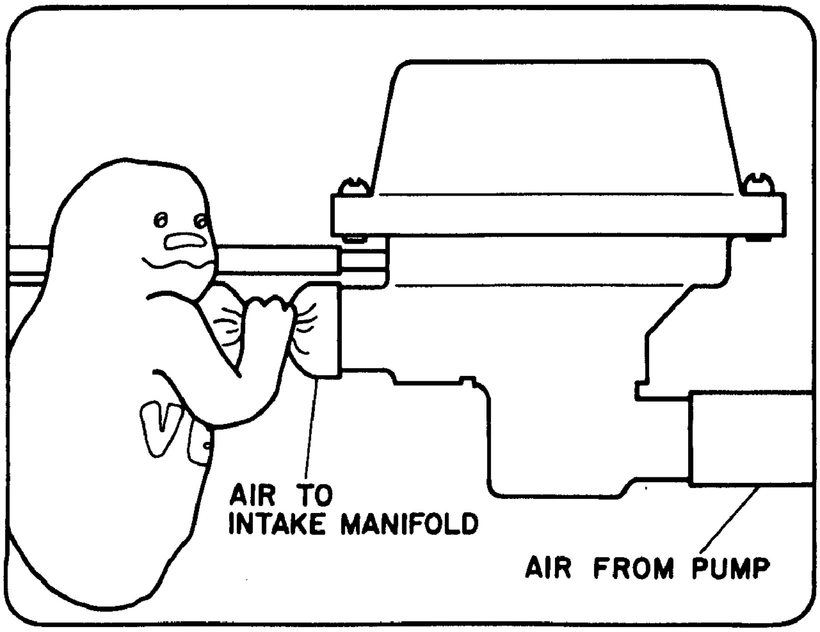


FIGURE 3-28

be removed for about 5 seconds, then replaced. If the gulp valve is operating correctly, the engine will run rough for about 1-3 seconds. Always check the manufacturer's specifications before conducting this test. On certain foreign models you will damage the air pump by pinching the hose shut.

DIVERTER VALVE TEST

Figure 3-29 shows the first step to testing the diverter type anti-backfire

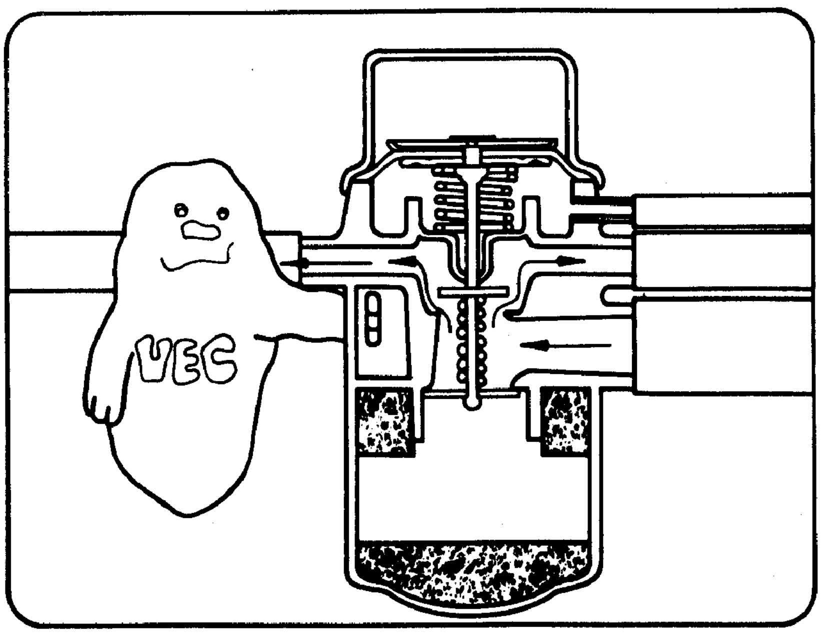


FIGURE 3-29

valve. With the engine idling, hold your fingers by the vent port. No air should be felt escaping from the vent. The engine should then be sped up to produce excessive pump pressure. As shown in figure 3-30, some air should be felt escaping from the combination pressure regulator

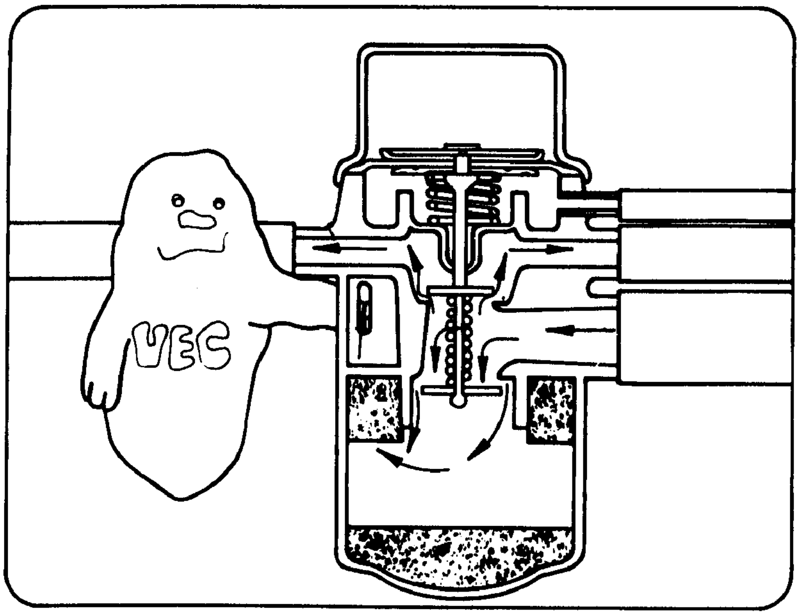


FIGURE 3-30

diverter valve or the pump relief valve. When the engine is decelerated from the high engine speed hold your fingers by the diverter valve vent. As you can see in figure 3-31, you should feel all the air from the pump

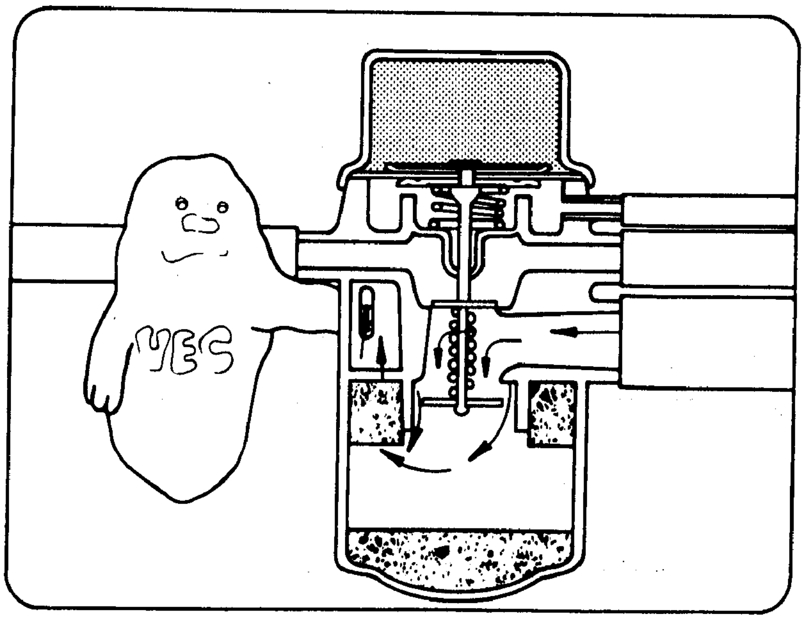


FIGURE 3-31

being vented for 1 to 3 seconds. If the valve fails to operate properly, you should check the vacuum signal line before replacing the valve. Figure 3-32 shows that manifold vacuum should be present in this line.

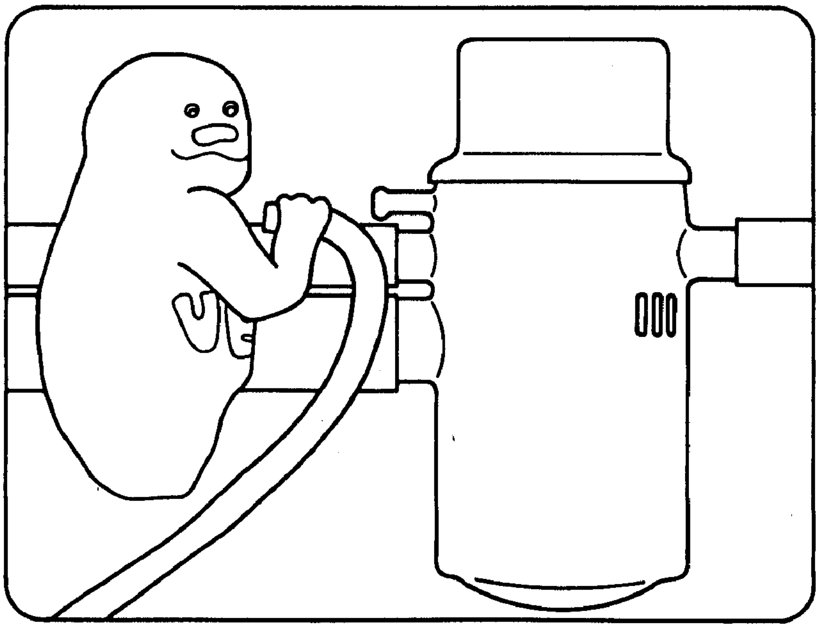


FIGURE 3-32

CHECK VALVE TEST

The last component to be tested in the AIR system is the check valve. To test the check valve you must first remove the air supply hose from

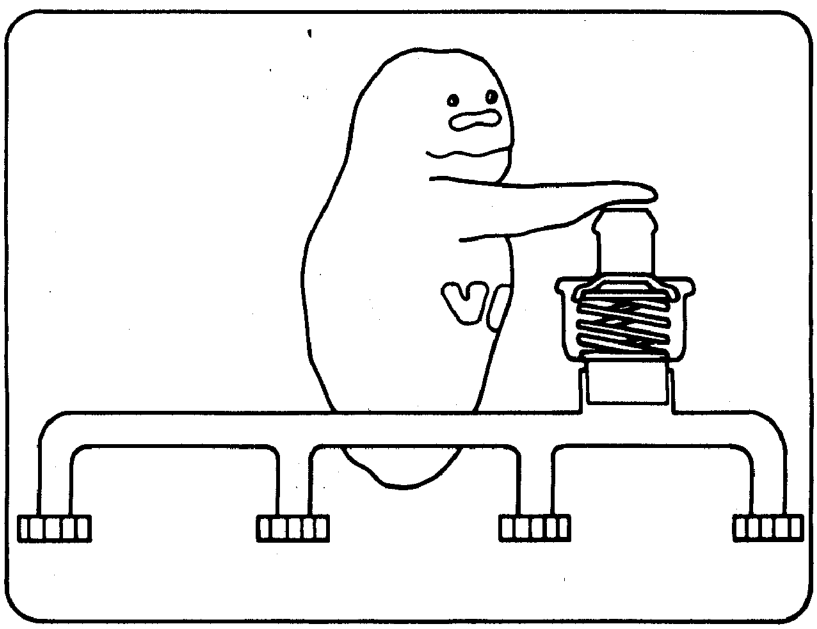


FIGURE 3-33

the check valve. With the engine running, carefully hold your hand over the check valve and feel for any leakage. There should be no exhaust escaping from the check valve. The engine should now be shut off and a simple test made to assure that the check valve is not stuck closed. As you can see in figure 3-34, when you push down on the check valve with a screwdriver or solid rod the valve plate should move freely.

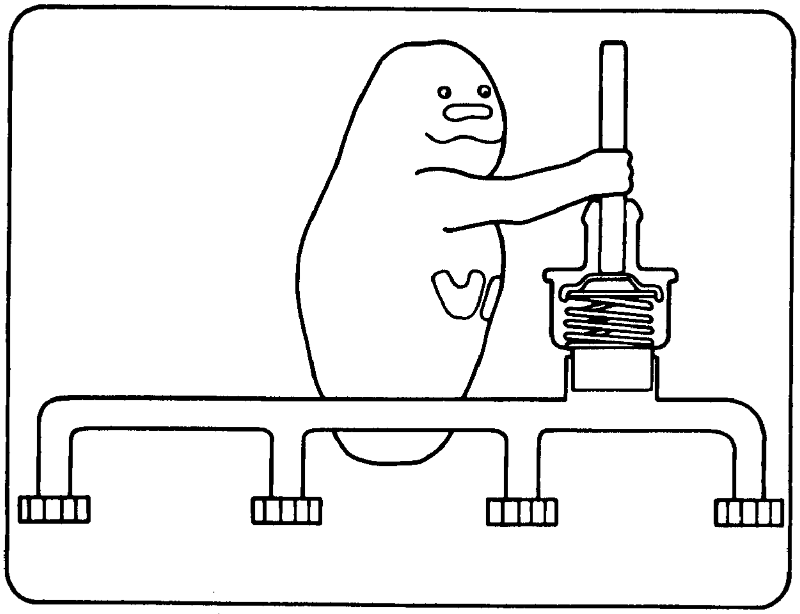


FIGURE 3-34

Lastly to test for leaks with the engine operating, use soap and water on a brush while watching for bubbles at the connections.

After you have performed these tests you will be sure that the AIR system is operating properly and helping to keep our air clean.

---

34. One test which should be done to the diverter valve is to decelerate the engine from a high speed while holding your fingers by the ________________ __________ vent. As the engine slows down you should feel all the air from the pump being vented for only 1 to 3 seconds.

---

35. When testing a check valve you should push down on the check valve with a screwdriver or solid rod. The __________ __________ should move freely.

SYSTEM SUMMARY

PURPOSE

The purpose of the air injection system is to supply additional oxygen (air) at the exhaust ports near the exhaust valves to extend the combustion process into the exhaust system. This reduces the unburned hydrocarbon and carbon monoxide emissions.

MAIN COMPONENTS

Air Pump - Supplies filtered low pressure air to the system.

Diverter Valve - Diverts air pump output to atmosphere during deceleration to prevent backfire and has a built-in pressure relief valve to protect the system.

Check Valve - Prevents hot exhaust gases from backing up into the hoses and pump.

Air Manifold - Distributes air to each cylinder.

Air Nozzles - Injects air to each exhaust passage near the exhaust valves.

Manifold Vacuum Signal Line - Senses manifold vacuum to actuate the diverter valve.

SYSTEM FUNCTION

During normal operating conditions the air pump supplies air to the diverter valve which then passes the air on to the air nozzles for injection into the exhaust manifold. There the hot exhausted gases receive the fresh oxygen charge and undergo further combustion. During deceleration there is high intake manifold vacuum and an excessively rich fuel mixture. If fresh oxygen were supplied to these exhaust gases, reignition and engine backfire could result. The diverted valve senses the high intake manifold vacuum and vents air from the pump to the atmosphere.

ANSWERS

1. air
2. exhaust manifold
3. air injection reaction
4. combustion
5. hydrocarbons, carbon monoxide
6. carburetion
7. air pump
8. air filter
9. belt
10. pressure relief
11. overheating
12. backfire
13. muffler
14. intake manifold
15. backfire
16. check
17. exhaust
18. seven
19. high
20. atmosphere
21. deceleration
22. atmosphere
23. timing orifice
24. injection manifold or exhaust ports
25. seconds
26. gulp
27. injection or distribution manifold
28. intake manifold
29. one
30. pump
31. injection or distribution
32. testing
33. components
34. diverter valve
35. valve plate

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-450/3-77-038	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Motor Vehicle Emissions Control - Book Three Air Injection Reaction Systems		5. REPORT DATE November 1977 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) B.D. Hayes R.A. Ragazzi M.T. Maness R.A. Barrett		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Industrial Sciences Colorado State University Fort Collins, Colorado 80523		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. T008135-01-0 T900621-01-0
12. SPONSORING AGENCY NAME AND ADDRESS Control Programs Development Division Office of Air Quality Planning and Standards Office of Air and Waste Management U.S. Environmental Protection Agency Research Triangle Park, North Carolina 27711		13. TYPE OF REPORT AND PERIOD COVERED Final Report 14. SPONSORING AGENCY CODE EPA 200/04

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This book is one of a series designed specifically to teach the concepts of automobile emissions control systems. It is intended to assist the practicing mechanic or the home mechanic to better understand the Air Injection Reaction Systems which are an integral part of automobiles today. The mechanic's increased knowledge should help him keep "emissions controlled" vehicles operating as designed. Respectable fuel economy, performance and driveability, as well as cleaner air, can be obtained from the automobile engine that has all of its emissions systems functioning properly.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution	Carbon Monoxide		
Air Injection Reaction Systems	Oxides of Nitrogen		
Photochemical	Carburetion		
Intake Manifold	Combustion		
Exhaust Manifold	Backfire		
System Inspector	Muffler		
Hydrocarbons	Exhaust		
	Deceleration		

18. DISTRIBUTION STATEMENT Release Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 52
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE