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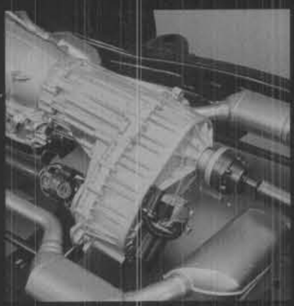
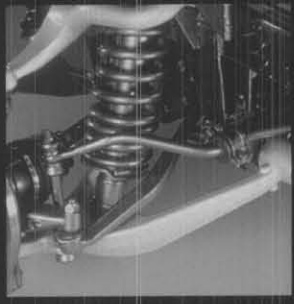
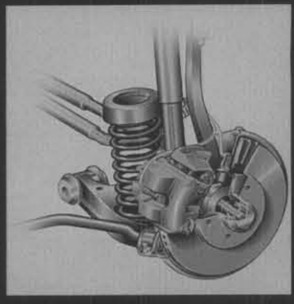
X1 Exhaust Systems







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Taking an ASE Certification Test

This study guide will help prepare you to take and pass the ASE test. It contains descriptions of the types of questions used on the test, the task list from which the test questions are derived, a review of the task list subject information, and a practice test containing ASE style questions.

ABOUT ASE

The National Institute for Automotive Service Excellence (ASE) is a non-profit organization founded in 1972 for the purpose of improving the quality of automotive service and repair through the voluntary testing and certification of automotive technicians. Currently, there are over 400,000 professional technicians certified by ASE in over 40 different specialist areas.

ASE certification recognizes your knowledge and experience, and since it is voluntary, taking and passing an ASE certification test also demonstrates to employers and customers your commitment to your profession. It can mean better compensation and increased employment opportunities as well.

ASE not only certifies technician competency, it also promotes the benefits of technician certification to the motoring public. Repair shops that employ at least one ASE technician can display the ASE sign. Establishments where 75 percent of technicians are certified, with at least one technician certified in each area of service offered by the business, are eligible for the ASE Blue Seal of Excellence program. ASE encourages consumers to patronize these shops through media campaigns and car care clinics.

To become ASE certified, you must pass at least one ASE exam and have at least two years of related work experience. Technicians that pass specified tests in a series earn Master Technician status. Your certification is valid for five years, after which time you must retest to retain certification, demonstrating that you have kept up with the changing technology in the field.

THE ASE TEST

An ASE test consists of forty to eighty multiple-choice questions. Test questions are written by a panel of technical experts from vehicle, parts and equipment manufacturers, as well as working technicians and technical education instructors. All questions have been pre-tested and quality checked on a national sample of technicians. The questions are derived from information presented in the task list, which details the knowledge that a technician must have to pass an ASE test and be recognized as competent in that category. The task list is periodically updated by

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X1 - EXHAUST SYSTEMS

ASE in response to changes in vehicle technology and repair techniques.

There are five types of questions on an ASE test:

- **Direct, or Completion**
- **MOST Likely**
- **Technician A and Technician B**
- **EXCEPT**
- **LEAST Likely**

Direct, or Completion

This type of question is the kind that is most familiar to anyone who has taken a multiple-choice test: you must answer a direct question or complete a statement with the correct answer. There are four choices given as potential answers, but only one is correct. Sometimes the correct answer to one of these questions is clear, however in other cases more than one answer may seem to be correct. In that case, read the question carefully and choose the answer that is most correct. Here is an example of this type of test question:

A compression test shows that one cylinder is too low. A leakage test on that cylinder shows that there is excessive leakage. During the test, air could be heard coming from the tailpipe. Which of the following could be the cause?

A. broken piston rings
B. bad head gasket
C. bad exhaust gasket
D. an exhaust valve not seating

There is only one correct answer to this question, answer D. If an exhaust valve is not seated, air will leak from the combustion chamber by way of the valve out to the tailpipe and make an audible sound. Answer C is wrong because an exhaust gasket has nothing to do with combustion chamber sealing. Answers A and B are wrong because broken rings or a bad head gasket would have air leaking through the oil filler or coolant system.

MOST Likely

This type of question is similar to a direct question but it can be more challenging because all or some of the answers may be nearly correct. However, only one answer is the most correct. For example:

When a cylinder head with an overhead camshaft is discovered to be warped, which of the following is the most correct repair option?

A. replace the head
B. check for cracks, straighten the head, surface the head
C. surface the head, then straighten it
D. straighten the head, surface the head, check for cracks

The most correct answer is B. It makes no sense to perform repairs on a cylinder head that might not be usable. The head should first be checked for warpage and cracks. Therefore, answer B is more correct than answer D. The head could certainly be replaced, but the cost factor may be prohibitive and availability may be limited, so answer B is more correct than answer A. If the top of the head is warped enough to interfere with cam bore alignment and/or restrict free movement of the camshaft, the head must be straightened before it is resurfaced, so answer C is wrong.

Technician A and Technician B

These questions are the kind most commonly associated with the ASE test. With these questions you are asked to choose which technician statement is correct, or whether they both are correct or incorrect. This type of question can be difficult because very often you may find one technician's statement to be clearly correct or incorrect while the other may not be so obvious. Do you choose one technician or both? The key to answering these questions is to carefully examine each technician's statement independently and judge it on its own merit. Here is an example of this type of question:

A vehicle equipped with rack-and-pinion steering is having the front end inspected. Technician A says that the inner tie rod ends should be inspected while in their normal running position. Technician B says that if movement is felt between the tie rod stud and the socket while the tire is moved in and out, the inner tie rod should be replaced. Who is correct?

A. Technician A
B. Technician B
C. Both A and B
D. Neither A or B

The correct answer is C; both technicians' statements are correct. Technician B is clearly correct because any play felt between the tie-rod stud and the socket while the tire is moved in and out indicates that the assembly is worn and requires replacement. However, Technician A is also correct because inner tie- rods should be inspected while in their normal running position, to prevent binding that may occur when the suspension *is allowed* to hang free.

EXCEPT

This kind of question is sometimes called a negative question because you are asked to give the incorrect answer. All of the possible answers given are correct EXCEPT one. In effect, the correct answer to the question is the one that is wrong. The word EXCEPT is always capitalized in these questions. For example:

All of the following are true of torsion bars **EXCEPT**:

A. They can be mounted longitudinally or transversely.
B. They serve the same function as coil springs.
C. They are interchangeable from side-to-side
D. They can be used to adjust vehicle ride height.

The correct answer is C. Torsion bars are not normally interchangeable from side-to-side. This is because the direction of the twisting or torsion is not the same on the left and right sides. All of the other answers contain true statements regarding torsion bars.

LEAST Likely

This type of question is similar to EXCEPT in that once again you are asked to give the answer that is wrong. For example:

Blue-gray smoke comes from the exhaust of a vehicle during deceleration. Of the following, which cause is **LEAST** likely?
A. worn valve guides
B. broken valve seals
C. worn piston rings
D. clogged oil return passages

The correct answer is C. Worn piston rings will usually make an engine smoke worse under acceleration. All of the other causes can allow oil to be drawn through the valve guides under the high intake vacuum that occurs during deceleration.

PREPARING FOR THE ASE TEST

Begin preparing for the test by reading the task list. The task list describes the actual work performed by a technician in a particular specialty area. Each question on an ASE test is derived from a task or set of tasks in the list. Familiarizing yourself with the task list will help you to concentrate on the areas where you need to study.

The text section of this study guide contains information pertaining to each of the tasks in the task list. Reviewing this information will prepare you to take the practice test.

Take the practice test and compare your answers with the correct answer explanations. If you get an answer wrong and don't understand why, go back and read the information pertaining to that question in the text.

After reviewing the tasks and the subject information and taking the practice test, you should be prepared to take the ASE test or be aware of areas where further study is needed. When studying with this study guide or any other source of information, use the following guidelines to make sure the time spent is as productive as possible:

- Concentrate on the subject areas where you are weakest.
- Arrange your schedule to allow specific times for studying.
- Study in an area where you will not be distracted.
- Don't try to study after a full meal or when you are tired.
- Don't wait until the last minute and try to 'cram' for the test.

REGISTERING FOR ASE COMPUTER-BASED TESTING

Registration for the ASE CBT tests can be done online in myASE or over the phone. While not mandatory, it is recommended that you establish a myASE account on the ASE website (www.ase.com). This can be a big help in managing the ASE certification process, as your test scores and certification expiry dates are all listed there.

Test times are available during two-month windows with a one-month break in between. This means that there is a total of eight months over the period of the calendar year that ASE testing is available.

Testing can be scheduled during the daytime, night, and weekends for maximum flexibility. Also, results are available immediately after test completion. Printed certificates are mailed at the end of the two-month test window. If you fail a test, you will not be allowed to register for the same test until the next two-month test window.

TAKING THE ASE TEST – COMPUTER-BASED TESTING (CBT)

On test day, bring some form of photo identification with you and be sure to arrive at the test center 30 minutes early to give sufficient time to check in. Once you have checked in, the test supervisor will issue you some scratch paper and pencils, as well as a composite vehicle test booklet if you are taking advanced tests. You will then be seated at a computer station and given a short online tutorial on how to complete the ASE CBT tests. You may skip the tutorial if you are already familiar with the CBT process.

The test question format is similar to those found in written ASE tests. Regular certification tests have a time limit of 1 to 2 hours, depending on the test. Recertification tests are 30 to 45 minutes, and the L1 and L2 advanced level tests are capped at 2 hours. The time remaining for your test is displayed on the top left of the test window. You are given a warning when you have 5 minutes left to complete the test.

Read through each question carefully. If you don't know the answer to a question and need to think about it, click on the "Flag" button and move on to the next question. You may also go back to previous questions by pressing the "Previous Question" button. Don't spend too much time on any one question. After you have worked through to the end of the test, check your remaining time and go back and answer the questions you flagged. Very often, information found in questions later in the test can help answer some of the ones with which you had difficulty.

Some questions may have more content than what can fit on one screen. If this is the case, there will be a "More" button displayed where the "Next Question" button would ordinarily appear. A scrolling bar will also appear, showing what part of the question you are currently viewing. Once you have viewed all of the related content for the question, the "Next Question" button will reappear.

You can change answers on any of the questions before submitting the test for scoring. At the end of the examination, you will be shown a table with all of the question numbers. This table will show which questions are answered, which are unanswered, and which have been flagged for review. You will be given the option to review all the questions, review the flagged questions, or review the unanswered questions from this page. This table can be reviewed at any time during the exam by clicking the "Review" button.

If you are running out of time and still have unanswered test questions, guess the answers if necessary to make sure every question is answered. Do not leave any answers blank. It is to your advantage to answer every question, because your test score is based on the number of correct answers. A guessed answer could be correct, but a blank answer can never be.

Once you are satisfied that all of the questions are complete and ready for scoring, click the "Submit for Scoring" button. If you are scheduled for more than one test, the next test will begin immediately. If you are done with testing, you will be asked to complete a short survey regarding the CBT test experience. As you are leaving the test center, your supervisor will give you a copy of your test results. Your scores will also be available on myASE within two business days.

To learn exactly where and when the ASE Certification Tests are available in your area, as well as the costs involved in becoming ASE certified, please contact ASE directly for registration information.

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Exhaust Systems

TEST SPECIFICATIONS FOR EXHAUST SYSTEMS (TEST X1)

CONTENT AREA		NUMBER OF QUESTIONS IN ASE TEST	PERCENTAGE OF COVERAGE IN ASE TEST
A. Exhaust System Inspection And Repair		11	28%
1. Inspection	(6)		
2. Repair	(5)		
B. Emissions Systems Diagnosis		8	20%
C. Exhaust System Fabrication		6	15%
1. Pipe Bending	(3)		
2. Welding And Cutting	(3)		
D. Exhaust System Installation		8	20%
E. Exhaust System Regulations		7	18%
	Total	**40**	**100%**

The 5-year Recertification Test will cover the same content areas as those listed above. However, the number of questions in each content area of the Recertification Test will be reduced by about one-half.

The following pages list the tasks covered in each content area. The task descriptions offer detailed information to technicians preparing for the test, and to those who may be instructing technicians in Exhaust System repair. The task list also may serve as a guideline for question writers, reviewers and test assemblers.

It should be noted that the number of questions in each content area may not equal the number of tasks listed. Some of the tasks are complex and broad in scope, and may be covered by several questions. Other tasks are simple and narrow in scope; one question may cover several tasks. The main purpose for listing the tasks is to describe accurately what is done on the job, not to make each task correspond to a particular test question.

EXHAUST SYSTEMS TEST TASK LIST

INSPECTION AND REPAIR
(11 questions)

1. Inspection
(6 questions)

Task 1 - Inspect all exhaust system components for noises, rattles, missing parts, configuration and routing by visual, audible and thump testing; determine needed repair.

Task 2 - Inspect exhaust system for leaks, restrictions, and overheating by visual, audible, backpressure, vacuum and temperature testing; determine needed repair.

Task 3 - Inspect exhaust subsystems [air injection reactor (AIR), exhaust gas recirculation (EGR), oxygen sensor(s) (O_2S/HO_2S), heat riser/early fuel evaporation (EFE), turbochargers] and mounting hardware; determine needed repair.

Task 4 - Visually inspect exhaust system for evidence of tampering (missing/modified and/or improperly installed components); determine needed repair.

Task 5 - Inspect exhaust system electrical components; determine needed repair.

Task 6 - Inspect engine/transmission mount condition and alignment; determine needed repair.

2. Repair
(5 questions)

Task 1 - Repair or replace failed or damaged mufflers, pipes and related components.

Task 2 - Repair or replace damaged catalytic converters.

Task 3 - Repair or replace exhaust manifolds.

Task 4 - Repair or replace exhaust system mounting hardware and related installation components.

Task 5 - Repair or replace exhaust subsystems [air injection reactor (AIR), exhaust gas recirculation (EGR), oxygen sensor(s) (O_2S/HO_2S), heat riser/early fuel evaporation (EFE), turbochargers] and mounting hardware.

B. EMISSIONS SYSTEMS DIAGNOSIS
(8 questions)

Task 1 - Identify failed catalytic converter(s); determine cause of failure; determine needed repair.

Task 2 - Identify failed air injection reactor (AIR) system; determine root cause of failure; determine needed repair.

Task 3 - Identify failed exhaust gas recirculation (EGR) system; determine root cause of failure; determine needed repair.

Task 4 - Identify failed early fuel evaporation (EFE) system [heat riser]; determine root cause of failure; determine needed repair.

Task 5 - Identify failed oxygen sensor(s) (O_2S/HO_2S) component(s) and circuitry; determine cause of failure; determine needed repair.

Task 6 - Inspect emission systems for evidence of tampering (missing/ modified and/or improperly installed components); determine needed repair.

C. EXHAUST SYSTEM FABRICATION

(6 questions)

1. Pipe Bending

(3 questions)

Task 1 - Determine bending method (program card, pattern/copy or custom).

Task 2 - Determine center of bends, rotation of pipe, depth of bends and pipe diameter(s); perform bending operation.

Task 3 - Perform end-forming and hardware installation operations.

Task 4 - Determine the cause of pipe material failures that occur during bending operations.

2. Welding And Cutting

(3 questions)

Task 1 - Select appropriate welding method (gas or MIG); perform welding operation; verify integrity of weld.

Task 2 - Set up and adjust welding equipment to repair application; observe applicable personnel, vehicle and equipment safety procedures.

Task 3 - Select appropriate cutting method (gas or mechanical); perform cutting operation.

Task 4 - Set up and adjust cutting equipment to repair application; observe applicable personnel, vehicle and equipment safety procedures.

D. EXHAUST SYSTEM INSTALLATION

(8 questions)

Task 1 - Identify exhaust system configuration and options according to manufacturer's specifications (routing, single/dual, etc).

Task 2 - Select components according to accepted standards regarding material, type, design and size.

Task 3 - Install appropriate exhaust system components (mufflers, resonators, catalytic converters, pipes and manifolds).

Task 4 - Install appropriate exhaust system hardware (clamps, hangers, gaskets, flanges, fasteners and heat shields).

Task 5 - Inspect system for proper exhaust component clearance and routing.

Task 6 - Inspect system for proper exhaust component-to-component connection sealing.

Task 7 - Install exhaust subsystem components [air injection reactor (AIR), exhaust gas recirculation (EGR) valve, oxygen sensor(s) (O_2S/ HO_2S), early fuel evaporation (EFE) system (heat riser)].

E. EXHAUST SYSTEM REPAIR REGULATIONS

(7 questions)

NOTE: Federal EPA law establishes minimum compliance requirements for emission systems repair. States and local municipalities may institute requirements that exceed the federal EPA requirements. Knowledge of the Federal EPA requirements will be addressed in the following tasks.

Task 1 - Comply with warranty and diagnostic requirements regarding permissible catalytic converter installations.

Task 2 - Comply with requirements regarding prohibited catalytic converter installations.

Task 3 - Comply with requirements regarding record keeping.

Task 4 - Comply with requirements regarding catalytic converter replacement, location and type.

Task 5 - Comply with requirements regarding replacement of air injection reactor (AIR), exhaust gas recirculation (EGR), oxygen sensor (O_2S/ HO_2S), heat riser [early fuel evaporation (EFE)], and turbocharger systems.

Task 6 - Comply with requirements regarding exhaust system configuration.

The preceding Task list data details all of the relevant subject matter you are required to know in order to sit for this ASE Certification Test. Your own years of experience in the professional automotive service trade as a technician also should provide you with additional background.

Finally, a conscientious review of the self-study material provided in this Training for ASE Certification unit also should help you to be adequately prepared to take this test.

Exhaust System Inspection and Repair

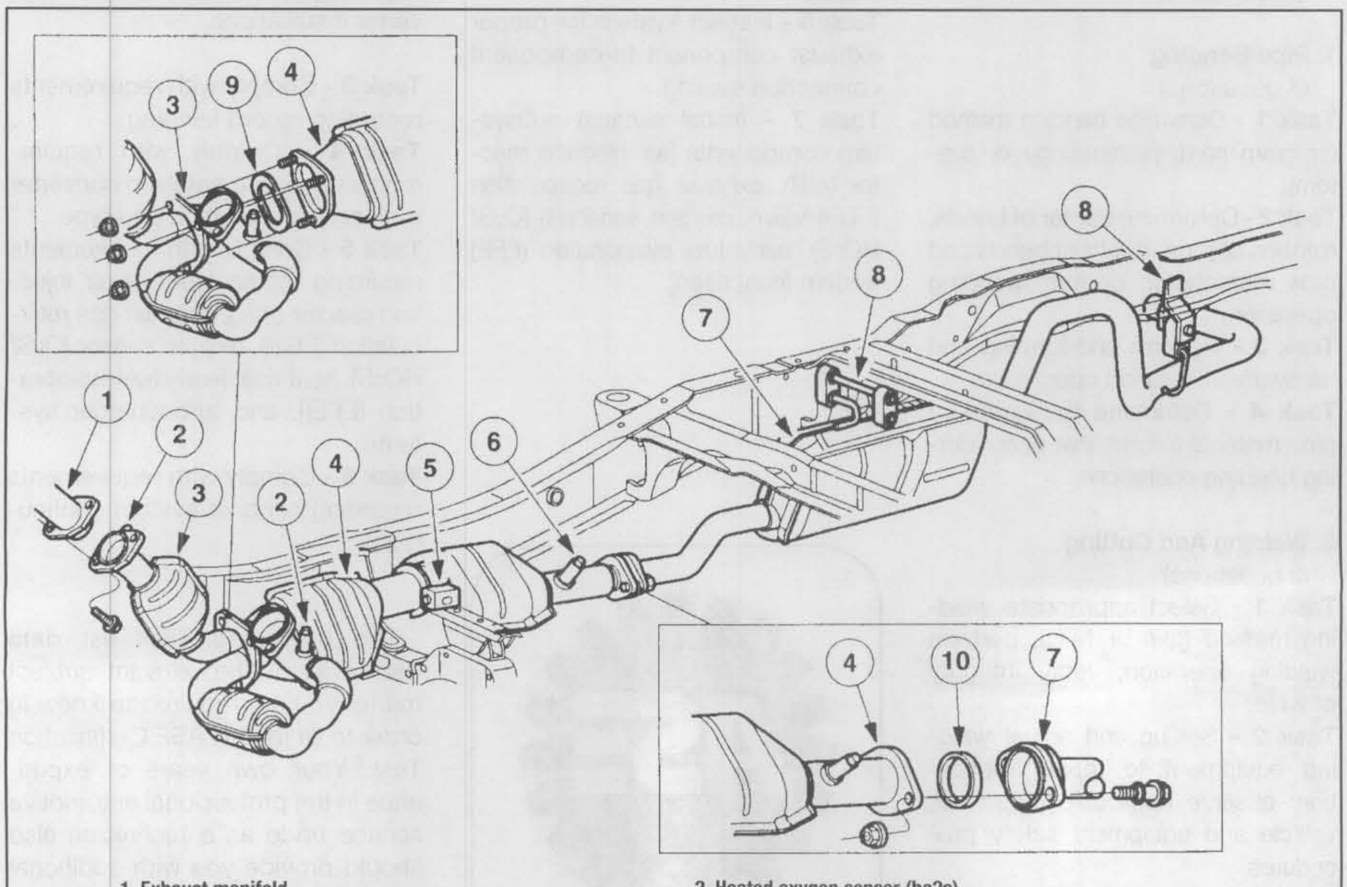
EXHAUST SYSTEM

The exhaust system quiets the noise of combustion and carries the exhaust gases to the rear of the vehicle, away from the passenger compartment. A basic exhaust system consists of the exhaust manifold, exhaust pipe, muffler and tailpipe.

One end of the exhaust manifold is connected to the exhaust ports of the cylinder head and the other end to the exhaust pipe. The muffler is located between the exhaust pipe and the tailpipe, usually toward the rear of the vehicle. The muffler contains baffles, tubes and chambers that reduce the pressure pulsations and resulting noise produced by the engine's exhaust. For further noise reduction, some exhaust systems also contain a resonator, which looks and functions like a small muffler, located between the muffler and tailpipe.

Some vehicles have two separate exhaust systems, a design commonly known as dual exhaust. Dual exhaust systems are most often found on vehicles with V6 or V8 engines where, in effect, each bank of cylinders has its own exhaust system. Dual exhaust systems are used to reduce exhaust backpressure and increase performance. A vehicle with a V6 or V8 engine and a single exhaust system has an exhaust pipe called a Y-pipe, which connects both cylinder banks to the muffler.

For many years, this was how the exhaust systems on most cars and



A single exhaust system on a vehicle with a V6 engine. Note the warm-up catalytic converters located in the Y-pipe. *(Courtesy: Ford Motor Co.)*

light trucks were configured. Then, in the 1970s, the advent of stricter government mandated emissions standards led automobile manufacturers to begin installing catalytic converters in the exhaust systems of gasoline engine vehicles. The catalytic converter reduces the amount of Hydrocarbons (HC), Carbon Monoxide (CO) and Oxides of Nitrogen (NOx) in the exhaust gas and is located in the exhaust system, between the exhaust manifold and muffler. Most vehicles that are manufactured today also have a small catalytic converter that is part of the exhaust manifold or located just behind it. These converters are used to clean the exhaust during engine warm-up and are known as warm-up converters.

Heat shields made of sheet metal are attached to the catalytic converter, muffler and sometimes the exhaust manifold and exhaust pipe. They may also be attached to the underside of the vehicle. These are installed to protect other components and the underside of the vehicle from the heat that radiates from the exhaust system.

The exhaust system is suspended beneath the vehicle with brackets, hangers and clamps. Hangers are made of rubber or reinforced fabric and are flexible enough to allow the exhaust system to expand as it gets hot, and move with engine torque, yet rigid enough to keep the system from contacting other components on the underside of the vehicle. The hangers also isolate the vehicle from vibrations in the exhaust system. Clamps are used to secure the exhaust system parts to one another. On some vehicles, the exhaust system components are welded together at the factory.

Inspection

WARNING: When servicing exhaust systems, certain safety precautions must be observed or serious injury could result. Exhaust system components get very hot when the engine is running and will remain hot long after the engine is turned off. Serious burns can result if your skin contacts these components. If possible, wait until the exhaust system has cooled or, if exhaust system parts must be handled beforehand, wear insulated gloves specifically made for the purpose. In addition, always wear goggles to protect your eyes from rust particles and other falling debris.

Exhaust system components can fail due to physical or chemical damage. Since it is located under the vehicle, the exhaust system is subject to damage and wear from dirt, stones, water and other road hazards. The components in the system can also rot out from the inside. When the engine is started from cold, combustion gases mix with condensation that forms when the hot exhaust contacts the colder exhaust parts, forming acids that corrode the metal. This type of failure is common on vehicles that are driven short distances, since the exhaust system never gets warm enough to evaporate the moisture.

Whether it is caused by physical or chemical damage, the result is cracks, holes or other damage to the exhaust system that cause excessive noise and can allow harmful exhaust gases to enter the passenger compartment. Engine exhaust contains CO, which can cause headache, nausea and drowsiness, and if enough is ingested, can even result in unconsciousness and death. Any exhaust system damage that results in exhaust leakage must be repaired immediately.

Damage to the exhaust system can also result in a restriction in the system. A blockage can be caused by physical damage, such as a dent in a pipe, or a clogged muffler or catalytic converter. A restriction can also be caused by a collapsed exhaust pipe. Some vehicles use double wall tubing for exhaust pipes. The inside tube can collapse or rust inside the outer tube and cause a restriction, even though the outer tube looks OK. Tap on the exhaust pipes with a mallet and listen for rattling or rust breaking loose, which would indicate a problem inside the pipe. A restricted exhaust system can cause a lack of power, poor fuel economy, backfiring, and if completely clogged, the engine may not run at all.

Begin exhaust system inspection by raising and safely supporting the vehicle. Visually inspect the exhaust system for physical damage, holes, cracks, separated components, bulging muffler seams, and broken or missing clamps and hangers. A catalytic converter that appears bluish or brownish indicates that it is overheating.

Wiggle the exhaust system at various points to check for excessive movement caused by broken or cracked connections or broken or missing hangers. Tap on the exhaust system components with a mallet. A part that is in good condition will make a solid metallic sound, while a part that is worn out will have a dull sound. Rattling noises can be caused by loose heat shields, loose clamps or an exhaust pipe interfering with another component.

When tapping on the muffler, listen for the sound of loose rust particles. Mufflers usually rot out from the inside, so even if the outside of the muffler appears OK, it still may be ready for replacement.

A telltale sign of exhaust leakage is black streaks or soot on the outside of a component. However, if the source of exhaust leakage is not evident, you may have to start the engine and listen carefully for leaks at all joints. Do not overlook welded connections, as these can crack. A small exhaust leak will make a hissing or popping noise. A tapping sound that may sound like a valve-train noise can actually be caused by an exhaust leak at the exhaust manifold/cylinder head juncture. Keeping in mind that the exhaust system will be very hot, carefully pass your hand close to a suspected leak area to see if escaping exhaust can be felt.

While inspecting the exhaust system, make sure that the emissions equipment that the vehicle is supposed to have is installed properly and that the vehicle has not been tampered with. It is against the law to remove or disable emissions control devices. In most cases, signs of tampering will be obvious, such as the replacement of the catalytic converter with a straight pipe, or plugs installed in the exhaust manifold where the Air Injection Reactor (AIR) pipes were installed. However, in other cases evidence of tampering may not be so obvious. In these situations, consult a factory service manual or a manual like those used at state motor vehicle inspection facilities, which lists the emissions equipment that is installed on vehicles at the manufacturer.

To check for a restricted exhaust system, connect a vacuum gauge to the intake manifold and start the engine. At idle, there should be approximately 17-21 in. Hg. vacuum. Accelerate the engine gradually to 2000 rpm. The vacuum should momentarily drop to zero and then return to normal without delay; if the exhaust is restricted, as the engine rpm is increased the vacuum will slowly drop to zero and slowly rise to normal. When closing the throttle, the vacuum should momentarily increase and then resume the normal reading; if the exhaust is restricted the vacuum will not increase when the throttle is closed. Accelerate the engine to 2500 rpm and hold. If the vacuum reading drops 3 in. Hg below the original reading after a few minutes, there is a restriction in the exhaust system.

A backpressure test can also be used to check for a restricted exhaust system. Remove the front oxygen sensor and install a suitable pressure gauge in the sensor hole. Start the engine and compare the pressure reading with specifications for the vehicle in question. A pressure reading that is higher than specifications indicates an exhaust restriction.

Repair

MUFFLER AND PIPES

During engine operation, pressure pulses are created each time an exhaust valve opens and a burst of high pressure exhaust gas is forced out of the exhaust port. If an engine is run without an exhaust system, like a race car with open headers, the sound you hear is created by these pressure pulses making your eardrum vibrate back-and-forth.

In an exhaust system, these pressure pulses create sound waves that travel down the exhaust pipe and into the muffler. The sound waves enter the muffler through the center tube, bounce off the back of the muffler and are reflected through a hole into the main body of the muffler. They then pass through more holes into another chamber, and then turn and go out the muffler outlet. Mufflers are carefully designed so that the size of the chambers, tubes and baffles allow the sound waves to cancel each other out, thereby reducing engine noise.

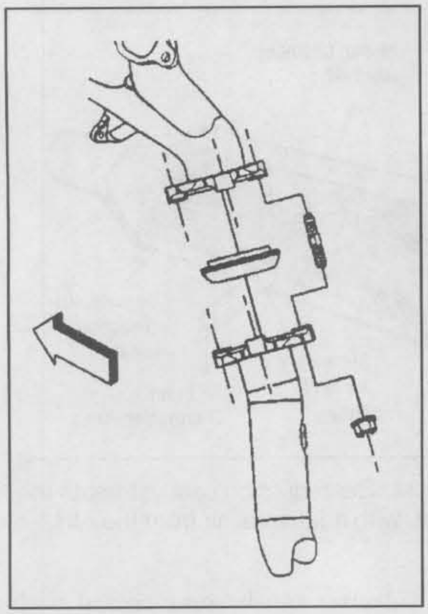
This describes the operation of a reverse-flow muffler, which is the most common type of muffler used. However, there are also straight-through mufflers that rely on perforations inside the muffler to break up the exhaust pulsations and glass insulation inside the muffler body to absorb some of the pressure pulses. Straight-through mufflers are less restrictive and therefore better for performance in some applications. However, they do not reduce the sound level as well as reverse-flow mufflers. Straight-through mufflers are generally aftermarket parts and may not be legal for installation on some vehicles.

Always wait until the exhaust system is cool to the touch before beginning exhaust system repairs. Disconnect the negative battery cable and raise and safely support the vehicle. Have the new parts on hand and compare them with the old parts to make sure they are the correct ones for the vehicle.

The greatest hindrance encountered during exhaust repair is rust. Nuts rust solid to clamps and exhaust manifold studs and exhaust system components rust together at their connections. Threaded fasteners that must be reused can be soaked with penetrating oil or heated with a torch to facilitate removal. Also, always use six-point sockets to remove exhaust system fasteners, as a 12-point socket will only round off the corners of a corroded fastener.

Support the rest of the exhaust system with a suitable jack and remove the necessary clamps, fasteners and hangers from the component being removed. If removing the exhaust pipe, remove the oxygen sensor from the pipe using a suitable socket, if necessary. Remove the nuts from the exhaust manifold studs and pull the pipe flange away from the studs. Remove the exhaust pipe from the catalytic converter and remove the exhaust pipe from the vehicle.

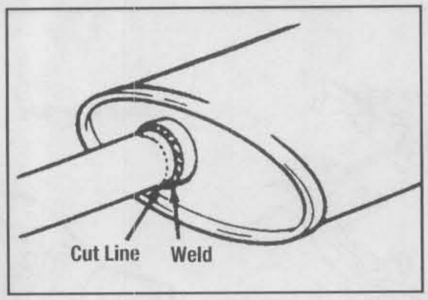
Inspect the exhaust manifold studs for corrosion. Even if the studs did not break during removal, they may be weak enough to break when the exhaust pipe flange nuts are tightened. It may be necessary to remove the exhaust manifold and install new studs. A time saving option is to use the stud welding attachment that is available on some MIG welders. With this tool, a new stud can be welded to the exhaust manifold without removing the manifold from the vehicle.



Typical exhaust pipe-to-manifold connection. *(Courtesy: GM Corp.)*

Many exhaust system components use slip-joint connections. In these connections an inner pipe fits inside an outer pipe or an inner pipe fits inside the muffler. When separating these connections, care must be taken not to damage the part that is not being replaced. With these types of connections, if the part being replaced is the inner pipe, then the pipe can be cut in half just outside the outer pipe using a hacksaw, cold chisel, air chisel, cutoff wheel or cutting torch. Cut a slit in the remaining part of the pipe, which will allow it to be pulled from the muffler or outer pipe. There are slitting tools that are specially made for this purpose. If replacing the muffler or outer pipe, use the slitting tool to cut the outer pipe or muffler opening, which will allow it to be removed from the inner pipe.

If you are replacing a component on an exhaust system that has been welded together, it is not necessary to weld the replacement component into place. Adapters are available that allow a slip-joint connection



Cut the exhaust pipe at the line when replacing a welded on muffler with a replacement that will be secured with clamps. *(Courtesy: GM Corp.)*

and clamps to be used to secure the component.

When installing a new pipe into an old muffler or outer pipe, the new pipe may not fit because the muffler or outer pipe opening may be distorted from damage or if the old clamp was over tightened. A cone-shaped pipe shaping tool and a hammer can be used to make a pipe opening round. A pipe expander can be used to smooth out or enlarge the diameter of a pipe. Install the expander and tighten the bolt with a socket and ratchet until the pipe is suitable for use.

Make sure all pipes and the muffler are fully inserted into their mating pipes. Install the clamps and hangers, but do not tighten them yet. If installing a new exhaust pipe, use a new gasket at the exhaust manifold. Replace the exhaust pipe flange nuts with brass nuts, which will not rust to the studs. Make sure the exhaust system is properly aligned and that there is enough clearance between the system and all underbody components. Tighten all clamps and hangers. Do not over tighten the clamps as this could distort the pipes and cause leaks.

Install the oxygen sensor and any heat shields or other components that were removed. Start the engine and check for exhaust leaks. Road test the vehicle, listening for rattles.

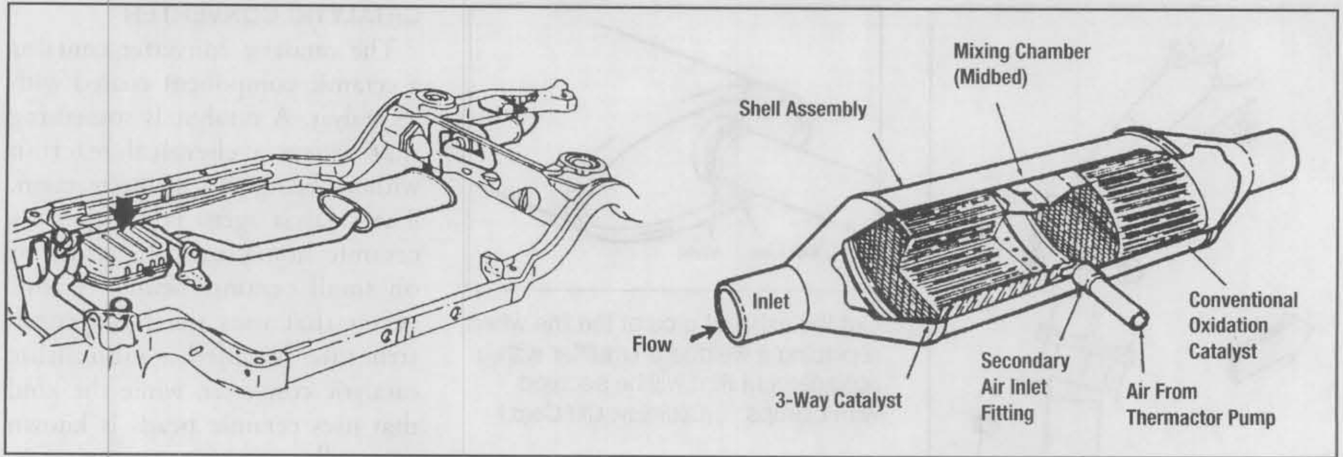
CATALYTIC CONVERTER

The catalytic converter contains a ceramic component coated with a catalyst. A catalyst is something that causes a chemical reaction without being part of the reaction. The catalyst agent is coated on a ceramic honeycomb structure or on small ceramic beads. A converter that uses the honeycomb structure is called a monolithic catalytic converter, while the kind that uses ceramic beads is known as a pellet catalytic converter. As exhaust flows through the converter, the catalyst agent causes a chemical reaction to take place, converting harmful exhaust gases to harmless ones.

The elements platinum, palladium and rhodium are used as catalysts in the catalytic converter. When HC and CO gases are exposed to hot surfaces inside the converter that are coated with platinum and palladium, the HC and CO combine with oxygen to become Carbon Dioxide (CO2) and water (H2O). Because platinum and palladium are called oxidizing catalysts, a catalytic converter that only reduces HC and CO is known as an oxidation converter, or two-way catalytic converter.

Three-way catalytic converters also contain the catalyst rhodium, which reduces NOx emissions. When NOx is exposed to a hot surface coated with rhodium, the oxygen is removed and only Nitrogen (N) remains. Because rhodium is called a reducing catalyst, a three-way catalytic converter is also called a reduction type converter. In a three-way converter, the oxidizing catalysts and reduction catalyst are separated in two compartments.

Most vehicles that are manufactured today also have a small catalytic converter that is part of the exhaust manifold or located just behind it. These converters are



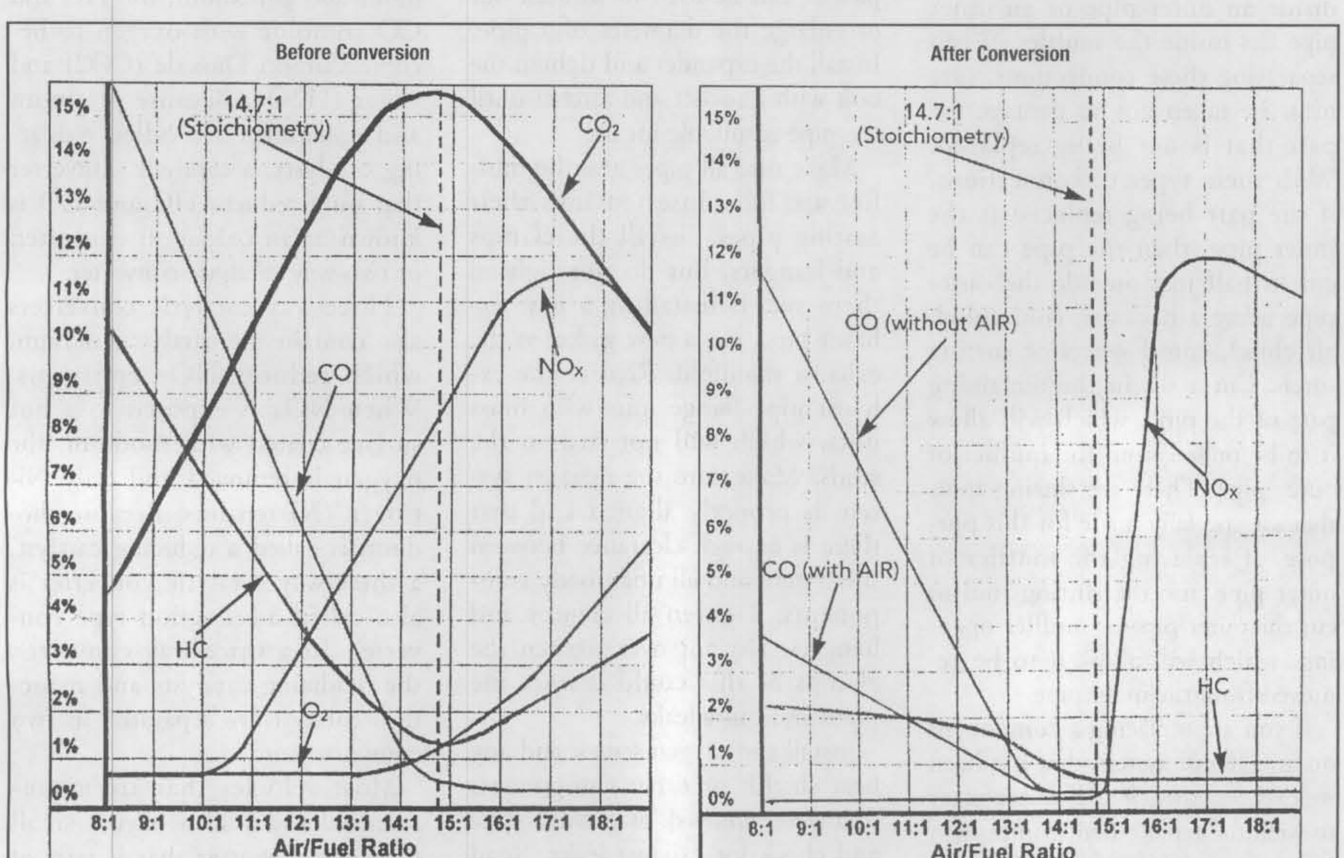
A three-way catalytic converter contains a reduction catalyst and an oxidizing catalyst. The reduction catalyst treats the incoming exhaust by reducing NOx into oxygen and nitrogen. The oxidation catalyst, with additional air from the AIR system, oxidizes HC and CO into CO_2 and water.

used to clean the exhaust during engine warm-up and are known as warm-up converters.

Most catalytic converters have fresh air injected into the converter by the AIR system. The extra air helps in the oxidation of HC and CO. The Powertrain Control Module (PCM) controls when the air is injected. If air is injected at the wrong time the converter could overheat or actually produce more NOx.

A catalytic converter can fail in several ways. If the engine is run with leaded gas, the catalysts in the converter can become coated with lead, making them useless. Leaded gas is no longer generally available, so this type of failure is rare.

The converter can become clogged if exposed to an overly rich air/fuel mixture, which can overheat the converter and melt



Exhaust gas relationship before and after the catalytic converter. Note especially the reduction of NOx.

the ceramic substrate. To determine if the converter is clogged, perform the vacuum test or backpressure test described in the exhaust system inspection section of this study guide. To isolate the source of the restriction, disconnect the exhaust system one part at a time, until the vacuum or pressure readings are normal. Also, remember that if a converter is being replaced because it is clogged, the cause of the clog must be determined and repaired or the replacement converter will also clog.

The catalytic converter can also fail like any other exhaust system component, due to rust or physical damage. Over time, the ceramic substrate can come loose in the converter and slowly disintegrate, which is indicated by a rattling noise when the converter is struck with a mallet.

A failed converter must be replaced. The converter can be attached to the system with slip-joints and clamps or be secured to the exhaust pipes with bolts and/or nuts. Soak the fasteners with penetrating oil or heat them with a torch to facilitate removal. Disconnect the AIR pipe from the converter, if equipped. Support the rest of the exhaust system and cut or unbolt the converter from the system, as necessary. If the converter is attached with bolts and/or nuts, use new gaskets or seals when the new converter is installed. Be sure to reinstall all heat shields.

If a warm-up converter that is part of the exhaust manifold fails, then the exhaust manifold must be replaced.

EXHAUST MANIFOLD

The exhaust manifold is bolted to the cylinder head over the exhaust ports. There is usually one opening in the manifold per exhaust port, however, on cylinder heads with siamesed exhaust ports, two ports may empty into one manifold opening. The exhaust manifold channels the exhaust gas from each exhaust port into runners that feed into one outlet, which connects to the exhaust pipe. There are usually studs at the exhaust manifold outlet, where the exhaust pipe flange is secured with nuts. Most exhaust manifolds are made of cast iron, however, the manifolds on many newer vehicles are made of steel or stainless steel.

In-line four- and six-cylinder engines usually have one exhaust manifold, whereas V6 and V8 engines have two, one per cylinder head. On some older in-line six-cylinder engines, the intake and exhaust manifold were included in one casting. When vehicles with V6 or V8 engines have a single exhaust system, both exhaust manifolds are connected to the catalytic converter with an exhaust pipe called a Y-pipe.

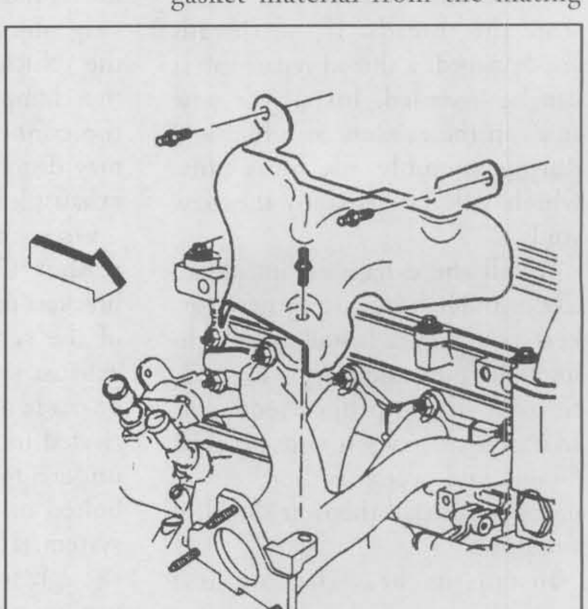
The AIR system pipe(s) and/or an oxygen sensor are installed in the exhaust manifold on some vehicles. A heat riser or vacuum controlled heat valve may also be connected to the exhaust manifold. These components are part of the Early Fuel Evaporation (EFE) system and are discussed in the EFE system sections of this study guide.

Do not attempt to remove an exhaust manifold from an engine until it is cool to the touch. Begin exhaust manifold removal by raising and safely supporting the vehicle. Soak the exhaust manifold stud nuts with penetrating oil or heat them with a torch to facilitate removal. Remove the nuts from the exhaust manifold studs using a six-point socket. Support the exhaust system and separate the exhaust pipe flange from the exhaust manifold studs.

Unbolt the heat shield from the exhaust manifold, if equipped. Remove any accessory brackets that may be attached to the manifold. If an oxygen sensor is mounted in the manifold, disconnect the sensor's electrical connector and remove the sensor from the manifold using a suitable socket. Disconnect the AIR pipe(s) from the manifold, if equipped. Remove the exhaust manifold mounting bolts/nuts in the reverse order of their torque sequence, and remove the exhaust manifold from the vehicle. Remove the heat riser or heat valve, if equipped.

Carefully examine the exhaust manifold for cracks or other damage. An exhaust manifold heats up and cools down thousands of times during the normal lifespan of a vehicle. Depending on the design of the manifold, some areas of the manifold get hotter than others, particularly those areas that are covered by heat shields. The resulting uneven expansion and contraction that occurs during the heating and cooling cycle can cause cracks and manifold warpage.

Thoroughly clean all dirt and old gasket material from the mating



Removing the heat shield from an exhaust manifold.
(Courtesy: GM Corp.)

surfaces of the manifold and cylinder head. Examine these surfaces for gouges or other imperfections that could cause an exhaust leak. Check the cylinder head mating surface of the exhaust manifold for warpage using a feeler gauge and straightedge, and compare with manufacturer's specifications.

If the cylinder head mating surface of the exhaust manifold is marred or warped, it may be able to be corrected through resurfacing by an automotive machine shop. Some engines come from the factory without exhaust manifold gaskets. Gaskets for these applications are generally available in the aftermarket, and using gaskets may be enough to compensate for marring or warpage if it is not severe.

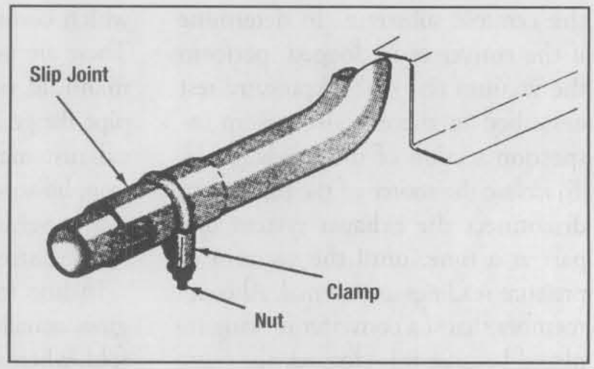
Inspect the exhaust manifold studs for any corrosion. Even if the studs did not break during removal, they may be weak enough to break when the exhaust pipe flange nuts are tightened. A damaged stud usually must be drilled out and the hole tapped to restore the threads. If the threads are damaged, a thread repair insert can be installed. Install the new studs in the exhaust manifold and during assembly, use brass nuts, which will not rust to the new studs.

Install the exhaust manifold to the cylinder head, using new gaskets, as required. Install the attaching bolts/nuts and torque to specification in the proper sequence. Install the oxygen sensor, AIR pipe(s) and accessory brackets, as necessary. Install the heat shield, if equipped.

Install the heat riser or heat valve, if equipped, using a new gasket. Install the exhaust pipe to the manifold using a new gasket. Tighten the exhaust pipe flange nuts to specification. Start the engine and check for exhaust leaks.

EXHAUST SYSTEM MOUNTING HARDWARE

The exhaust system is attached to the vehicle using brackets, hangers and clamps. Clamps are U-bolts that come in sizes that correspond to the common pipe diameters used in exhaust systems. Clamps are used to secure the slip-joint connections that attach some exhaust system components and may also be used to attach hangers in some applications. Always use the correct size clamp for the pipe in question, or the pipe may distort when the clamp is tightened, causing a leak.



An exhaust clamp on a slip-joint connection. *(Courtesy: DaimlerChrysler Corp.)*

Always make sure the inside pipe is fully inserted in a slip-joint connection and the clamp is positioned around both pipes, but not too close to the edge of the outer pipe. Position the clamp so that the ends of the U-bolt will not contact other components or snag objects that may pass under the vehicle while driving. Tighten the clamp only enough to secure the connection. Over tightening may distort the pipes and cause an exhaust leak.

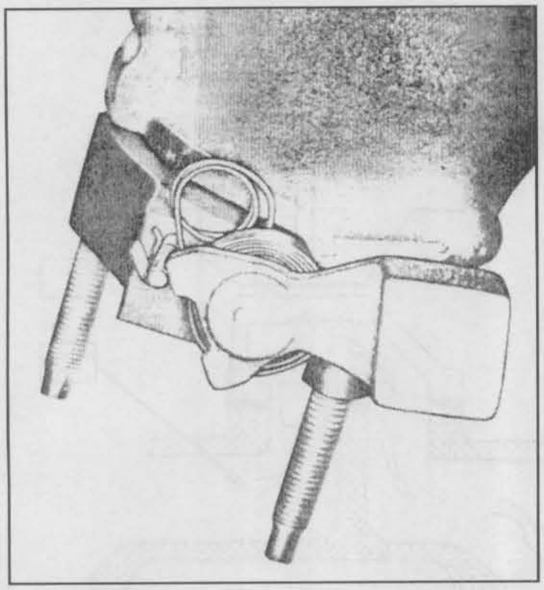
On some vehicles, hangers are rubber O-rings that attach to brackets mounted on the underside of the vehicle and welded to the exhaust system. Hangers can also be made of reinforced fabric that is riveted to brackets that bolt to the underside of the vehicle and are bolted or clamped to the exhaust system. Hangers must be flexible enough to allow the exhaust system to expand as it gets hot, and move with engine torque, yet rigid enough to keep the system from contacting other components on the underside of the vehicle. The hangers also isolate the vehicle from vibrations in the exhaust system.

When installing exhaust system components, take the necessary time to properly position them. Hangers should be used to support the exhaust system, but not to draw components into place. Hangers that are used this way will be under constant stress and will fail prematurely.

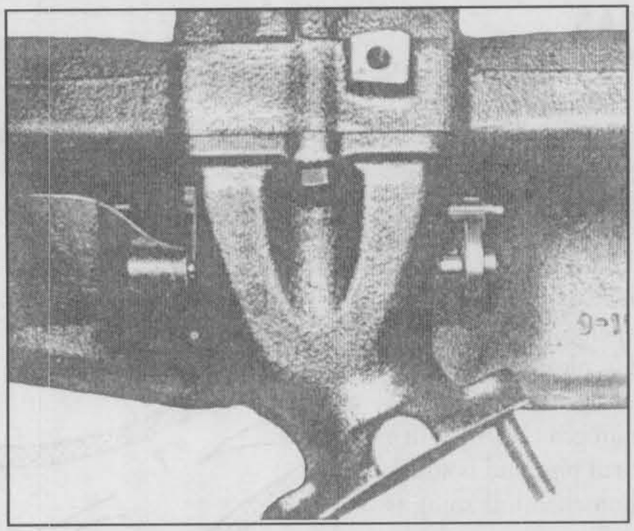
EARLY FUEL EVAPORATION (EFE) SYSTEM

The EFE system heats the intake manifold when the engine is cold, to improve vaporization of the fuel coming from the carburetor or throttle body injection unit. This heating is necessary to prevent the fuel from condensing on cold surfaces. Heating the intake manifold quickens fuel vaporization, providing faster warm-up times and reduced HC and CO emissions.

The EFE system consists of a heat riser or heat control valve, mounted on the exhaust manifold, and an exhaust passage in the intake manifold that runs under the floor of the manifold, beneath the throttle blades. The heat riser or heat control valve on an inline four- or six-cylinder engine may be part of the exhaust manifold. On a V6 or V8 engine, it is located between one of the exhaust manifolds and the exhaust pipe.



Typical heat riser on a V8 engine.
(Courtesy: GM Corp.)



Typical heat riser on an in-line six-cylinder engine.
(Courtesy: GM Corp.)

A heat riser is used on older vehicles and is controlled by a bimetallic spring and counterweight. When the engine is cold, the valve inside the heat riser is closed, forcing hot exhaust gases into the passage under the floor of the intake manifold. As the engine warms up, the spring uncoils and allows the counterweight to open the valve, allowing normal exhaust flow.

The heat control valve is operated by a vacuum motor. Vacuum is supplied by a thermal switch that applies full vacuum to the motor when the engine is cold. When full vacuum is applied to the motor, the valve is pulled to the closed position, forcing hot exhaust gases into the passage under the floor of the intake manifold. As the engine warms up, the vacuum supply to the motor is gradually reduced by the thermoswitch, and the heat control valve is opened by a spring, allowing normal exhaust flow.

Inspection

The two most common problems with EFE systems are stuck heat risers or heat control valves and manifold heat passages that are clogged with carbon. A heat riser or heat control valve that is stuck open can cause slow warm-up, stalling, hesitation and increased emissions, while one that is stuck closed can cause overheating, detonation, burned valves and manifold warpage. If the manifold heat passages are clogged, it will have the same effect as a stuck open heat riser or heat control valve.

A heat riser can be easily checked by moving the counterweight when the engine is cold. The valve should move freely throughout its travel. If the valve does not move or binds, it must be repaired or replaced.

To check a heat control valve, observe the valve when the engine is cold; it should be in the closed position. If it is in the open position, then the thermoswitch is bad, the diaphragm in the vacuum motor is leaking, the valve is stuck open or the linkage is binding. If there is vacuum at the diaphragm when the engine is cold, then suspect the vacuum motor diaphragm or a stuck valve or linkage. If there is no vacuum, then check the thermoswitch. If the switch is good, then check the vacuum supply to the switch.

Remove the vacuum hose from the vacuum motor when the engine is cold. The spring on the valve should move the valve to the open position. If it does not, then the valve is stuck closed or the linkage is binding.

Check for clogged manifold heat passages by starting the engine and letting it idle. Wait a few minutes and then attempt to touch the intake manifold heat passage. If the manifold feels relatively cool, then the heat passage is probably clogged. If the passage is not clogged, then that portion of the manifold should feel hotter than the rest of the manifold.

Repair

If the bimetallic spring on a heat riser is damaged, then the heat riser must be replaced. If the valve is stuck or binding, apply penetrating oil to both ends of the valve shaft where it passes through the heat riser or exhaust manifold. Work the valve back and forth until it is free. It may be necessary to gently tap on the ends of the shaft to assist in freeing up the valve. If the valve will not free up, then the heat riser or exhaust manifold must be replaced.

A heat control valve can be freed in the same manner. If the diaphragm in the vacuum motor is leaking, then the vacuum motor must be replaced.

A clogged manifold heat passage requires that the intake manifold to be removed. Use chisels, scrapers, wire brushes or other suitable tools to clear the carbon build-up from the passageways.

EXHAUST GAS RECIRCULATION (EGR) SYSTEM

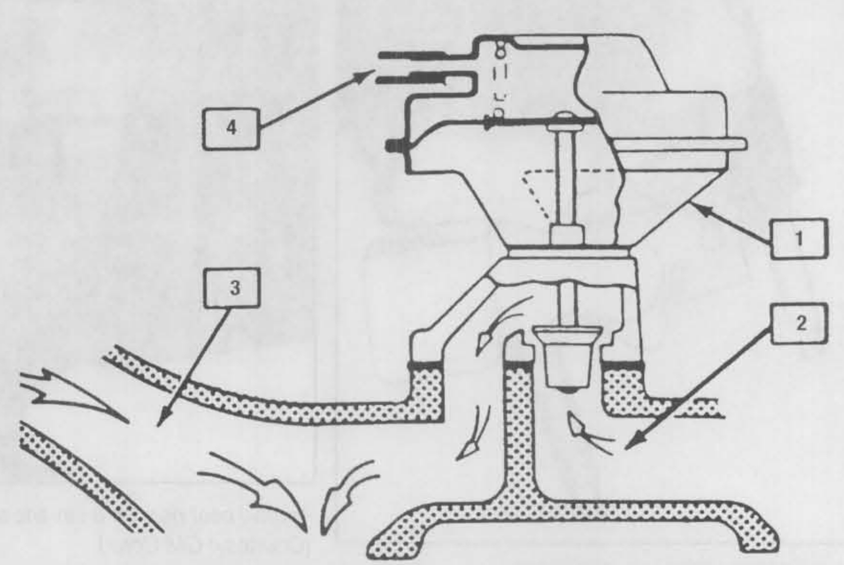
Most of the air around us is made up of harmless nitrogen. Ordinarily, nitrogen cannot combine with oxygen. However, under very high heat conditions, such as those that occur inside an engine's combustion chamber, where temperatures can exceed 2500°F (1371°C), nitrogen molecules can bond with oxygen molecules and form oxides of nitrogen (NOx). When NOx leaves the tail pipe and is struck by sunlight, photochemical smog is formed.

A simple way to reduce NOx would be to lower the temperature of combustion. This could be accomplished by running rich air/fuel mixtures, which contain a high level of cool liquid gasoline, or also by lowering thermostat temperatures. Unfortunately, both methods would produce high levels of HC and CO emissions and lower fuel economy, and are contradictory to the objective of using the minimum amount of fuel necessary for combustion. Burning leaner mixtures produces high temperatures.

The solution is to introduce a metered amount of an inert gas into the intake air stream. The gas takes up space that would otherwise be occupied by the regular incoming air/fuel charge, which contains 21% oxygen. Oxygen would contribute to combustion, and subsequently raise temperature. Replacing the oxygen with inert gas slows and cools the combustion burn.

Fortunately, a running engine produces large quantities of a suitable inert gas for this purpose: exhaust. Exhaust gas should theoretically contain very little, if any, oxygen because it should have all been consumed during the combustion process.

The EGR valve is used to meter the exhaust into the intake air stream. Most EGR valves consist of a vacuum operated diaphragm that is connected by a rod to a valve in its base, however on some EGR valves, control of the valve is fully electronic. The valve is located inside a connecting passage between the exhaust system and the intake manifold. When the valve opens, exhaust gas mixes with the incoming air that is to be used for combustion.



1. EGR Valve
2. Exhaust Gas
3. Intake Air
4. EGR Vacuum Port

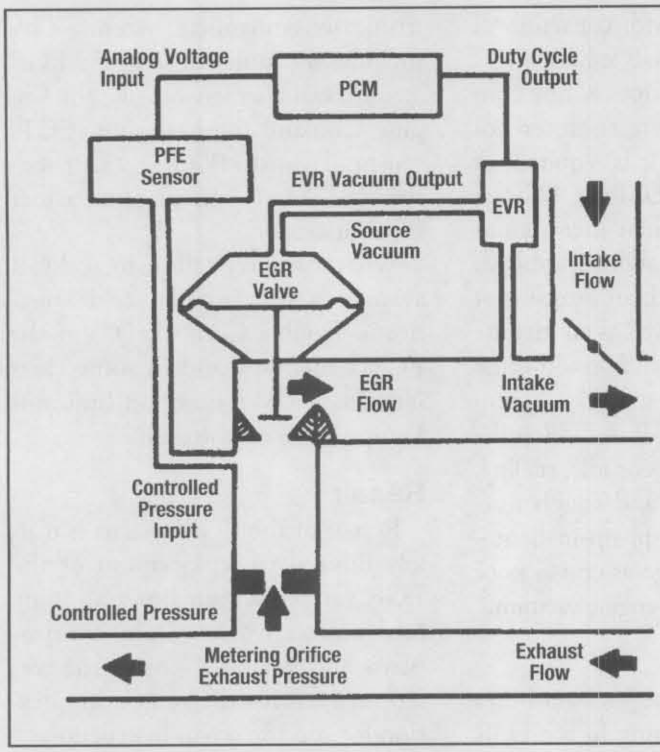
Typical vacuum operated EGR valve.

EGR function must be controlled because exhaust gas recirculation is not constantly required. EGR is not required when the engine is cold, at idle (warm or cold) and at WOT (Wide Open Throttle). Until the engine is warm, there is no need for exhaust gas recirculation because combustion is still sufficiently cool. Even when the engine is warm, there is no need for exhaust gas recirculation at idle because combustion pressures are relatively low and NOx is not formed, and exhaust gas recirculation would stall the engine because of too much dilution. At WOT, the need for power outweighs the need to control NOx emissions, and since WOT needs richer, and therefore slightly cooler mixtures, NOx formation is minimal anyway.

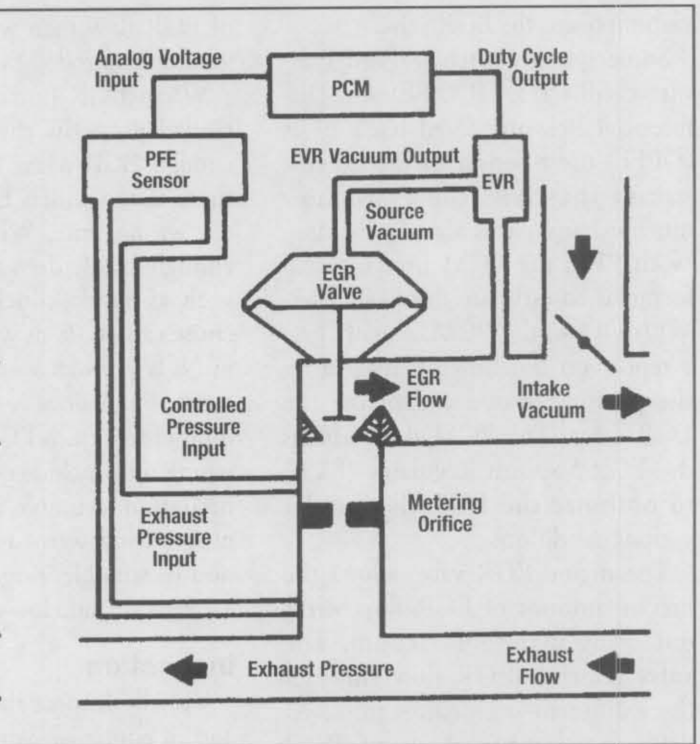
There are several systems currently used to control EGR function including ported, positive backpressure, negative backpressure, pulse-width modulated and electronic.

On the positive backpressure EGR valve, a control valve located in the EGR valve acts as a vacuum regulator valve. The control valve manages the amount of vacuum to the EGR diaphragm chamber by bleeding vacuum to atmosphere during certain operating conditions. When the control valve receives a backpressure signal from the exhaust through the hollow shaft of the EGR valve pintle, pressure on the bottom of the control valve closes it. When the EGR valve closes, the full vacuum signal is applied directly to the EGR valve diaphragm, which opens the valve and allows exhaust gas recirculation.

On the negative backpressure EGR valve, a vacuum signal is supplied through a hose connected to the upper part of the EGR valve. Manifold vacuum is also applied to the lower diaphragm through an intake



Pressure Feedback EGR (PFE) system.
(Courtesy: Ford Motor Co.)

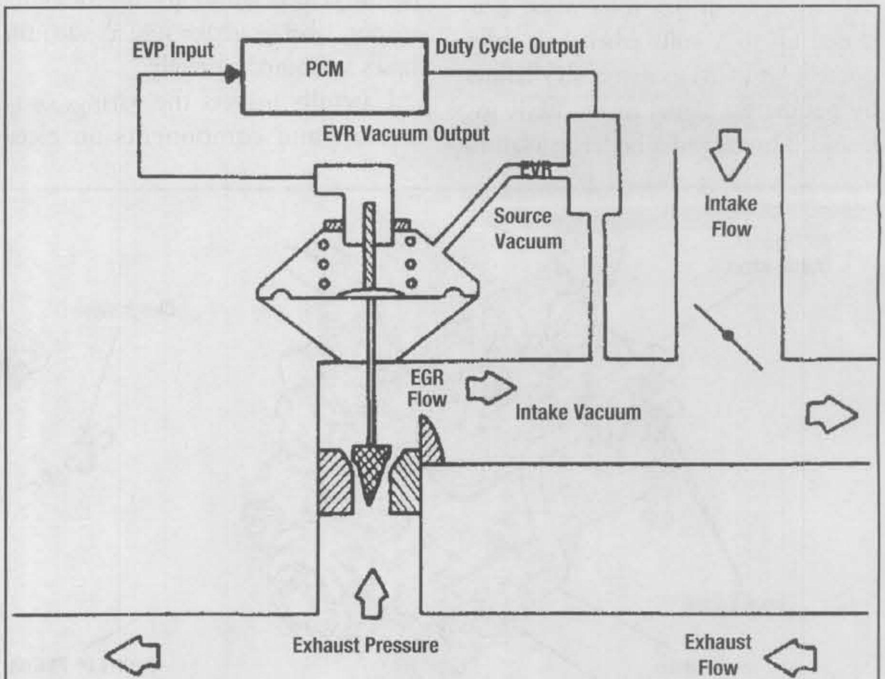


Differential Pressure Feedback EGR (DPFE) system.
(Courtesy: Ford Motor Co.)

port at the base of the EGR valve. When manifold vacuum in the lower chamber isn't strong enough to overcome the spring tension on the lower diaphragm, a bleed valve closes allowing vacuum in the upper chamber to open the EGR valve. Exhaust flow opens a check valve in the pintle so that vacuum bleeds to atmosphere and the valve rises, but tries to drop again. This process controls EGR flow.

The pulse-width modulated EGR system is controlled entirely by the PCM. The computer controls the flow rate by sending electrical signals to a solenoid vacuum valve between the PCM and EGR valve. The solenoid pulses up to 32 times per second. To determine pulse width, the PCM relies on a ported vacuum signal.

On computer controlled EGR systems, the PCM controls the vacuum signal to the EGR valve through a solenoid valve. The PCM uses coolant temperature, throttle position and MAP (Manifold Absolute Pressure) signals and sometimes other inputs, to determine solenoid operation. Whenever the engine is cold or idling, the solenoid valve blocks vacuum to the EGR valve. When the engine is warm and RPM is higher than idle speed, the solenoid ground is broken and



Electronically controlled EGR system.
(Courtesy: Ford Motor Co.)

vacuum opens the EGR valve.

Some systems, such as Ford Pressure Feedback EGR (PFE) and Differential Pressure Feed-back EGR (DPFE) use a sensor in the exhaust stream that tells the PCM how much exhaust gas is actually flowing. With PFE, the PCM uses internal formulas to estimate the EGR flow. With DPFE, the PCM actually gets a report on the flow by measuring the pressure above and below the EGR valve. The PCM then adjusts the EGR Vacuum Regulator (EVR) to optimize the EGR flow under various conditions.

The digital EGR valve allows the precise amount of EGR flow without using manifold vacuum. The valve controls EGR flow through three different size orifices for seven different combinations of EGR flow. When the PCM energizes a solenoid, the swivel pintle is lifted to open the orifice.

Some engines have an electronically controlled EGR valve. It has a control solenoid and EGR Valve Position (EVP) sensor. The return voltage signal ranges from 0.3 volts when it is closed up to 5 volts when it is fully open. The PCM controls EGR flow by pulsing the signal to the EGR solenoid. This provides better regulation of EGR flow than with conventional vacuum controlled EGR valves.

When EGR function is not controlled properly, there is either not enough EGR when it is required, or there is too much EGR or EGR at the wrong time. When there is not enough EGR, driveability problems such as spark knock or surging at cruise can occur, as well as an increase in NOx emissions which could cause a failed emissions inspection. Symptoms of too much EGR or EGR at the wrong time include poor idle, stalling, hesitation, stumble and rough running during warm up, tip-in hesitation or stumble, surge at cruise, poor acceleration, and low engine vacuum.

Inspection

Visually inspect the vacuum hoses and, if equipped, wiring in the EGR system. Check the vacuum hoses for cuts, cracks and kinks that could cause a vacuum leak or a vacuum restriction. Also check hoses for flexibility; even though a hose appears OK, it could be hardened and ready to break. Use a vacuum diagram, such as that found on the vehicle emissions control information label, to make sure all vacuum hoses are routed correctly.

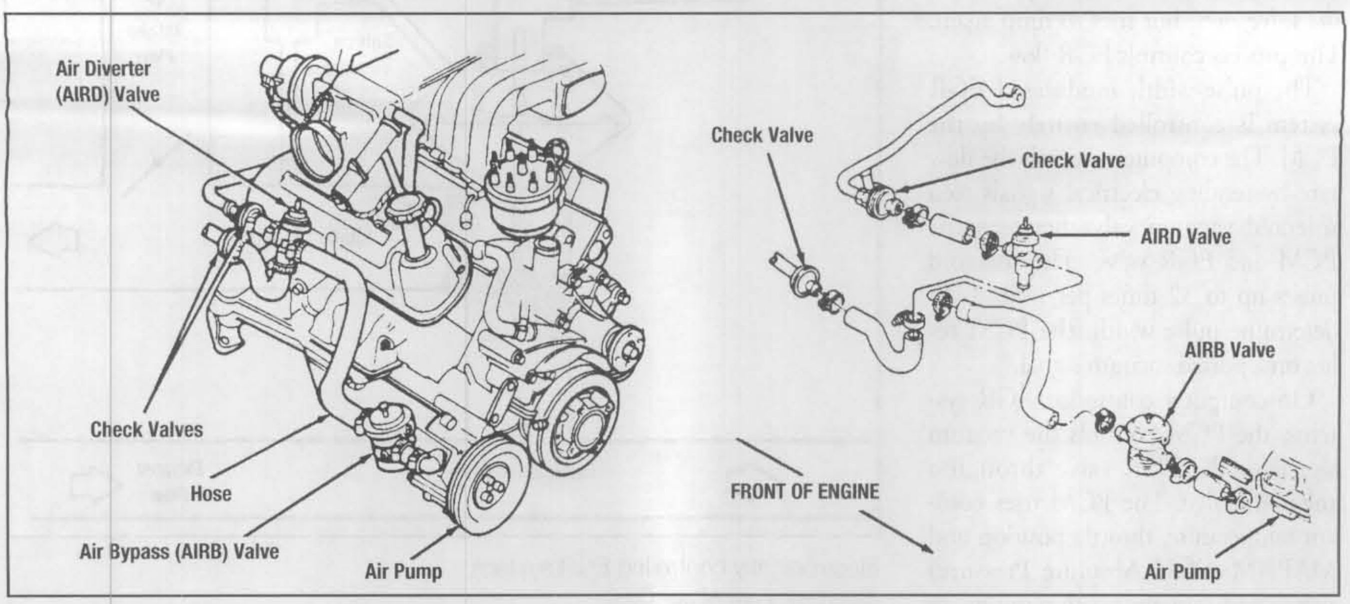
Carefully inspect the wiring, connectors and components on electronically controlled systems. This includes not only those in the EGR system, but also sensors like the Engine Coolant Temper-ature (ECT) sensor, Throttle Position (TP) sensor and MAP sensor that affect EGR operation.

When there is a failure in an EGR system, it will usually set a Diagnostic Trouble Code (DTC) in the PCM's memory, and in some cases illuminate a Mal-function Indicator Lamp (MIL) on the dash.

Repair

Repair of the EGR system is usually limited to replacement of the EGR valve, vacuum hoses and any faulty electronic system components and wiring. Consult the service manual for the vehicle in question for specific repair instructions.

One of the most common problems with EGR systems is the buildup of combustion deposits on the valve and in the manifold passages. Even when all components of the EGR system are operating properly, the engine may exhibit faulty EGR symptoms, excessive emissions or in some cases even set a DTC if the manifold passages are blocked or restricted. Any time that the EGR valve is removed, the manifold



Typical air pump AIR system. *(Courtesy: Ford Motor Co.)*

passages should be inspected and cleaned with a wire brush or scraper.

AIR INJECTION REACTOR (AIR) SYSTEM

The AIR system forces fresh air into the exhaust system to reduce HC and CO emissions. The oxygen in the fresh air combines with the post-combustion HC and CO to provide secondary oxidation, converting the residual HC and CO to water vapor and CO2. The fresh air is fed into the exhaust stream at the cylinder head exhaust ports or in the exhaust manifold just past the exhaust ports, and on some vehicles, the catalytic converter. There are two kinds of systems: pump systems, that use an engine driven or electric pump to pump air into the exhaust system, and pulse-air systems, that use the natural pulses in the exhaust system to pull air into the exhaust system.

A basic pump air injection system consists of a belt driven air pump, a diverter valve to vent pumped air to the atmosphere during engine acceleration to prevent backfire, a one-way check valve to allow air flow into the exhaust manifold or cylinder head and keep exhaust out of the air pump, and hoses and tubing to route the air to the exhaust manifolds or cylinder heads. Systems that include the catalytic converter use an Air Bypass (AIRB) valve to direct pumped air to atmosphere or to an Air Diverter (AIRD) valve that directs air to the exhaust manifolds/cylinder heads or catalytic converter.

Intake air enters the pump through a centrifugal filter positioned behind the drive pulley. The filter consists of small fins that deflect airborne contaminants away from the pump as it rotates. Under certain conditions, pump air is delivered to the exhaust manifold(s), and on some vehicles, the catalytic converter. Check valves are used to prevent hot exhaust gases from backing up into the pump. When air is being supplied to the exhaust manifold for example, the check valve opens under pump pressure. When pump air is directed away from that location, exhaust system backpressure forces the check valve closed.

The AIRB and AIRD valves contain solenoids that are controlled by the PCM. These solenoids are used to direct air flow to a specific location depending on engine operating conditions. Typically, air is directed to the exhaust manifolds/cylinder heads during open loop, when the engine is warming up. At this time, the rich air/fuel mixture that is used for engine start-up results in high amounts of unburned HC and CO in the exhaust. The oxygen in the incoming air combines with the HC and CO and oxidation continues.

The air is then switched to the catalytic converter when the engine has reached normal operating temperature and gone into closed loop.

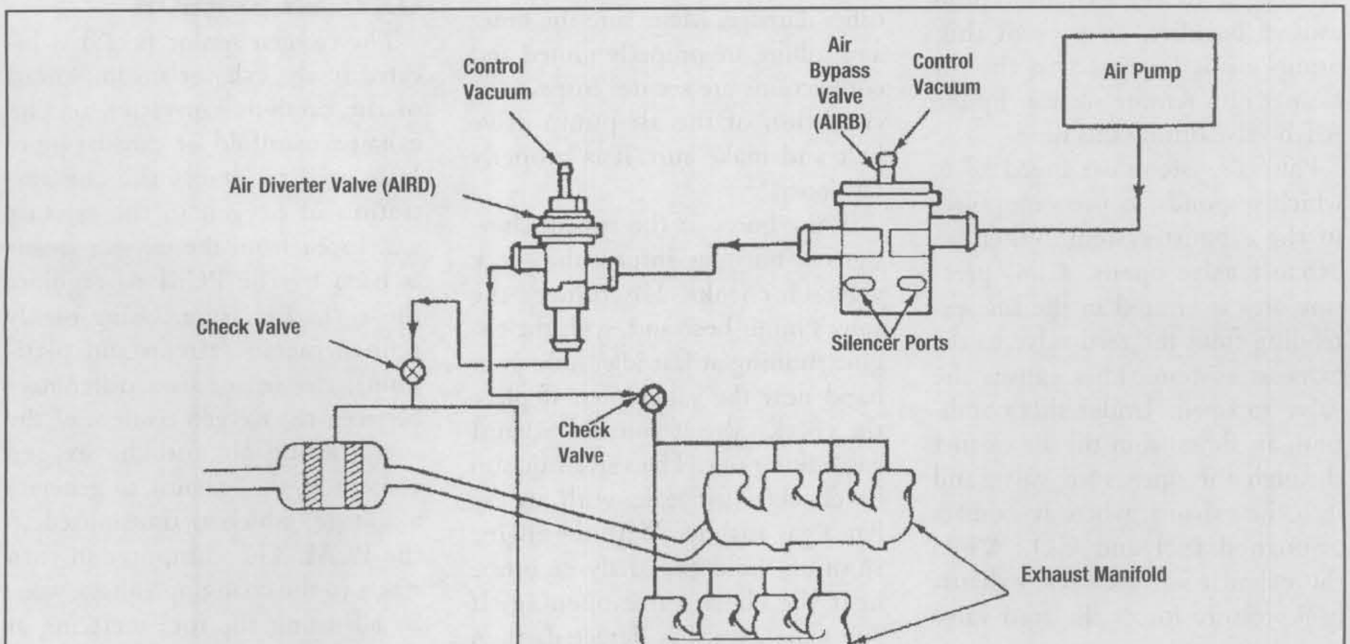
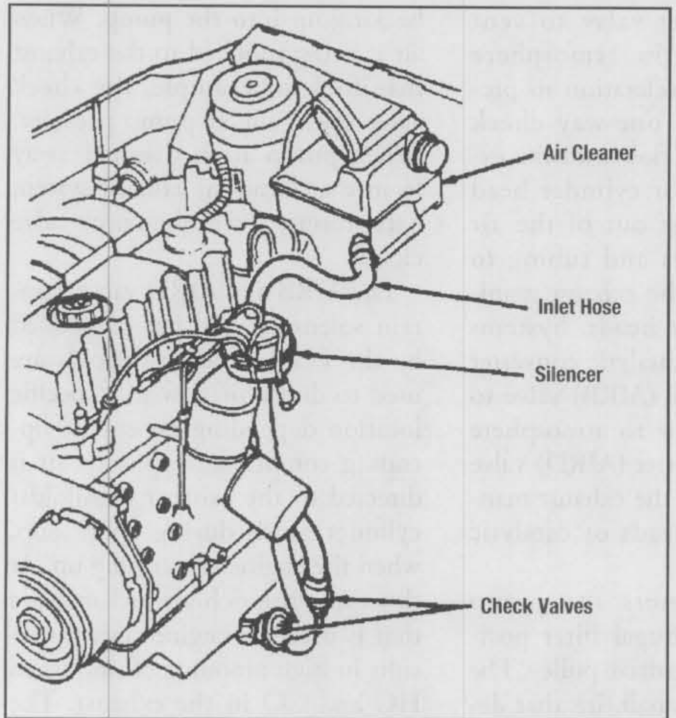


Diagram of a typical AIR system. *(Courtesy: Ford Motor Co.)*



Typical pulse-air AIR system. *(Courtesy: Ford Motor Co.)*

The air that is injected into the converter helps with the oxidation of HC and CO.

Under certain conditions, such as heavy acceleration, the addition of oxygen to the exhaust could cause a backfire. To prevent this, pump air is bypassed to the air cleaner or a remote silencer by the AIRB valve during this time.

Pulse-air systems use a reed valve, which responds to pressure pulses in the exhaust system. When an exhaust valve opens, a low-pressure area is created in the line extending from the reed valve to the exhaust system. This causes the valve to open. Under this condition, air flows from the air cleaner through the open reed valve and into the exhaust, where it oxidizes unburned fuel and CO. When the exhaust valve closes, exhaust backpressure forces the reed valve closed.

Inspection

On pump driven systems, check the vacuum hoses and wiring in the system. Check the vacuum hoses for cuts, cracks and kinks that could cause a vacuum leak or a vacuum restriction. Also check hoses for flexibility; even though a hose appears OK, it could be hardened and ready to break. Use a vacuum diagram, such as that found on the vehicle emissions control information label, to make sure all vacuum hoses are routed correctly. Carefully inspect the wiring for damage and corrosion.

Check the hoses, tubing and connections in the system for looseness, cracks, corrosion or other damage. Make sure the hoses and tubing are properly routed and connections are secure. Inspect the condition of the air pump drive belt and make sure it is properly tensioned.

If any hoses in the system show signs of burning, inspect the check valves for leaks. Disconnect the valve's input hose and, with the engine running at fast idle, hold your hand near the valve inlet. Replace the check valve if you feel exhaust gas leaking out. The valve can also be checked for leaks with an exhaust gas analyzer. With the engine running, hold the analyzer probe near the check valve opening. If any exhaust gas is detected, then the valve is leaking.

On pulse-air systems, visually inspect the hoses, tubes and valves of the system for damage and replace parts as necessary. Disconnect the hoses from the check valve inlet(s) and check the in-side of the hoses for damage from hot exhaust gases. Replace the hoses and check valve(s), if damage is found.

Leave the inlet hose(s) disconnected and start the engine. Listen and feel for exhaust at the check valve(s). Intake air pulses should be found and the check valve(s) will make a burbling sound as air is drawn in. If exhaust is heard and/or felt, replace the valve(s).

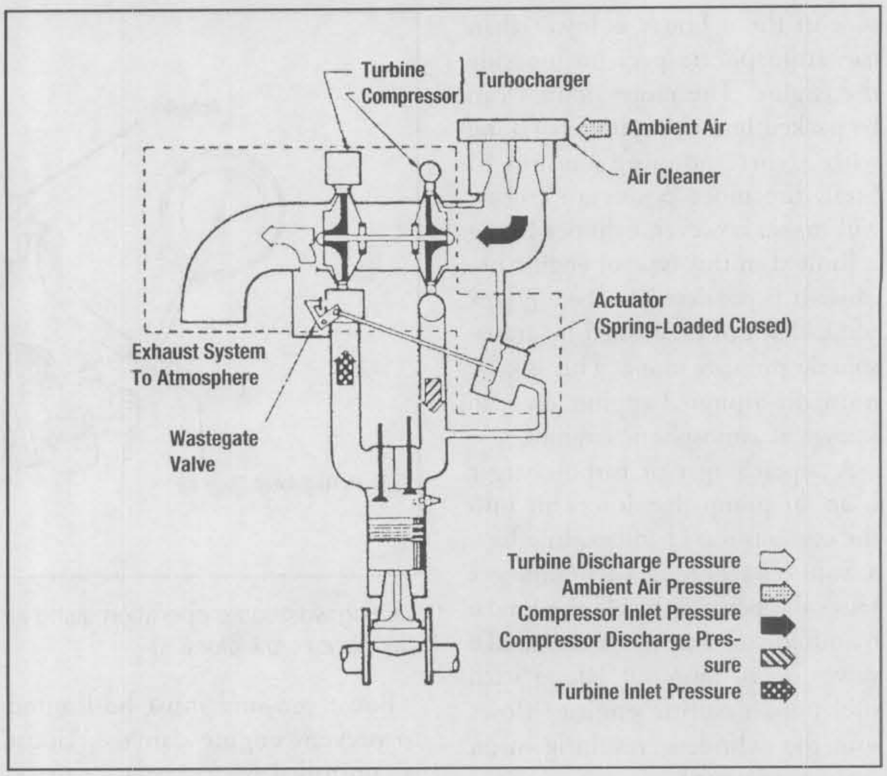
Repair

Pump driven AIR systems usually require maintenance in the form of periodic pump filter (if equipped) replacement and belt tensioning/ replacement. If any system components are found to be defective during inspection and diagnosis, then they must be replaced. Air pumps are usually not rebuilt but rather replaced as a unit. Consult the repair manual for the vehicle in question for specific repair procedures.

OXYGEN SENSOR

The oxygen sensor (O2S) is located in the exhaust stream, ahead of the catalytic converter, on the exhaust manifold or exhaust pipe. It is used to detect the concentration of oxygen in the exhaust gas. Input from the oxygen sensor is used by the PCM to regulate the air/fuel mixture. Using highly refined metals (zircon and platinum), the sensor uses differences between the oxygen content of the surrounding air and the oxygen content of the exhaust to generate a voltage, which is transmitted to the PCM. The computer in turn reacts to the changing voltage value by adjusting the fuel metering at the fuel injectors.

There is an opening in the oxygen sensor that is exposed to atmosphere. The atmosphere contains 21% oxygen, so this percentage



Turbocharger operation. *(Courtesy: GM Corp.)*

is used as a reference with which to compare the oxygen content of the exhaust. The oxygen sensor's voltage signal ranges from zero to one volt. Signals below 450 mV indicate a lean condition (excessive oxygen), while readings above 450 mV point to a rich condition (little residual oxygen).

Most newer vehicles use a heated oxygen sensor (HO2S), which contains a heating element that brings the sensor to operating temperature faster. Since an oxygen sensor must be hot (at least 500°F) in order to work, the heating element allows the PCM to use the sensor's input signals sooner. The heating element also stabilizes the temperature of the sensor during cold weather.

Several oxygen sensors may be installed on a vehicle. V6 and V8 engines can have a sensor installed in each manifold. The sensor(s) that is located closest to the engine is used to check the exhaust oxygen content as the exhaust leaves the engine and is known as a primary sensor. A secondary sensor may be installed closer to the catalytic converter to monitor the oxygen content of the exhaust before it enters the converter.

OBD II systems use a sensor mounted downstream from the catalytic converter to check its efficiency. This sensor checks the oxygen content of the exhaust after it leaves the converter and is known as a catalyst monitor. If the signal from the catalyst monitor is too similar to the signal from the primary oxygen sensor, it means that the converter is not functioning properly. This will usually set a DTC in the PCM's memory and illuminate the MIL.

Inspection

Inspect the oxygen sensor wiring for cuts and abrasion and contamination from oil or transmission fluid. Disconnect the electrical connector and inspect the terminals for corrosion, distortion and contamination. Connectors that are in poor condition should be replaced. Wiring can be repaired in some cases using a quality splice (soldering joints and using heat shrink tubing), however, many manufacturers recommend that damaged wiring in computer circuits only be replaced with a new harness.

Check the sensor for physical damage. Remove the sensor from the exhaust system and examine its appearance. Black sooty deposits on the sensor tip may indicate a rich air/fuel mixture. White gritty deposits could be an internal antifreeze leak. Brown deposits indicate oil consumption. All of these contaminants will destroy a sensor, and if the problem is not repaired the new sensor will also be destroyed.

Repair

Disconnect the negative battery cable and disconnect the oxygen sensor electrical connector. The sensor may be difficult to remove, so apply penetrating oil to the sensor threads and allow it to soak in. Use a suitable socket to remove the oxygen sensor from the manifold or exhaust pipe. Special sockets are made specifically for oxygen sensor removal and installation.

Apply a light coating of high temperature anti-seize lubricant to the sensor threads and install the sensor. Torque the sensor to specification. Connect the sensor harness connector and connect the negative battery cable. Check engine operation.

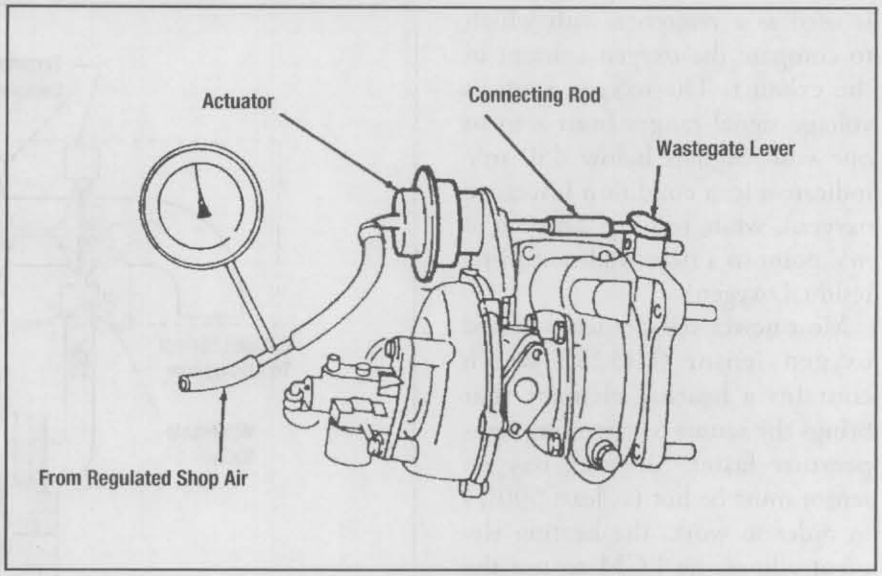
TURBOCHARGERS

In a normally-aspirated engine, when the piston moves down the cylinder on the intake stroke, a vacuum is created that draws the air into the cylinder. The air moves into the cylinder because the pressure in the cylinder is lower than the atmospheric pressure outside the engine. The more air that can be packed into the cylinders (along with a corresponding amount of fuel), the more power an engine will make, however, cylinder filling is limited in this type of engine because it is restricted to the amount of air that can be pushed by atmospheric pressure alone. This is why normally-aspirated engines are also known as atmospheric engines.

A supercharger or turbo-charger is an air pump that forces air into the combustion chamber. In effect, a supercharger or turbocharger raises the pressure inside the intake manifold, so that when the intake valves open, more air (along with fuel on a gasoline engine) flows into the cylinders, resulting in an increase in power.

Superchargers are driven off the engine's crankshaft by a belt or gears, so some of the increased power that the supercharger generates is used to drive the supercharger itself. Turbochargers are driven by the engine's exhaust, so the power increase is said to be 'free' horsepower, since the turbocharger does not use any of the horsepower it creates.

A turbocharger is divided into two sections, the turbine and the compressor. The turbine is attached to the exhaust manifold, where a turbine wheel inside the turbine housing is driven by the exhaust gas pressure and heat energy. The turbine wheel is connected by a shaft to the compressor wheel inside the compressor housing. The spinning of the turbine wheel causes the compressor wheel to spin, drawing in air to the compressor housing where it is compressed and pumped through ducts into the intake manifold. As the speed of the turbine increases, so does the pressure output, or boost, of the compressor.



Testing wastegate operation using air pressure.
(Courtesy: Ford Motor Co.)

Boost pressure must be limited to prevent engine damage. Boost is controlled by a wastegate or by shutting off the fuel supply to the engine.

A wastegate is a valve activated either by a diaphragm or a boost control solenoid. Waste-gates are either integral to the turbine housing or are remotely mounted in the exhaust system. If controlled by a diaphragm, when a preset boost limit is reached, the diaphragm moves a rod that opens the wastegate. If controlled by a boost control solenoid, which is operated by the PCM, the wastegate opens and closes in response to sensor inputs to the PCM. When the wastegate is opened, excess exhaust pressure is released from the turbine housing, directed to the exhaust system and expelled into the atmosphere.

The fuel supply to the engine can be shut off by the PCM in response to inputs regarding intake manifold pressure or engine speed. The MAP (Manifold Absolute Pressure) sensor sends a signal to the PCM when a specified intake manifold pressure is reached. The PCM then cuts the fuel supply to the engine, causing boost and engine speed to decrease. When intake manifold pressure falls below the limit, fuel delivery resumes. When boost is controlled in response to engine speed, the PCM will cut the fuel supply when inputs are received that a specific engine speed has been reached. Fuel delivery resumes when engine speed drops below the limit.

Inspection

Turbocharger related engine performance problems are caused by too little boost pressure or by overboost. These problems can usually be traced to a malfunction in the boost control system however, other components should also be inspected before any are condemned. If there is a lack of power, check for a dirty air cleaner, loose or restricted intake ducting or restricted exhaust system. Listen for unusual noises coming from the turbocharger that could be an indication that the rotating assembly is binding or dragging.

A wastegate actuator that is stuck can be the cause of too little boost and low power if it is stuck open, or overboost if it is stuck closed.

Overboost can cause detonation and possible engine damage. A wastegate can stick or bind due to carbon buildup or be inoperative due a leaking diaphragm or vacuum hose. Check for free movement of the actuator by hand if possible and check for obstructions that could prevent free movement or closure. Wastegate operation can be checked using air pressure and a pressure gauge. Consult the appropriate service manual for testing procedures and pressure specifications.

WARNING: *Turbochargers operate at extremely high temperatures. Do not touch the turbocharger while the engine is operating. Allow the turbocharger to cool sufficiently after the engine has been turned off before performing testing or servicing procedures.*

If a wastegate problem is suspected, always check the ignition timing, knock sensor and vacuum lines before replacing the wastegate. If the wastegate is controlled by a boost control solenoid and the solenoid fails, a DTC should set in the PCM's memory and the MIL may illuminate.

Most turbocharger failures are caused by lubrication problems such as oil lag, restriction or lack of oil flow and foreign material in the oil. The exhaust flow past the turbine wheel creates extremely high temperatures, which creates a harsh operating environment for the turbocharger shaft bearings. Some manufacturers connect coolant lines to the turbocharger to cool the shaft bearings, but others rely on engine oil to lubricate and to cool. With the latter design, it is a good idea to let the engine idle for about a minute before shutting it off, particularly if the vehicle has been run hard, to let oil cool the turbocharger. If the engine is shut off immediately, the oil may burn causing hard carbon particles to form, which in turn will destroy the bearings.

Repair

It is common for turbochargers to be rebuilt, but it is generally not done in the field. The turbocharger is generally serviced by replacement with a new or factory rebuilt unit.

When replacing a turbo-charger, use new gaskets and torque all fasteners to specification. The unit should be preoiled prior to installation and the engine should not be revved before proper oil pressure has been established.

To prolong turbocharger service life, the oil and filter should changed at regular intervals and the air filter should be inspected regularly. Inspect the routing and integrity of the oil supply and oil drain lines and check for oil leaks.

POWERTRAIN MOUNTS

Broken powertrain mounts can cause exhaust system noise and even exhaust component breakage. Exhaust system hangers are designed to allow the system some movement with the torque of the engine, but usually not the amount of movement that can be caused by a broken mount. Also, if broken mounts allow the powertrain to move from its intended position in the vehicle, since the exhaust system is attached to the engine, it can also move out of position and contact other components under the vehicle.

To inspect the mounts on a rear-wheel drive vehicle, carefully raise the engine just high enough to remove the weight from the mounts. This will place a slight tension on the mount's rubber cushion. Repeat the procedure at the transmission to relieve pressure on the rear mount where it attaches to the frame's crossmember.

On a front-wheel drive vehicle, perform the same procedure by raising the powertrain at the various support points along the subframe. If the rubber cushion has separated from the mounting plate, you'll be able to raise the powertrain completely off of the frame. With the weight removed from the mount, look for any signs of cracking, or splitting in the rubber section. Obviously, any of the aforementioned conditions requires that the mount be replaced.

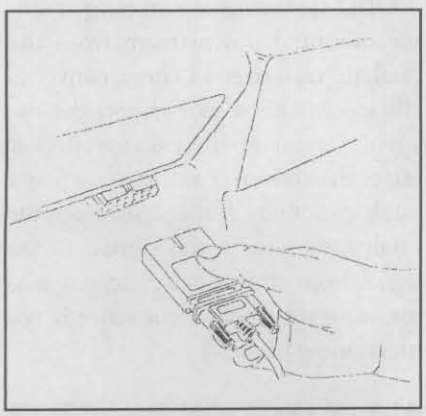
Be careful to maintain proper powertrain alignment when replacing the mounts. Incorrect alignment can cause vibration and shifting problems. Some manufacturers specify that the fasteners be installed and tightened in a certain order. Refer to the vehicle service manual for instructions.

Notes

Emissions systems diagnosis

Most exhaust system related emissions systems include sensors and actuators that are part of the computerized engine control system. Most computerized engine control systems have self-diagnostic capabilities, so when a problem is detected in the system, it is stored in the PCM's memory as a DTC.

Most of the time, when a DTC is stored in memory, the PCM will illuminate the MIL (also known as the CHECK ENGINE or SERVICE ENGINE SOON light) to show that service is needed. Under normal conditions, the MIL will come on for a few seconds when the ignition key is turned ON and during engine cranking, but should go off when the engine starts. If the MIL comes back on, it means that there is probably a DTC stored in memory.



The DLC is located under the dash on the driver's side on all OBD II vehicles. *(Courtesy: Snap-on Tools)*

If the MIL is illuminated or you suspect that there are DTCs stored in the PCM memory, the codes can be retrieved several ways. On some older non-OBD II vehicles, a jumper wire can be connected between terminals of the DLC (Data Link Connector), which causes the engine control system to go into self-diagnostic mode. The MIL then flashes and codes can be read by interpreting the flashes with a service manual. On other vehicles, the codes can be read on a digital display on the instrument panel.

A scan tool must be used to obtain codes from OBD II systems, but it is also a better choice for older vehicles as well since a scan tool can perform tests and read serial data. The scan tool may require an adapter to connect to the DLC, particularly on older vehicles, and it must be loaded with the proper software applicable to the year, make and model of the vehicle being serviced.

Once all codes are retrieved and recorded, determine whether they are hard faults or intermittent faults. Clear the PCM memory following the manufacturers recommended procedure. On OBD II vehicles codes can be cleared using a scan tool, while on some older vehicles the battery may have to be disconnected. Drive the vehicle and watch for the MIL to illuminate. Any codes that reappear are hard faults and should be serviced first.

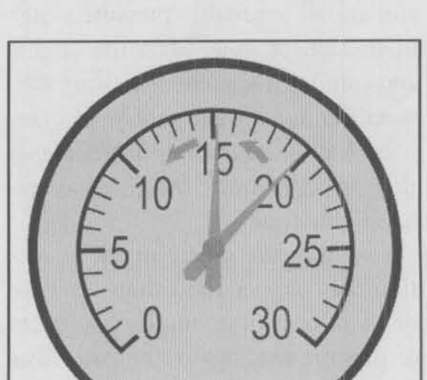
Once you have the DTCs that require diagnosis, refer to the appropriate service information to identify the systems and circuits that the DTCs represent. The diagnostic charts will describe the circuit and the fault that the code represents and contain troubleshooting procedures and tests that must be performed, to determine the cause of the malfunction.

Remember that a DTC does not indicate that there is a problem with a particular component, but rather that there is a problem in the circuit that includes the component. The problem could be an open circuit caused by a broken wire, high resistance due to dirty, corroded or loose terminals in a connector, or a short circuit caused by worn wiring insulation.

CATALYTIC CONVERTER

A catalytic converter must be replaced if it leaks, if it is clogged or if it does not function properly. If exhaust leakage is suspected, visually inspect the converter for holes, cracks or other physical damage. A telltale sign of exhaust leakage is black streaks or soot on the outside of the converter. However, if the source of exhaust leakage is not evident, you may have to start the engine and listen carefully for leaks. A small exhaust leak will make a hissing or popping noise.

While inspecting the converter, tap on it with a mallet. If the converter makes a rattling sound, it means that the ceramic substrate has



A restricted exhaust system can be identified by a steady drop in vacuum as rpm is increased.

come loose and is disintegrating, and the converter must be replaced.

The catalytic converter can become clogged from using leaded gas or if exposed to an overly rich air/fuel mixture, which can overheat the converter and melt the ceramic substrate. A clogged converter can cause a lack of power, poor fuel economy, backfiring, and if completely clogged, the engine may not run at all.

To determine if the converter is clogged, connect a vacuum gauge to the intake manifold and start the engine. At idle, there should be approximately 17-21 in. Hg. vacuum. Accelerate the engine gradually to 2000 rpm. The vacuum should momentarily drop to zero and then return to normal without delay; if there is a restriction in the exhaust system, as the engine rpm is increased the vacuum will slowly drop to zero and slowly rise to normal. When closing the throttle, the vacuum should momentarily increase and then resume the normal reading; if the exhaust is restricted the vacuum will not increase when the throttle is closed. Accelerate the engine to 2500 rpm and hold. If the vacuum reading drops 3 in. Hg below the original reading after a few minutes, there is a restriction in the exhaust system.

A backpressure test can also be used to check for a restricted exhaust system. Remove the front oxygen sensor and install a suitable pressure gauge in the sensor hole. Start the engine and compare the pressure reading with specifications for the vehicle in question. A pressure reading that is higher than specifications indicates an exhaust restriction.

To isolate the source of the restriction, disconnect the exhaust system one part at a time, until the vacuum or pressure readings are normal. Also, remember that if a converter is being replaced because it is clogged, the cause of the clog must be determined and repaired or the replacement converter will also clog. A cylinder that is misfiring due to an ignition problem (bad plug wire, etc.) or mechanical problem (valve not seating, etc.) will allow raw fuel to enter the exhaust system, and also may cause the PCM to enrich the mixture in the other cylinders because it detects the unused oxygen from the dead cylinder. This can cause serious overheating in the catalytic converter, which can melt the ceramic substrate, clogging the converter.

A simple test for whether a catalytic converter is functioning properly is by measuring the inlet and outlet temperatures. With the engine at normal operating temperature, check the temperature of the exhaust inlet and outlet surface before and after the converter using a temperature probe and a DMM (Digital Multimeter) or an exhaust pyrometer. The exhaust surface temperature should be at least 100˚F (38˚C) hotter than the intake surface temperature. If not, the converter is probably not operating at peak efficiency. Since the converter needs oxygen to convert HC and CO into CO2 and water, this may be caused by a problem in the AIR system.

WARNING: Be very careful when performing this test as catalytic converters operate at extremely high temperatures.

Another test can be performed using a four- or five-gas exhaust analyzer. For proper results with this test, there should be no defects in the vehicle's ignition, fuel or O2 feedback systems, no leaks in the exhaust system, and the analyzer must be calibrated and working 100% properly.

Disable the air injection system, if equipped, since any extra air in the exhaust will produce unreliable results. Bring the engine to normal operating temperature and make sure it enters closed loop. Connect the analyzer to the exhaust system.

Run the engine at 2000 rpm and note the exhaust readings. If the converter is cold, the readings should continue to drop until the converter reaches full operating temperature.

When the readings stabilize, check the oxygen level; it should be close to zero, indicating that the converter is using all available oxygen. There is one exception to this however. If there is no CO left for the converter to use, there may be a little oxygen in the exhaust. If there is too much oxygen and no CO in the exhaust, stop the test and verify that the system is in control. If not, perform the necessary repairs and retest.

If the system was in control, use a propane enrichment tool to bring the CO level up to about 0.5%. The oxygen level should drop to zero, because the converter now has enough CO to convert.

Once a solid oxygen reading is being obtained, snap the throttle wide open and let it drop back to idle. Check the rise in oxygen level; it should not rise past 1.5%.

If the converter passes the above tests, it is working properly. If the converter fails the tests, its efficiency is probably compromised, if it is functioning at all.

OBD II systems use an oxygen sensor mounted downstream from the catalytic converter to check converter efficiency. This sensor checks the oxygen content of the exhaust after it leaves the converter and is known as a catalyst monitor. If the signal from the catalyst monitor is too similar to the signal from the primary oxygen sensor, it means that the converter is not functioning properly.

AIR INJECTION REACTOR (AIR) SYSTEM

A faulty secondary air system can cause several problems including backfiring, excessive HC and CO emissions, and improper fuel control. The latter occurs when pump air is delivered to the exhaust manifold(s) during closed loop. This is because the oxygen sensor interprets the additional air as a lean condition. In response, the computer commands a rich mixture. Eventually, this condition will lead to poor fuel economy, rotten egg odor, an overheated converter, and/or an illuminated MIL.

A functional check of the AIR system can be performed using a four- or five-gas analyzer. Run the engine at idle and record the exhaust gas readings. Then disable the AIR system by removing the pump drive belt or pinching off the hose to the air distribution manifold. Run the engine at idle and again record the exhaust gas readings.

When the engine was run without the AIR system, there should have been 2-5% less oxygen in the exhaust and the HC and CO readings should have increased. This would mean that the AIR system was injecting air into the exhaust system and thereby functioning properly. If there was no change in the readings with and without the AIR system, then the AIR system is not functioning properly. Check the system for the cause of the malfunction.

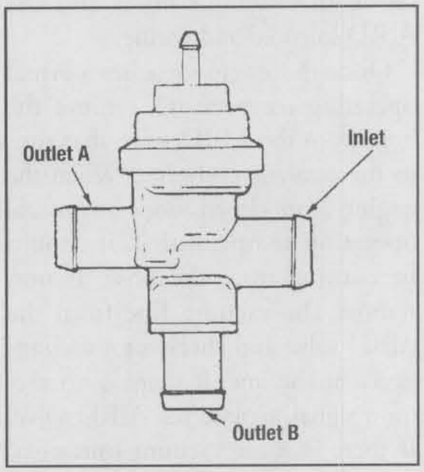
On pump driven systems, check the vacuum hoses and wiring in the system. Check the vacuum hoses for cuts, cracks and kinks that could cause a vacuum leak or a vacuum restriction. Also check hoses for flexibility; even though a hose appears OK, it could be hardened and ready to break. Use a vacuum diagram, such as that found on the vehicle emissions control information label, to make sure all vacuum hoses are routed correctly. Carefully inspect the wiring for damage and corrosion.

Check the hoses, tubing and connections in the system for looseness, cracks, corrosion or other damage. Make sure the hoses and tubing are properly routed and connections are secure. Inspect the condition of the air pump drive belt and make sure it is properly tensioned.

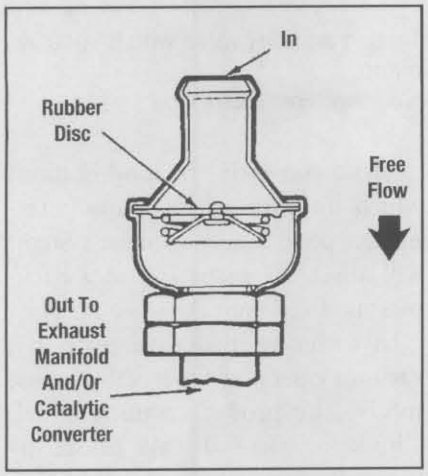
If any hoses in the system show signs of burning, inspect the check valves for leaks. Disconnect the valve's input hose and, with the engine running at fast idle, hold your hand near the valve inlet. Replace the check valve if you feel exhaust gas leaking out. The valve can also be checked for leaks with an exhaust gas analyzer. With the engine running, hold the analyzer probe near the check valve opening. If any exhaust gas is detected, then the valve is leaking.

If the system passes a visual inspection, check the air pump output. Start the engine and remove the outlet hose from the pump. Air should be coming from the pump outlet. A low pressure gauge can be used to measure the pump pressure. A properly functioning pump should typically produce 1-3 psi, but always check manufacturer's specifications for the vehicle in question. If pressure is low, check the air filter for clogging before condemning the pump.

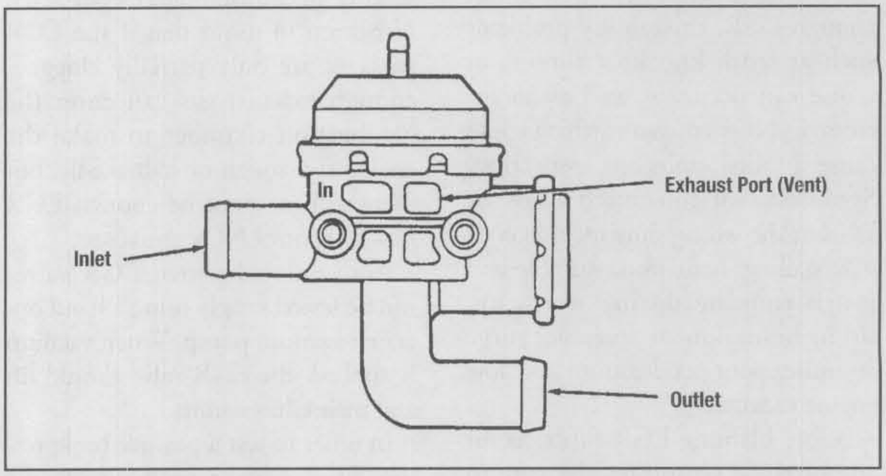
Start the engine and remove the vacuum hose from the Air Bypass (AIRB) valve. There should be a vacuum signal with the engine running. Reinstall the vacuum line and remove the outlet hose from the AIRB valve. Air should be coming from the hose. Reinstall the hose and open and quickly release the throttle. There should be a sudden release of air from the AIRB valve vent if there is air supply from the pump and the



Typical AIRD valve.
(Courtesy: Ford Motor Co.)



Cutaway view of an air check valve.
(Courtesy: Ford Motor Co.)



Typical AIRB valve.
(Courtesy: Ford Motor Co.)

valve is working properly.

While the engine is warming up from a cold start, remove the hose from the Air Diverter (AIRD) valve that goes to the cylinder head or exhaust manifold. Air should be coming from the hose. If not, check for a vacuum signal at the vacuum hose to the valve. If there is an adequate vacuum signal (refer to manufacturer's specifications) replace the AIRD valve. If there is no vacuum signal, check the vacuum hoses and the AIRD solenoid and wiring.

Once the engine reaches normal operating temperature, remove the hose from the AIRD valve that runs to the catalytic converter. When the engine is in closed loop, at normal operating temperature, air should be coming from the hose. If not, remove the vacuum line from the AIRD valve and check for a vacuum signal at the line. If there is no vacuum signal, replace the AIRD valve. If there is some vacuum (measured with a vacuum gauge), check the AIRD solenoid and wiring.

EXHAUST GAS RECIRCULATION (EGR) SYSTEM

When EGR function is not controlled properly, there is either not enough EGR when it is required, or there is too much EGR or EGR at the wrong time. When there is not enough EGR, driveability problems such as spark knock or surging at cruise can occur, as well as an increase in NOx emissions which could cause a failed emissions inspection. Symptoms of too much EGR or EGR at the wrong time include poor idle, stalling, hesitation, stumble and rough running during warm up, tip-in hesitation or stumble, surge at cruise, poor acceleration, and low engine vacuum.

Before blaming EGR function for any of these symptoms, be sure to check the basics as other components and systems could also be the cause. For example, carbon buildup in the combustion chamber could be the cause for that spark knock, and vacuum leaks could be the cause of hard starting and hesitation. Check for DTCs (Diagnostic Trouble Codes) that could narrow your troubleshooting focus.

Basically, the EGR system can malfunction in four ways: problems with EGR passages, problems with the EGR valve itself, problems with the vacuum control system and problems with the computer control system.

If you lift up on the EGR valve diaphragm (after protecting your fingers with a glove or shop towel) with the engine idling and there is no effect on idle speed, the EGR passages are probably clogged with carbon. Check the NOx readings using a five-gas exhaust analyzer. Run the engine until it reaches normal operating temperature and then increase engine speed to 2000 rpm. If the EGR system is functioning properly, the NOx readings should generally be below 1000 ppm (parts per million). If the NOx reading is above 1000 ppm and the EGR valve is functioning, then the EGR passages are probably clogged.

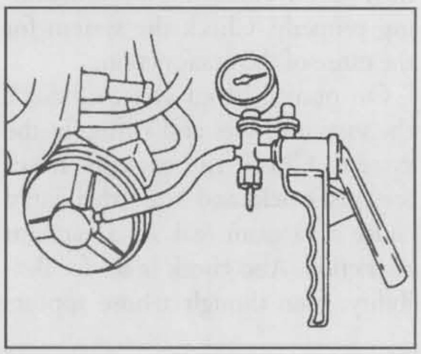
Remove the valve and clean the EGR passages until they are clear. Carbon stuck between the pintle and seat can also cause the EGR valve to not fully close causing poor idle, stalling or stumble after cold start. Also keep in mind that if the EGR passages are only partially clogged, enough exhaust gas can enter the combustion chamber to make the engine run rough or stall at idle, but there still may not be enough EGR flow to control NOx emissions.

Conventional ported EGR valves can be tested simply using a hand operated vacuum pump. When vacuum is applied, the EGR valve should lift and maintain vacuum.

In order to test a positive backpressure EGR valve, a restriction in the exhaust system must be created to simulate exhaust backpressure. Place a suitable object in the tailpipe to restrict exhaust flow, then connect a hand operated vacuum pump to the EGR valve and apply vacuum. The vacuum should hold providing the diaphragm is not leaking. Start the engine and place the transmission in gear. The engine should stall when the restriction created exhaust backpressure builds up enough to open the EGR valve at idle.

To test a negative backpressure EGR valve, disconnect the vacuum hose from the EGR valve and connect a hand operated vacuum pump. With the engine off, apply vacuum and feel for diaphragm movement with your finger. The diaphragm should move up and hold vacuum. Have an assistant operate the ignition key. When the engine is cranked, you should feel the diaphragm drop, closing the valve.

Note that damage to the exhaust system that restricts exhaust flow (dented or collapsed pipe, clogged catalytic converter) or modifications which improve exhaust flow (aftermarket performance exhaust system) will affect the operation of a backpressure EGR valve.



Testing an EGR valve with a vacuum pump.
(Courtesy: Ford Motor Co.)

In order to function properly, vacuum operated EGR valves must receive the proper vacuum signal. Check for vacuum leaks caused by loose, broken, pinched or missing vacuum hoses. Check the hose routing against the schematic shown on the emissions label. Most systems use a TVS (Thermal Vacuum Switch) to prevent EGR when the engine is cold. If the switch is operating properly, it should not allow vacuum flow until the engine reaches a specific operating temperature.

Computer controlled EGR systems usually have a vacuum control solenoid controlled by the PCM. To test operation, use a tee fitting to connect a vacuum gauge into the hose at the EGR valve. With the engine warm, place the transmission in gear, apply the brakes and accelerate the engine. There should be a vacuum reading on the gauge. When the electrical connector at the solenoid is disconnected, vacuum should vent off and the gauge reading should be zero.

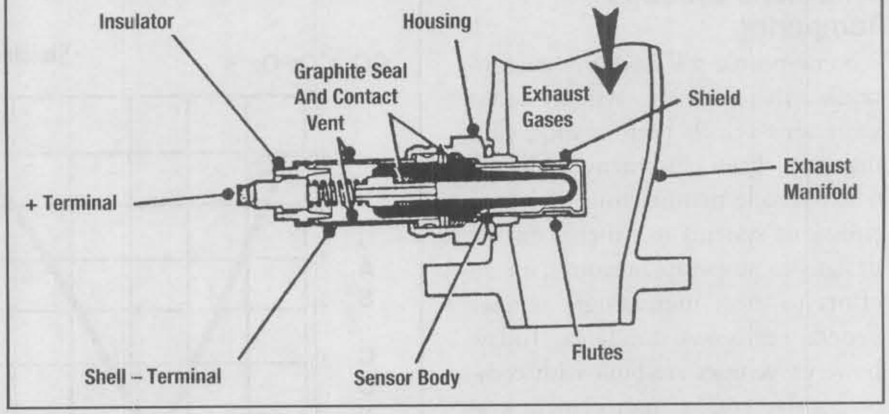
Some GM systems use a solenoid with a vent filter that can cause driveability problems if the filter becomes restricted, which could trap vacuum and hold the EGR valve open. Test these solenoids by covering the solenoid vent with your finger. The engine should stumble or stall. If it doesn't, the vent solenoid is probably defective.

Some Chrysler and import computer controlled systems use a backpressure transducer. These systems are also tested in the same way as a positive backpressure EGR valve, using an exhaust flow restriction. Restrict the exhaust flow at the tailpipe, start the engine and unplug the solenoid. The engine should stall.

OXYGEN SENSOR

Since the oxygen sensor signal is used by the PCM to regulate the air/fuel mixture, a faulty oxygen sensor can cause the PCM to meter the fuel delivery incorrectly, causing overly rich or lean misfire conditions.

Inspect the oxygen sensor wiring for cuts and abrasion and contamination from oil or transmission fluid. The cavity in the sensor that senses the oxygen content in the atmosphere must be clear for the sensor to function properly. Disconnect the electrical connector and inspect the terminals for corrosion, distortion and contamination.



Cutaway view of a typical oxygen sensor.

Start the engine and allow it to run until it reaches normal operating temperature. The oxygen sensor must be tested with the engine at normal operating temperature and the engine control system in closed loop.

Connect the positive lead of a DMM to the sensor signal wire and the negative lead to the engine ground. The voltage reading should fluctuate as the oxygen sensor detects varying levels of oxygen in the exhaust stream.

If the sensor reads above 550 mV constantly, the air/fuel mixture is probably too rich or the sensor may be contaminated from carbon caused by rich air/fuel mixtures, the use of leaded fuel, or from silicones found in antifreeze or sealers. If the sensor voltage reads below 350 mV constantly, the air/fuel mixture may be too lean, there may be an exhaust leak near the sensor, diluting the reading, there may be high resistance in the wire between the sensor and the PCM, or the sensor may be defective.

Under normal conditions, the sensor should fluctuate high and low. If the sensor voltage does not fluctuate, the sensor may be defective. However, before condemning the sensor, try forcing the system rich by restricting the air intake or injecting propane into the air inlet. The voltage reading should increase to 800-900 mV. Then, force the system lean by pulling off a large vacuum hose. The voltage reading should drop to 200-300 mV.

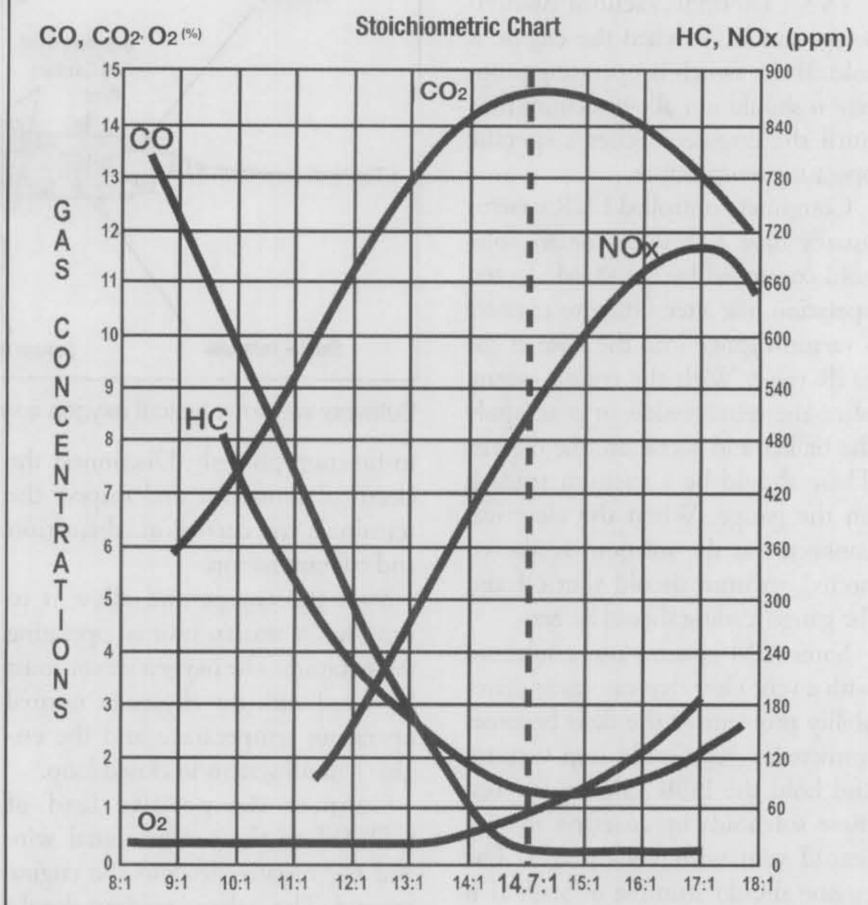
If the voltage did not change accordingly when the system was forced rich or lean, then the sensor is defective and must be replaced. Remove the sensor from the exhaust system and examine its appearance. Black sooty deposits on the sensor tip may indicate a rich air/fuel mixture. White gritty deposits could be an internal antifreeze leak. Brown deposits indicate oil consumption. All of these contaminants will destroy a sensor, and if the problem is not repaired the new sensor will also be destroyed.

OBD II systems use an oxygen sensor mounted downstream from the catalytic converter to check converter efficiency. This sensor checks the oxygen content of the exhaust after it leaves the converter and is known as a catalyst monitor. If the converter is functioning properly, the voltage signal from the catalyst monitor will fluctuate very little in comparison to the signal from the primary oxygen sensor. If the signal from the catalyst monitor is too similar to the signal from the primary oxygen sensor, it means that the converter is not functioning properly.

Emissions Systems Tampering

Some people still have the misconception that emissions systems necessarily hurt vehicle performance. This may have been true many years ago when vehicle manufacturers adapted emissions systems to existing engine designs as stop-gap measures, in an effort to meet increasingly stricter Federal emissions standards. Today, however, vehicles are built with comprehensive engine management systems that include emissions systems in their design. Disabling or removing an emissions system component from a modern vehicle will in most cases hurt, not improve, vehicle performance.

Besides affecting performance, it is also against the law to remove or disable any part of an emissions control system. In most cases, signs of emissions system tampering will be obvious, such as the replacement of the catalytic converter with a straight pipe, a missing AIR pump belt or plugs installed in the exhaust manifold where the AIR pipes were installed. However, in other cases evidence of tampering may not be so obvious. In these situations, consult a factory service manual or a manual like those used at state motor vehicle inspection facilities, which lists the emissions equipment that is installed on vehicles at the manufacturer.



An air/fuel ratio of 14.7:1 represents the chemically correct proportions of air and fuel necessary to become a stoichiometric mixture. This ideal combination of air and fuel allows an engine to produce the most power, best economy and least exhaust emissions per pound of gasoline. When the amount of air in the mixture is less than 14.7 lbs., the mixture is said to be 'rich'. Conversely, air in proportions greater than 14.7 lbs. Will cause the mixture to be 'lean'.

Notes

Exhaust system fabrication

PIPE BENDING

NOTE: The following is a description of general pipe bending procedures. Always follow the specific instructions provided by the pipe bender manufacturer.

There are three methods of bending exhaust pipes, program card, pattern and custom. Program cards are provided by the pipe bender manufacturer and contain all the information necessary to duplicate the exhaust pipes found on most vehicles. The number of the program card is found by looking up the make, model, year and engine in the card catalog. There are separate cards for each pipe in the exhaust system.

The program card lists the length and diameter of the pipe, the distance between the center of the bends, and the rotation and depth of the bends in degrees. There may also be remarks that describe bending instructions for peculiar applications. Using this information, the technician can make a pipe identical to the one which was originally installed by the vehicle manufacturer.

Pattern bending means measuring and comparing the old exhaust pipe to make a new one. This may be necessary when making a pipe for an older or low production vehicle for which no program card exists.

Custom bending is necessary when there is no program card or existing pipe. Applications for which custom bending may be necessary include installing other than the original type of system on the vehicle, such as when a dual exhaust system is installed on a vehicle that originally came with single exhaust, or if the tailpipe rotted and fell off of a vehicle for which there is no program card.

Safety Precautions

Certain safety precaution must be observed when operating a pipe bender. Always wear eye protection, gloves and protective shoes or boots. Do not wear loose fitting clothing that could be snagged by the machine or a pipe.

Makes sure the area around the machine inside the length of the pipe being bent is clear. The pipe will move as it is bent, so make sure beforehand that the pipe will not contact anything during the bending procedure. Do not operate the machine without the safety guards in place and keep your hands clear of the bending dies when the machine is in motion.

Use caution when handling the ends of pipes that have just been cut, as they can be sharp.

Program Bending

Using make, model, year and engine information, look up the program card in the card catalog for the pipe that is needed, and remove the card from the card file. Thoroughly read and make sure you understand all of the information on the card before proceeding with the bending operation.

Select a straight length of pipe in the outside diameter listed on the program card, which is 12-in. longer than the cutoff point listed on the program card. Wipe the excess oil and dirt from the pipe and then turn on the bending machine.

Install the dies and back shoes on the machine that correspond with the diameter of the pipe and the radius of the first bend that will be made. The die fits on the hydraulic ram that pushes against the pipe during the bending operation, while the back shoes mount on the swing gates and clamp the pipe in position during bending, and also form the outside radius of the pipe. Position the pipe on the machine, seam side up, and engage the die using the ram until the pipe is held firmly, with the greater portion of the pipe extending from the left side of the machine.

Using a felt-tipped pen, mark the points on the pipe where the bends will be made, as listed on the program card. At each point, position the marker on the pipe and then rotate the pipe until the mark is completely around the pipe. The last mark made is the final cutoff point for overall length.

Release the pipe from the machine and reposition it so it extends from the right side of the machine, seam side up, with the first bending mark between the back shoes. Engage the die until the pipe is firmly held in place. Position the rotation dial at the right end of the pipe, at least 12-in. from the final bend. Rotate the dial so that the indicator points to zero, which should also line up with the pipe seam. Secure the dial to the pipe.

Adjust the depth-of-bend setting on the machine according to the information on the program card. Operate the machine until the bend is made. Some machines must be operated manually, while others will automatically make the bend, reverse the ram and then stop, with the touch of a button.

Retract the ram until the pipe is free of the die, then slide the pipe until the next bend mark is between the back shoes. Change the die if a different radius die is called for by the program card. Engage the die until the pipe is snug, but still can be rotated. Turn the pipe until the rotation setting corresponds with the information on the program card.

Adjust the depth-of-bend setting according to the program card, and bend the pipe. Repeat bending operations until the last bend has been made. When all bends are completed, remove the rotation dial and cut the pipe at the cutoff line. Finish the ends of the pipe, as required.

Pattern Bending

Measure the outside diameter of the old pipe. Dies come in different radiuses, so fit the bends of the old pipe into the various radius dies in that diameter, until the necessary die(s) is identified. Install the die and back shoes that will be used for the first bend on the pipe bending machine. Measure the overall length of the old pipe and select a new pipe that is long enough for the job.

Place the new pipe in the bending machine and position it so the largest portion extends from the right side of the machine. Place the old pipe over the back shoes so that the center of the first bend is between the shoes. Push the new pipe from the left side of the machine until the end of the pipe lines up with the end of the old pipe.

Position the first bend of the old pipe on top of the back shoes, parallel with the new pipe, then gradually bend the new pipe until the bends of both pipes match. Retract the ram and move the pipe to the left. Place the old pipe on top of the back shoes and line up the center of the second bend with the center between the back shoes. Line up the first bend on both pipes, then rotate the new pipe until it is parallel with the old pipe. Clamp the new pipe into position with the die.

Position the second bend of the old pipe on top of the back shoes, then gradually bend the new pipe until the bends of both pipes match. Repeat bending operations until the last bend has been made. When all bends are completed, cut the pipe to match the length of the old pipe. Finish the ends of the pipe, as required.

Custom Bending

Since there is no program card or old pipe to go by, inspect the area where the pipe is supposed to fit and try to visualize the pipe routing in relation to the components under the vehicle. Look for things like heat shields on the underside of the vehicle and old hangers that can indicate how the pipe was routed.

Hold a length of stiff wire (welding rod works well) up to the exhaust system component to which the new pipe will be attached. Bend the wire to match the projected routing of the new pipe, making sure to allow enough clearance around other components. To make the new pipe, use the wire in the same manner as the old pipe described under pattern bending.

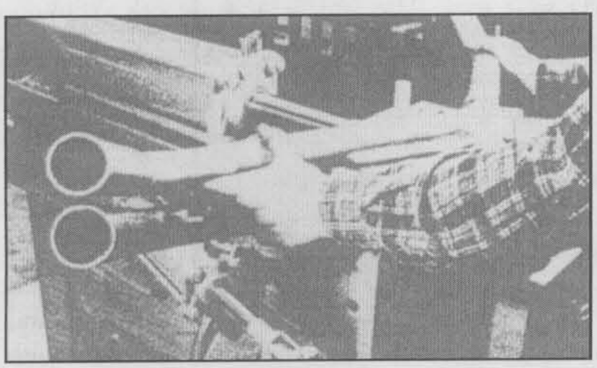
Once the new pipe is made, perform a test fit under the vehicle to ensure the routing is as projected and that there will be no interference with other components.

End Finishing

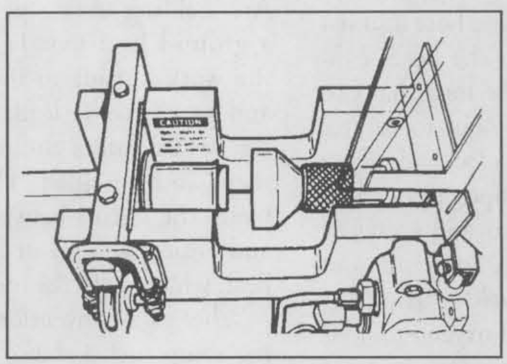
There are a variety of ways that exhaust system components are connected. A common type is the slip-joint connection, where an inner pipe fits inside an outer pipe. If both pipes are the same diameter, then the end of one pipe must be made larger to fit over the other pipe. Other connections use gaskets and require that the end of the pipe be flared or flanged to make a good seal.

To expand, reduce or flare the ends of exhaust pipes, pipe bending machines have swaging and expanding attachments. These attachments come with tooling that can end finish a pipe for any kind of connection. Besides the expansion for slip joint connections, other common end finishes are flares, flat flares, male ball joints, female ball sockets, flare flanges and flat flanges.

Follow the manufacturers instructions for pipe positioning, tooling combinations and swaging and expanding procedures. If a flange is used to secure a pipe, such as an exhaust pipe to an exhaust manifold, be sure that the flange is installed before the end of the pipe is flared.



Here a technician uses an old exhaust pipe as a pattern for making a new one.
(Courtesy: Huth Manufacturing Corp.)



A pipe bender swaging attachment forming a manifold gasket flange.
(Courtesy: Huth Manufacturing Corp.)

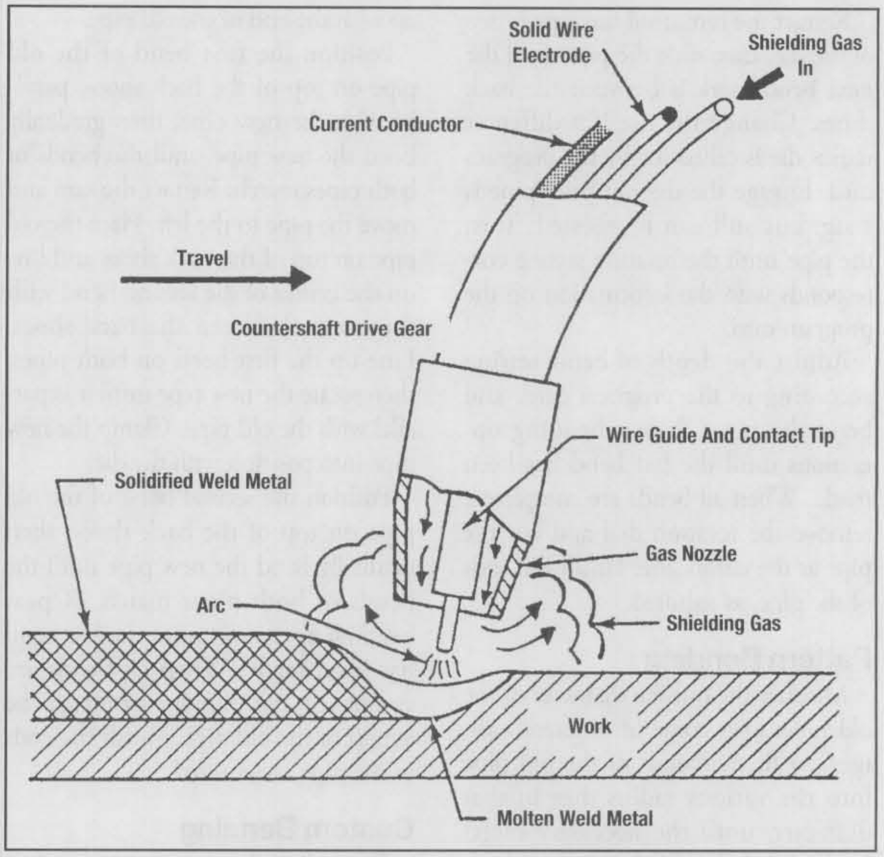
WELDING AND CUTTING

Besides being clamped or bolted together, exhaust system components can also be welded together. Welding is the joining of two pieces of metal by heating them until they become molten, while melting new metal into the joint at the same time. The new metal, referred to as rod, must be the same kind of metal as that being welded; steel rod is used to weld steel, stainless steel rod is used for stainless steel, and aluminum rod for aluminum. The two most common types of welding used for exhaust system work are oxyacetylene gas welding and MIG (Metal Inert Gas) welding.

Oxyacetylene welding uses a flame of oxygen and acetylene gas to melt metal. Acetylene gas is highly flammable by itself, but combined with oxygen it can create a gas flame of 5600-6300°F. The oxygen itself does not burn, but rather speeds up the burning of the acetylene. The oxygen and acetylene are contained in two separate tanks and each tank has a set of two gauges mounted on a regulator. The pressure in the tanks is very high, 2200 psi in the oxygen tank and 250-325 psi in the acetylene tank, and the regulator is used to reduce these pressures to those that can be used in the torch.

Hoses connect the regulators with the torch. The acetylene hose is red and the oxygen hose is green. The fitting on the acetylene hose also has left-hand threads so the hoses cannot be mixed up. The torch has two valves operated by knobs to control gas flow and a threaded end where tips of various size openings can be attached. The oxygen and acetylene mix inside the torch and come out the tip, with the welder using the valves to control the oxygen-to-acetylene ratio. The tip size is selected according to the gas flow and flame shape required by the particular job.

In gas welding operation, the torch is lit and then the flame is adjusted using the torch valves. The flame is used to heat the metals to be joined until they begin to form a molten puddle. With his other hand, the welder feeds a piece of filler rod into the molten puddle as the flame is moved along the joint.



MIG welder operation.
(Courtesy: Lincoln Electric Co.)

MIG welding is a form of arc welding, in fact its technical name is Gas Metal Arc Welding (GMAW). Arc welding uses a power source, a ground lead that is attached to the work outside of the weld area, and an electrode lead, with which the welder strikes an arc against the metal to be welded. The arc completes the circuit between the leads and creates an area of concentrated heat, which melts the metal.

Whereas a conventional arc welding setup uses a clamp and a piece of welding rod for the electrode, which must be replaced as it is used, the MIG welder uses wire as the electrode, which is constantly fed through a cable and gun and used up at the weld. A flow of shielding gas also comes from the gun, which prevents contamination of the weld.

A MIG welder includes a power source, a ground wire and clamp, the gun and the cable that attaches the gun to the machine. The machine contains a roll of wire and a bottle of compressed shielding gas. The wire and gas are both fed to the gun through the cable.

Wire is available in steel, stainless steel and aluminum in various diameters and is selected according to the thickness of the material being welded. The most common shielding gas that is used is CO_2 because it is the least expensive, but argon and mixtures of gases such as argon and CO_2 and argon and helium are also used.

Both gas and MIG welding have their advantages and disadvantages. Gas welding is harder to master and requires good hand-eye coordination. It is also easy to distort the surface being welded if you are not careful. MIG welding has a shorter learning curve and since you don't have to feed the welding rod with your other hand, you can use it to position the components to be welded while you tack them together.

One distinct advantage of a MIG welder for exhaust system work is an attachment available on some machines that can attach a new stud to an exhaust manifold. The old stud is cut off flush with the manifold, then a special attachment on the MIG gun that holds a hollow stud is positioned on the remains of the old stud. When the gun is turned on the wire feeds through the stud and welds it to the old stud. This can prevent the frustration that could ensue from trying to drill out the old stud and tap the hole from underneath the car or save the time it would take to remove, repair and reinstall the exhaust manifold.

The biggest advantage of gas welding is that it is more versatile. An oxyacetylene torch can not only be used to join metal parts, but can also be used to heat and cut them. One of the biggest obstacles faced in exhaust system repair is nuts that are rusted to fasteners. Heating the nut with a torch expands the metal and breaks the bond with the stud, allowing the nut to be removed. And simply by installing a cutting attachment, an oxyacetylene torch can be used to quickly cut off old exhaust system components.

Safety Precautions

Anything that involves an open flame, flying sparks and compressed flammable gases can be dangerous if the proper safety precautions are not taken. Wear a fire-resistant long sleeve shirt or jacket, leather gloves and steel-toed safety shoes. Since the exhaust system is underneath the vehicle, you will be welding upside down, so a welding helmet, and not just welding goggles, should be used so that your entire face is protected. Do not tuck your pants into boots or wear pants with cuffs, as sparks could get caught and start a fire.

Remove any flammable materials from the work area and have a fire extinguisher and water source handy. When using a gas welder, be careful when welding or cutting around fuel tanks and lines, brake lines and electrical components. Make sure oxygen and acetylene tanks are secured with a chain to a work bench or welding cart.

Oxyacetylene Welding

Begin by selecting the welding tip appropriate for the thickness and type of metal to be welded and the proper type and size welding rod. A welding tip with a larger opening provides more heat than a smaller tip because it covers more area. A larger tip also requires higher gas pressures. The tip must be matched to the job. If it is too small, the metal may not get hot enough to puddle and if it is too large, the metal may melt too fast, the weld can be hard to control and the metal may distort.

The filler rod must be of the same material as the metal being welded. As a general rule, use filler rod that is the same diameter as the thickness of the metal being welded.

Each gas cylinder regulator has two gauges, one that shows cylinder pressure and one that shows the torch pressure. Turn the regulator pressure adjusting screw out all the way, stand away from the ends of the cylinders and slowly open the cylinder valves. Open the oxygen valve all the way and the acetylene valve about 11/2 turns.

Open the acetylene torch valve one turn and then turn the acetylene regulator screw until the gauge reads the pressure that is recommended for the torch tip that will be used. Close the acetylene torch valve. Open the oxygen torch valve one turn and then turn the oxygen regulator screw until the gauge reads the pressure that is recommended for the torch tip that will be used. Close the oxygen torch valve.

Hold the torch in your right hand if you are right-handed or your left hand if you are left-handed and hold the torch striker in the other hand. Never use an open flame to light a torch. Open the acetylene valve on the torch 1/2 turn and operate the striker at the torch tip. A flame should appear along with particles of soot. Open the oxygen valve on the torch a small amount and the soot should disappear.

At this time you will probably have a wide yellow flame with a large cone near the tip. This flame is acetylene rich and not ideal for welding. Open the torch oxygen valve to gradually add more oxygen to the flame. The ideal flame should be blue at the end opposite the tip and white near the tip of the torch, with a light blue inner cone. This is called a neutral flame and should make a purring sound. If too much oxygen has been added, the inner core of the flame will be small and it will make a hissing sound.

Pull down your helmet and position the tip of the torch about an inch away from the joint to be welded. Hold the torch at approximately a 45 degree angle to the work. When the metal begins to puddle, insert the welding rod into the center of the hot puddle and then pull it out. Move the torch in the direction that the flame is pointing so that the metal ahead is being heated. Continue inserting the rod into the puddle and pulling it out as the bead advances along the joint.

When welding is completed, close the acetylene torch valve first and then close the oxygen valve. If the oxygen valve is closed first, a small amount of gas could be left in the tip that could ignite. If you will not be welding again for some time, close the gas cylinder valves.

MIG Welding

CAUTION: to prevent damage to electronic components, always disconnect the negative battery cable before using an electric welder on a vehicle.

Before you begin welding, make sure the machine contains the proper type of wire for the material that is to be welded. Attach the ground cable clamp to a clean metal surface close to the area that will be welded. Open the shielding gas cylinder valve all the way and adjust the gas regulator to the proper flow rate for the material and wire that will be welded. Set the amperage and wire feed speed that is recommended by the manufacturer for the material that will be welded.

Bring the tip of the gun to the joint to be welded until the wire sticking out of the gun contacts the joint. Hold the gun at about a 35 degree angle to the work. Flip your helmet down and pull the trigger on the gun. As soon as the trigger is pulled, the wire will arc to the metal and it will begin to melt and puddle. Move the gun forward along the joint, forming a bead. In most cases you should tack the parts together and then check to make sure everything fits properly before sealing the joint with a bead all the way around.

The wire speed and amperage may have to be varied from that recommended by the manufacturer in order to achieve satisfactory welds. Generally, when the wire speed is correct, the machine will make a sizzling sound. If the wire speed is too fast, there will be a loud crackling sound. If you burn through the metal, the amperage may be too high or you may be moving the gun too slow. If the weld does not seem to be penetrating the surface, the amperage may be too low or you may be moving the gun too fast.

Cutting Operations

After many years in service, most exhaust system components rust together at their connections. When replacement is necessary, in some cases it may be easier to cut off components rather than try to separate them the conventional way. Exhaust system components can be cut using a hacksaw, cold chisel, air chisel, cutoff wheel or cutting torch. The challenge is to cut off the unwanted parts without damaging the good parts.

Some exhaust system components use slip-joint connections. In these connections an inner pipe fits inside an outer pipe or an inner pipe fits inside the muffler. When separating these connections, care must be taken not to damage the part that is not being replaced. With these types of connections, if the part being replaced is the inner pipe, then the pipe can be cut in half just outside the outer pipe. Cut a slit in the remaining part of the pipe, which will allow it to be pulled from the muffler or outer pipe. There are slitting tools that are specially made for this purpose. If replacing the muffler or outer pipe, use the slitting tool to cut the outer pipe or muffler opening, which will allow it to be removed from the inner pipe.

By far the quickest method of cutting is the oxyacetylene cutting torch. A cutting torch has an extra oxygen supply operated by a lever instead of a valve. The cutting torch tip has small holes surrounding a large hole in the middle. The smaller holes are for the conventional oxyacetylene flame, which is used to heat the area to be cut. The area of the metal is heated until it is cherry red, then the welder presses the cutting lever and sends a stream of pure oxygen through the center hole, which cuts the metal.

Because oxyacetylene cutting always creates a shower of sparks, be sure to clear the area around the cutting operation of anything flammable and have a fire extinguisher on hand. Be careful when cutting around fuel tanks, fuel lines, brake lines and electrical components.

Before beginning the cutting operation, select the cutting tip that is recommended for the thickness metal that will be cut. Reset the gas cylinder regulator valves for 2-3 psi acetylene and 15-20 psi oxygen. The large increase in oxygen pressure is necessary because of the large amount that is used in the cutting process.

Light the torch in the same manner described under oxyacetylene welding. Hold the torch about 1/8-in. away from the part to be cut and heat the area until it is cherry red. Squeeze the lever and cut the component, using the jet of oxygen coming from the torch.

Notes

Exhaust system installation

SPECIFICATIONS AND MATERIALS

When replacing exhaust system components, it may be necessary to refer to the manufacturer's specifications to make sure the correct components are properly installed. These specifications can be found in the manufacturer's parts and service manuals and aftermarket parts manuals.

These specifications will usually show the following:

- exhaust system configuration (single/dual exhaust, pipe size, clamped or welded)
- routing (which side of the vehicle, tailpipe exit location)
- muffler and resonator location
- number and location of catalytic converters
- number and location of oxygen sensors
- location of heat shields
- location of hangers
- options.

In an effort to prolong the life of exhaust system components, many manufacturers are now using stainless steel, aluminized steel or coated steel in their construction. When replacing these components, make sure the new parts are of the same material. If parts made of different materials are substituted, they may not last as long and may cause rattles or leaks due to differing temperature expansion and contraction rates.

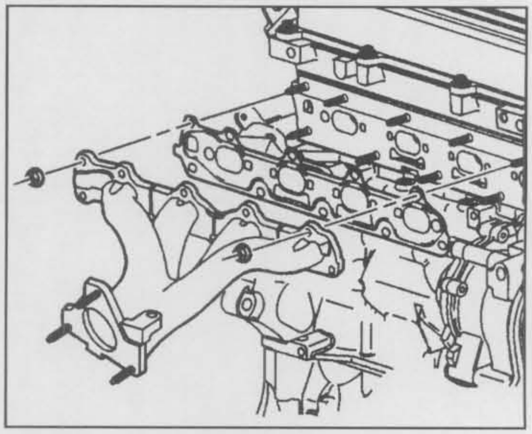
All exhaust systems are designed to have some backpressure. Components like the muffler create backpressure as they reduce engine noise. A properly designed system will have a minimum amount of backpressure and at the same time provide quiet operation. Although most vehicles have more than adequate power these days, there will always be drivers who will want to install larger diameter exhaust pipes and freer flowing mufflers to reduce backpressure and gain performance.

In some cases, however, doing this may create problems. The rate that exhaust gases pass through the exhaust system is calculated when the engine management system is designed. Less exhaust backpressure may have an unintended effect on engine performance. For example, modifications that improve exhaust flow will affect the operation of a backpressure EGR valve, and cause spark knock.

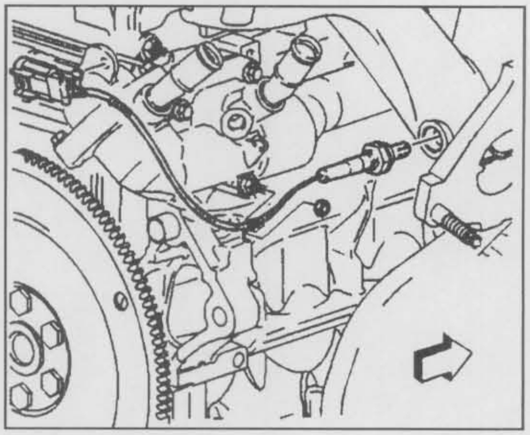
EXHAUST COMPONENT INSTALLATION

Install the exhaust manifold to the cylinder head, using new gaskets, as required. Install the attaching bolts/nuts and torque to specification in the proper sequence. Install the oxygen sensor, AIR pipe(s) and accessory brackets, as necessary. Install the heat shield, if equipped.

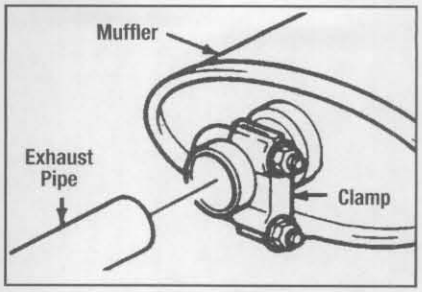
Install the heat riser or heat valve, if equipped, using a new gasket. Install the exhaust pipe to the manifold using a new gasket. Install and snug the exhaust pipe flange nuts but do not tighten them yet. Support the exhaust pipe using a suitable jack.



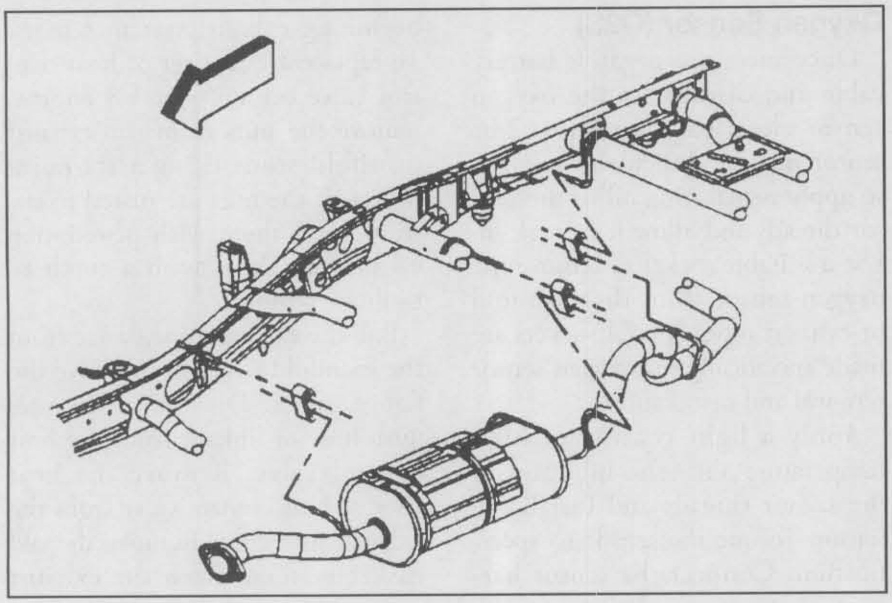
Exhaust manifold installation.
(Courtesy: GM Corp.)



Installing the oxygen sensor to the exhaust manifold.
(Courtesy: GM Corp.)



Attaching an exhaust pipe to a muffler with a slip-joint and clamp.
(Courtesy: GM Corp.)



Typical exhaust system hangers. *(Courtesy: GM Corp.)*

The catalytic converter can be attached to the exhaust pipe with a slip-joint and clamps or be secured to the exhaust pipe with bolts and/or nuts. If the converter is attached with bolts and/or nuts, use new gaskets or seals when the new converter is installed. If connected using a slip-joint, make sure that the inner pipe is inserted fully into the outer pipe. Install the clamp but do not fully tighten it yet.

The muffler may be connected to the converter using another pipe or the connecting pipe may be part of the muffler. Attach the pipe to the converter with bolts and/or nuts and new gaskets or seals, or install a clamp over the slip-joint, making sure the inner pipe is fully inserted. Loosely attach the system to the hangers, as required, but do not tighten the fasteners yet.

Install the tailpipe, if equipped. Attach the pipe to the muffler in the same manner as the previous exhaust components and also attach it to the hanger(s). Make sure the exhaust system is properly aligned and that there is enough clearance between the system and all underbody components. Take the necessary time to properly position all exhaust system components. Hangers should be used to support the exhaust system, but not to draw components into place. Hangers that are used this way will be under constant stress and will fail prematurely.

Tighten the fasteners at all connections, beginning at the front of the vehicle and working your way toward the rear. Always make sure the inside pipe is fully inserted in a slip-joint connection and the clamp is positioned around both pipes, but not too close to the edge of the outer pipe. Position the clamp so that the ends of the U-bolt will not contact other components or snag objects that may pass under the vehicle while driving. Tighten the clamp only enough to secure the connection. Over tightening may distort the pipes and cause an exhaust leak.

Install all heat shields and oxygen sensors. Start the engine and check for exhaust leaks. Road test the vehicle and check for vibration, rattles or other noises.

EXHAUST EMISSIONS SYSTEMS COMPONENT INSTALLATION

Air Injection Reactor (AIR) System

On pump driven systems, check the vacuum hoses and wiring in the system. Check the vacuum hoses for cuts, cracks and kinks that could cause a vacuum leak or a vacuum restriction. Also check hoses for flexibility; even though a hose appears OK, it could be hardened and ready to break. Use a vacuum diagram, such as that found on the vehicle emissions control information label, to make sure all vacuum hoses are routed correctly. Carefully inspect the wiring for damage and corrosion. Replace all hoses and repair wiring, as necessary.

A pump driven AIR system has steel tubing with fittings called manifold(s) that thread into the exhaust manifold or cylinder head. On some vehicles there is also a line to the catalytic converter. A check valve usually threads onto the other end of the manifold. Hoses secured with clamps connect the air pump, bypass and diverter valves and the manifold(s). When replacing the manifold(s) and/or hoses, tighten all connections and check for leaks after installation.

The air pump is mounted to the engine with brackets. Make sure the pump and brackets are secure and make sure the pump pulley aligns with the engine drive pulley. After installing a new pump, adjust the belt tension. Some air pumps have a remote filter. Inspect the filter and replace as necessary.

Exhaust Gas Recirculation System

Visually inspect the vacuum hoses and, if equipped, wiring in the EGR system. Check the vacuum hoses for cuts, cracks and kinks that could cause a vacuum leak or a vacuum restriction. Also check hoses for flexibility; even though a hose appears OK, it could be hardened and ready to break. Use a vacuum diagram, such as that found on the vehicle emissions control information label, to make sure all vacuum hoses are routed correctly. Carefully inspect the wiring, connectors and components on electronically controlled systems. Replace all hoses and repair wiring, as necessary.

Repair of the EGR system is usually limited to replacement of the EGR valve, vacuum hoses, EGR tube and any faulty electronic system components and wiring. Consult the service manual for the vehicle in question for specific repair instructions. Always use a new gasket when installing the EGR valve and torque all fasteners to specifications.

One of the most common problems with EGR systems is the buildup of combustion deposits on the valve and in the manifold passages. Even when all components of the EGR system are operating properly, the engine may exhibit faulty EGR symptoms, excessive emissions or in some cases even set a DTC if the manifold passages are blocked or restricted. Any time that the EGR valve is removed, the manifold passages should be inspected and cleaned with a wire brush or scraper.

Oxygen Sensor (O2S)

Disconnect the negative battery cable and disconnect the oxygen sensor electrical connector. The sensor may be difficult to remove, so apply penetrating oil to the sensor threads and allow it to soak in. Use a suitable socket to remove the oxygen sensor from the manifold or exhaust pipe. Special sockets are made specifically for oxygen sensor removal and installation.

Apply a light coating of high temperature anti-seize lubricant to the sensor threads and install the sensor. Torque the sensor to specification. Connect the sensor harness connector and connect the negative battery cable. Check engine operation.

Early Fuel Evaporation (EFE) System

The two most common problems with EFE systems are stuck heat risers or heat control valves and manifold heat passages that are clogged with carbon. A heat riser or heat control valve that is stuck open can cause slow warm-up, stalling, hesitation and increased emissions, while one that is stuck closed can cause overheating, detonation, burned valves and manifold warpage. If the manifold heat passages are clogged, it will have the same effect as a stuck open heat riser or heat control valve.

Always wait until the exhaust system is cool to the touch before beginning exhaust system repairs. To replace a heat riser or heat control valve on a V6 or V8 engine, remove the nuts from the exhaust manifold studs using a six-point socket. If the nuts are rusted to the studs, soak them with penetrating oil or heat them with a torch to facilitate removal.

Pull the exhaust pipe flange from the manifold studs and remove the flange gasket. Disconnect the vacuum hose or linkage from the heat control valve. Remove the heat riser or heat control valve from the exhaust manifold. Remove the old gasket material from the exhaust manifold.

Install the new heat riser or heat control valve using a new gasket. Connect the vacuum hose or linkage to the heat control valve. Install the exhaust pipe to the manifold using a new gasket and install and tighten the exhaust manifold flange nuts. Start the engine and check for leaks and proper heat riser or heat control valve operation.

The heat riser or heat control valve on in-line four- or six-cylinder engines may be part of the exhaust manifold or bolt to the exhaust manifold. Consult a service manual for specific repair instructions.

Notes

Exhaust system repair regulations

CATALYTIC CONVERTER REQUIREMENTS

When the air/fuel mixture is introduced into the engine, we are mixing air composed of nitrogen (78%), oxygen (21%) and other gases (one%) with the fuel, which is 100% HC (Hydrocarbons), in a semi-controlled ratio. As the combustion process is accomplished, power is produced to move the vehicle while the heat of combustion is transferred to the cooling system. The exhaust gases are then composed of N_2 (Nitrogen, a diatomic gas), the same as was introduced in the engine, CO_2 (Carbon Dioxide), the same gas that is used in beverage carbonation, and H_2O (water vapor). The N_2, for the most part, passes through the engine unchanged, while the O_2 (Oxygen) reacts (burns) with the HC and produces the CO_2 and the water vapors. If this chemical process would be the only process to take place, then exhaust emissions would be harmless.

In the real world however, the air/fuel mixture never burns completely. This is due to variables such as charge density, cylinder temperature, and engine load, among others. Consequently, during the combustion process, other compounds are formed which are considered dangerous. These pollutants are HC, CO (Carbon Monoxide), NOx (Oxides of Nitrogen), SOx (Oxides of Sulfur), and engine particulates.

The air/fuel ratio of 14.7:1 is the ideal combination of air and fuel that allows an engine to produce the most power, best economy, and least exhaust emissions per pound of gasoline. This is why modern-day fuel systems are designed to deliver this mixture under most operating conditions.

When the amount of air in the mixture is less than 14.7 lbs., the mixture is said to be 'rich.' Conversely, air in proportions greater than 14.7 lbs. will cause the mixture to be 'lean.' While maintaining the air/fuel ratio at 14.7:1 helps keep emissions at their lowest levels, this mixture is too lean for conditions such as cold starting and acceleration. In these situations, engines require a richer mixture to provide acceptable performance.

The performance of a catalytic converter is directly related to the air/fuel ratio. When the mixture is lean, the converter is more efficient at reducing HC and CO. However, lean mixtures cause an increase in combustion chamber temperature, resulting in higher NOx emissions. In contrast, the lack of oxygen in a rich mixture makes it more difficult for the converter to oxidize HC and CO, while the additional fuel inhibits the production of NOx. That's why the proper air/fuel mixture is essential for the converter to operate at peak efficiency.

The most common symptom of a defective catalytic converter is the inability to pass a state emissions test. Although there are several different tests that can help determine converter efficiency, the best way to be sure the converter is the source of an emissions failure is to eliminate all other possibilities first. On OBD II vehicles, the catalyst monitor is the best barometer for evaluating converter performance.

The catalyst monitor is an oxygen sensor mounted downstream from the catalytic converter to check converter efficiency. This sensor checks the oxygen content of the exhaust after it leaves the converter. If the converter is functioning properly, the voltage signal from the catalyst monitor will fluctuate very little in comparison to the signal from the primary oxygen sensor. If the signal from the catalyst monitor is too similar to the signal from the primary oxygen sensor, it means that the converter is not functioning properly.

The U. S. Environmental Protection Agency (EPA) has established certain guidelines for catalytic converter replacement. In addition, some state and local laws exceed Federal EPA requirements. If testing has determined that a catalytic converter has failed, be sure you are familiar with the legal requirements before proceeding with replacement.

According to the Federal Clean Air Act, vehicle manufacturers are required to provide two emissions related warranties, a production warranty and a performance warranty. The production warranty means that the manufacturer guarantees that the vehicle meets all emissions standards in effect when it is first sold. The performance warranty means that the manufacturer will repair a vehicle if it fails an emissions test that is a part of a state inspection program. For model year 1995 and newer vehicles, the warranty is two years or 24,000 miles for all emissions related parts, except catalytic converters and other specified parts, which are covered for eight years or 80,000 miles.

The manufacturer can only deny warranty coverage if there is evidence that the catalytic converter failed due to the vehicle owner's misuse of or failure to maintain the vehicle.

According to the EPA guidelines, a replacement catalytic converter can only be installed under the following conditions:

- If the catalytic converter is missing
- If a state or local emissions inspection program has determined that the converter needs replacement
- If the OEM warranty has expired and a legitimate need for replacement has been appropriately documented. For 1995 and later vehicles, the OEM warranty is eight years or 80,000 miles.

It is against the law to replace an OEM catalytic converter that is properly functioning.

When a replacement catalytic converter is installed, the EPA also specifies that:

- The replacement catalytic converter must be installed in the same location as the original one
- The replacement converter must be of the same type as the original (two-way, three-way, etc.)
- The replacement converter must be the proper one for the vehicle as specified by the manufacturer
- If equipped, the converter must be properly connected to the AIR system
- The replacement converter must be installed with any other required converter for the application
- The replacement converter must be accompanied by a warranty information card, which must be completed by the converter installer.

In addition to the above, there are certain paperwork requirement related to catalytic converter replacement. Before replacing the converter, the customer's authorization for the repair must be obtained in writing. The warranty card must be filled out by the installer and mailed to the converter manufacturer. The EPA documents that came with the converter must be kept by the installer, along with a copy of the repair order, for six months. The old converter must be kept for 15 days. The customer should keep their copy of the repair order and the warranty information for future reference.

EXHAUST RELATED EMISSIONS SYSTEMS REQUIREMENTS

The advances made in engine management and emission control technology over the past two decades have resulted in the steady decline of vehicle pollutants. Unfortunately, while HC, CO, and NOx output per vehicle is lower than ever before, emissions reductions have been offset by the extraordinary increase in the number of cars and trucks on the road. However, the vehicle pollution problem is not as much a result of increased volume as it is a consequence of greater numbers of maintenance-neglected vehicles. Inspection/Maintenance programs help weed out these vehicles by subjecting them to an annual emissions test. According to the requirements of the 1977 Clean Air Act, implementation of I/M programs is compulsory in those areas of the United States unable to meet the National Ambient Air Quality Standards (NAAQS).

As part of the emissions inspection, the vehicle may be inspected for the presence of all required emissions systems components that were installed on the vehicle at the time of manufacture. It is against the law to remove or disable any part of an emissions control system. In most cases, signs of emissions system tampering will be obvious, such as a missing AIR pump belt or plugs installed in the exhaust manifold where the AIR pipes were installed. However, in other cases evidence of tampering may not be so obvious. In these situations, consult a factory service manual or an emissions system application manual.

Before any repairs are begun, notify the customer if any evidence of tampering is found, and explain to them that the emissions system(s) in question must be repaired.

EXHAUST SYSTEM CONFIGURATION REQUIREMENTS

As stated previously, it is against the law to remove or disable any part of an emissions control system. Make sure all catalytic converters that were installed on the vehicle at the time of manufacture are installed and functioning properly. Substituting a straight pipe for a catalytic converter or gutting a converter in an effort to reduce backpressure is illegal. If a catalytic converter fails, it must be replaced with one that is documented to meet EPA requirements.

Before modifying an exhaust system in any way (larger diameter pipes, single to dual exhaust) from the factory configuration, consult state and local laws. Altering the flow path or altering the exhaust system in any way may be illegal. Some exhaust system modifications, such as substituting freer flowing mufflers, can result in increased noise, which can also violate laws in some areas.

Notes

Prepare yourself for ASE testing with these questions on EXHAUST SYSTEMS

1. Which of the following is the **MOST** important consequence of a rust hole in an exhaust system?
   A. excessive noise
   B. escaping exhaust gas
   C. failed state inspection
   D. repair cost

2. An exhaust system is being disassembled for repairs. Technician A says that a six-point socket should be used on threaded fasteners. Technician B says that a slitting tool should be used at slip-joint connections to prevent damage to pipes that must be saved. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

3. Two technicians are inspecting an exhaust system. When he taps on the muffler with a mallet, Technician A hears noise coming from inside the muffler and says that it is most likely rotting out from the inside. Technician B says that he hears noise coming from inside the catalytic converter when he taps on it with a mallet and says that the converter is rotting out from the inside. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

4. Two technicians are listening to a tapping noise coming from the top end of a V8 engine. Technician A says the noise could be a valve needing adjustment. Technician B says the noise could be an exhaust leak. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

5. A vehicle's exhaust system is being tested for a restriction, using a vacuum gauge connected to the intake manifold. All of the following are indications of a restricted exhaust **EXCEPT:**
   A. When the engine is gradually accelerated to 2000 rpm, the vacuum reading slowly drops to zero and slowly returns to normal.
   B. When the throttle is closed, the vacuum does not increase.
   C. When the throttle is closed, the vacuum momentarily increases and then resumes the normal reading.
   D. When the engine is accelerated to 2500 rpm, the vacuum reading drops 3 in. Hg below the original reading after a few minutes.

6. Two technicians are inspecting an exhaust manifold. The cylinder head mating surface is found to have a few small nicks and is slightly warped and there is a broken stud at the exhaust manifold outlet. Technician A says that the cylinder head mating surface of the manifold must be resurfaced. Technician B says that the broken stud must be drilled out and the hole tapped or fitted with a thread insert and a new stud installed. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

7. A carbureted vehicle hesitates and stalls when it is cold and seems to take a long time to warm up. Technician A says that the EFE heat passages are probably clogged. Technician B says that the heat control valve is stuck open. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

8. Technician A says that a heat shield can cause an exhaust manifold to crack. Technician B says that a heat shield can cause an exhaust manifold to warp. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

Prepare yourself for ASE testing with these questions on EXHAUST SYSTEMS

9. Under which of the following conditions is exhaust gas recirculation required?
   A. cold engine at part throttle
   B. warm engine at idle
   C. warm engine at part throttle
   D. warm engine at wide open throttle

10. Technician A says that the AIR system forces air into the intake ports. Technician B says that the AIR system reduces spark knock. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

11. A turbocharged vehicle performs poorly and lacks power. All of the following could be the cause **EXCEPT:**
   A. restricted intake duct
   B. a wastegate that is stuck open
   C. failed turbocharger shaft bearings
   D. a wastegate that is stuck closed

12. All of the following are symptoms of insufficient exhaust gas recirculation **EXCEPT:**
   A. spark knock
   B. stalling
   C. surging at cruise
   D. increased NOx emissions

13. When testing a catalytic converter with an exhaust pyrometer, the difference between the surface temperatures of the converter inlet and outlet should be ______ with the engine at normal operating temperature.
   A. 50°F (10°C)
   B. 100°F (38°C)
   C. 150°F (66°C)
   D. 200°F (93°C)

14. When an EGR valve diaphragm is raised with the engine idling, there is no effect on idle speed. Technician A says that the EGR valve is bad and should be replaced. Technician B says that the EGR passages are clogged with carbon. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

15. A vehicle with an AIR system backfires during acceleration. Which of the following should the technician check?
   A. operation of exhaust manifold check valve(s)
   B. output pressure of the air pump
   C. operation of the air bypass valve
   D. the AIR manifolds for restriction

16. With a DMM connected, the O2 sensor reads above 550 millivolts constantly, Technician A says that the fuel mixture is probably too rich. Technician B says the fuel mixture may be too lean or there may be an exhaust leak near the sensor. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

17. Which of the following is used to prevent EGR operation when the engine is cold?
   A. EGR valve position sensor
   B. EGR vacuum solenoid valve
   C. EGR vacuum regulator
   D. thermal vacuum switch

18. A new exhaust system is being installed. Technician A says that the U-bolts of the exhaust clamps should be positioned so as not to snag on anything passing beneath the vehicle. Technician B says that if there is not enough clearance between the exhaust system and other components under the vehicle, that the hangers can be used to draw the system into place. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

19. A customer complains of a vibration *coming from* under her vehicle, especially during acceleration. During inspection, a broken exhaust system hanger is found. Technician A says that the broken hanger could have allowed the exhaust system to contact other components, causing the vibration. Technician B says that a broken powertrain mount could be the cause of the vibration. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

Prepare yourself for ASE testing with these questions on EXHAUST SYSTEMS

20. With the engine off, vacuum is applied to a positive backpressure EGR valve using a hand held vacuum pump. Technician A says that the EGR valve should open. Technician B says that the valve will not open unless a restriction is created in the exhaust and the engine is started. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

21. All of the following are indications of a catalytic converter problem **EXCEPT:**
   A. The converter shell appears bluish.
   B. The converter makes a rattling noise when struck with a mallet.
   C. There is little difference between the inlet and outlet temperatures.
   D. The catalyst monitor signal is stable.

22. A vehicle is suspected of having a restricted exhaust system. Technician A says that a vacuum gauge and pressure gauge can both be used to determine if the exhaust system is restricted. Technician B says that the cause of the restriction could be a dent in an exhaust pipe, a collapsed exhaust pipe or a clogged catalytic converter. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

23. A customer wants to install a larger diameter exhaust system on his vehicle in an effort to reduce backpressure and improve performance, but wants to make sure the vehicle will not have any driveability problems. Technician A says that as long as all emissions equipment is properly installed, there will be no problems. Technician B says that increasing the pipe diameter may cause driveability problems. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

24. Technician A says that if a muffler was welded on to the original exhaust system, then its replacement must also be welded on. Technician B says that when installing a complete new exhaust system, the fasteners should be fully tightened only after all components are installed and checked for clearance. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

25. An oxygen sensor is being replaced. Technician A says that white, gritty deposits on the old sensor's tip is a sign of a possible internal coolant leak. Technician B says that high temperature anti-seize lubricant should be applied to the new sensor's threads prior to installation. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

26. Which of the following types of end finishes is needed for an exhaust pipe to fit over another pipe in a slip-joint connection?
   A. flare
   B. female ball socket
   C. flat flange
   D. expansion

27. A late model vehicle owned by a good customer has failed the emissions test at a state inspection facility. After testing, the technician determines that the catalytic converter must be replaced. Which of the following should he do first?
   A. Remove the old converter.
   B. Obtain the customer's authorization for the repair.
   C. Order a replacement converter from his parts supplier.
   D. Check the model year of the vehicle and the odometer reading.

Prepare yourself for ASE testing with these questions on EXHAUST SYSTEMS

28. Before using a MIG welder, all of the following must be adjusted to suit the material that will be welded **EXCEPT:**
   A. shielding gas
   B. amperage
   C. gun movement
   D. wire feed

29. Two technicians are discussing a computerized engine control system. Technician A says that a DTC corresponds to a part that requires service. Technician B says that multiple codes should be serviced in numerical order. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

30. When bending a pipe using a program card, the last mark made on the pipe represents the:
   A. center of last bend
   B. cutoff point
   C. rotation dial position
   D. slip-joint expansion depth

31. All of the following steps are required to set up an oxyacetylene welder for cutting with a cutting torch **EXCEPT:**
   A. Clear the area around the cutting operation of anything flammable.
   B. Install the cutting attachment.
   C. Select the proper cutting tip.
   D. Raise the acetylene pressure to 15-20 psi.

32. Technician A says that an OEM converter can be replaced with an aftermarket converter as long as the manufacturer's emissions warranty has expired. Technician B says that a replacement catalytic converter can be positioned anywhere in the exhaust system as long as it functions properly. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

33. During the inspection of the exhaust system on a five-year-old Ford F150, the tailpipe is found to be missing. Technician A says that since the pipe is missing, the only option is to custom bend a new pipe. Technician B says that a new pipe should be made using a program card. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

34. Two technicians are discussing welding equipment. Technician A says it is easier to tack components together using a MIG welder. Technician B says that an oxyacetylene welder can be used to heat parts as well as weld and cut. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

35. How long must an installer keep an old catalytic converter after it has been removed from a vehicle?
   A. 15 days
   B. 30 days
   C. 60 days
   D. 90 days

36. A customer wants to install a larger diameter exhaust system on his vehicle in an effort to reduce backpressure and improve performance, but wants to make sure the vehicle will still pass state *inspection*. Technician A says that larger diameter pipe may not pass inspection. Technician B says that as long as emissions equipment like the catalytic converter is properly installed in the correct location and the vehicle passes the emissions test, the vehicle will pass inspection. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

Prepare yourself for ASE testing with these questions on EXHAUST SYSTEMS

37. All of the following are requirements related to catalytic converter replacement **EXCEPT:**
   A. The EPA documents that came with the converter must be kept by the installer, along with a copy of the repair order, for three months.
   B. Before replacing the converter, the customer's authorization for the repair must be obtained in writing.
   C. The replacement converter must be of the same type as the original (two-way, three-way, etc.).
   D. The replacement converter must be accompanied by a warranty information card, which must be completed by the converter installer.

38. All of the following are evidence of emissions system tampering **EXCEPT:**
   A. substituting a straight pipe for a catalytic converter
   B. installing a plate on an intake manifold where the EGR valve was located
   C. installing a replacement catalytic converter with clamps instead of welding
   D. removing an AIR system and installing plugs in the manifold holes

39. After exhaust system installation, the engine should be started and all of the following should be checked for **EXCEPT:**
   A. rattles
   B. vibration
   C. routing
   D. leaks

40. Technician A says that the most common symptom of a defective catalytic converter is the inability to pass a state emissions test. Technician B says that the Federal Clean Air act requires the manufacturer to replace a failed converter without question if the vehicle is still within the emissions warranty coverage period. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

Notes

Answers to Study-Guide Test Questions

1. The correct answer is B. The most important consequence of a rust hole in an exhaust system is that it can allow harmful exhaust gases to enter the passenger compartment. Engine exhaust contains CO, which can cause headache, nausea and drowsiness, and if enough is ingested, can even result in unconsciousness and death. Any exhaust system damage that results in exhaust leakage must be repaired immediately.

2. The correct answer is C, both technicians. Always use six-point sockets to remove exhaust system fasteners, as a 12-point socket will only round off the corners of a corroded fastener. When separating slip-joint connections, care must be taken not to damage the part that is not being replaced. With these types of connections, if the part being replaced is the inner pipe, then the pipe can be cut in half just outside the outer pipe. Then, using a slitting tool, cut a slit in the remaining part of the pipe, which will allow it to be pulled from the muffler or outer pipe. If replacing the muffler or outer pipe, use the slitting tool to cut the outer pipe or muffler opening, which will allow it to be removed from the inner pipe.

3. The correct answer is A. When inspecting an exhaust system, tap on the muffler with a mallet and listen for the sound of loose rust particles. Mufflers usually rot out from the inside, so even if the outside of the muffler appears OK, it still may be ready for replacement. Technician B is incorrect because if a rattling sound is heard coming from a catalytic converter when it is struck with a mallet, it means that the ceramic substrate has come loose and is disintegrating.

4. The correct answer is C. A tapping noise that does not dissipate after the engine warms up could be caused by worn valvetrain components or excessive valvetrain clearance. A similar type noise can sometimes be caused by an exhaust leak at the exhaust manifold/cylinder head juncture.

5. The correct answer is C. When the throttle is closed on a properly operating vehicle with a good exhaust system, the vacuum should momentarily increase and then resume the normal reading. All of the other answers describe indications of a restricted exhaust system.

6. The correct answer is D, neither technician. Technician A is wrong because although resurfacing may repair the cylinder head mating surface, it is not the only solution. Since the damage was very slight, using exhaust manifold gaskets would probably be enough to compensate for the marring and warpage. Technician B is also incorrect because drilling out the stud is also not the only option. A stud welding attachment that is available on some MIG welders can be used to quickly weld on a new stud.

7. The correct answer is C, both technicians. The two most common problems with EFE systems are stuck heat risers or heat control valves and manifold heat passages that are clogged with carbon. A heat riser or heat control valve that is stuck open can cause slow warm-up, stalling, hesitation and increased emissions. If the manifold heat passages are clogged, it will have the same effect as a stuck open heat riser or heat control valve.

8. The correct answer is C, both technicians. An exhaust manifold heats up and cools down thousands of times during the normal lifespan of a vehicle. Depending on the design of the manifold, some areas of the manifold get hotter than others, particularly those areas that are covered by heat shields. The resulting uneven expansion and contraction that occurs during the heating and cooling cycle can cause cracks and manifold warpage.

9. The correct answer is C. When the engine is warm and above idle speed, EGR is required to prevent spark knock and reduce NOx emissions. Until the engine is warm, there is no need for exhaust gas recirculation because combustion is still sufficiently cool. Even when the engine is warm, there is no need for exhaust gas recirculation at idle because combustion pressures are relatively low and NOx is not formed, and exhaust gas recirculation would stall the engine because of too much dilution. At WOT, the need for power outweighs the need to control NOx emissions, and since WOT needs richer, and therefore slightly cooler mixtures, NOx formation is minimal anyway.

10. The correct answer is D, neither technician. The secondary air injection system injects air into the exhaust system. Since the secondary air injection system is used after the combustion event, it cannot reduce spark knock.

Answers to Study-Guide Test Questions

11. The correct answer is D. A wastegate that is stuck closed would cause overboost. A restricted intake duct, a stuck open wastegate, or failed shaft bearings, which would cause the rotating assembly to bind or drag, would all reduce boost pressure and vehicle performance.

12. The correct answer is B. Stalling is a symptom of too much EGR or EGR at the wrong time.

13. The correct answer is B. A simple test for whether a catalytic converter is functioning properly is by measuring the inlet and outlet temperatures. With the engine at normal operating temperature, check the temperature of the exhaust inlet and outlet surface before and after the converter using a temperature probe and a DMM or an exhaust pyrometer. The exhaust surface temperature should be at least 100˚F (38˚C) hotter than the intake surface temperature. If not, the converter is probably not operating at peak efficiency.

14. The correct answer is B. Manually raising the EGR diaphragm when the engine is idling should allow exhaust gas into the intake air stream, which should stall an engine at idle. Since this had no effect on the idle speed, we know that there is no exhaust gas flow, so replacing the EGR valve would have no effect. Technician B is correct because the lack of exhaust gas flow is most likely caused by carbon buildup in the EGR passages.

15. The correct answer is C. The air bypass valve momentarily exhausts the air pump's output by diverting it to the atmosphere during engine acceleration. During acceleration, the fuel injectors inject more fuel, providing a richer mixture. If oxygen is pumped into the exhaust manifold during this time, a backfire results when the excess hydrocarbons are burned.

16. The correct answer is A. The computer reacts to the oxygen sensor signal by adjusting the fuel metering at the injectors or at the carburetor. Too high a voltage indicates a rich mixture.

17. The correct answer is D. Most EGR systems use a TVS (Thermal Vacuum Switch) to prevent EGR when the engine is cold. If the switch is operating properly, it should not allow vacuum flow until the engine reaches a specific operating temperature.

18. The correct answer is A. Position the clamps so that the ends of the U-bolts will not contact other components or snag objects that may pass under the vehicle while driving. Technician B is wrong because hangers should be used to support the exhaust system, but not to draw components into place. Hangers that are used this way will be under constant stress and will fail prematurely.

19. The correct answer is C, both technicians. Technician A is correct because a broken hanger can allow the exhaust system to move out of position and contact other components under the vehicle. Technician B is also correct because a broken powertrain mount could allow the engine to move enough, especially during acceleration, to stress and eventually break the exhaust hanger. The broken mount could also cause the engine to move the entire exhaust system when it moved, contacting other components under the vehicle.

20. The correct answer is B. A ported or negative backpressure EGR valve will open when the engine is off and vacuum is applied with a hand operated vacuum pump. A positive backpressure EGR valve needs exhaust backpressure to open. This can be simulated for testing purposes by placing a restriction in the exhaust pipe, starting the engine and placing the transmission in gear. The engine should stall when the restriction created exhaust backpressure builds up enough to open the EGR valve at idle.

21. The correct answer is D. If the signal from the catalyst monitor fluctuates high and low like the signal from the primary oxygen sensor, it means that the converter is not functioning properly. All of the other answers are indicators of catalytic converter problems. If the converter shell appears bluish, it means that the converter has overheated. If the converter rattles inside when struck with a mallet, it means that the ceramic substrate has come loose and is disintegrating. The exhaust surface temperature should be hotter than the intake surface temperature. If not, the converter is probably not operating at peak efficiency.

22. The correct answer is C, both technicians. A vacuum gauge connected to the intake manifold or a pressure gauge installed in the front oxygen sensor hole can be used to check for a restricted exhaust system. A blockage in an exhaust system can be caused by physical damage, such as a dent in a pipe, a clogged muffler or catalytic converter or a collapsed exhaust pipe.

Answers to Study-Guide Test Questions

23. The correct answer is B. The rate that exhaust gases pass through the exhaust system is calculated when the engine management system is designed. Less exhaust backpressure may have an unintended effect on engine performance. For example, modifications that improve exhaust flow will affect the operation of a backpressure EGR valve, and cause spark knock.

24. The correct answer is B. Tighten the fasteners at all connections, beginning at the front of the vehicle and working your way toward the rear, after all components have been properly positioned. Technician A is wrong because when replacing a component on an exhaust system that has been welded together, it is not necessary to weld the replacement component into place. Adapters are available that allow a slip-joint connection and clamps to be used to secure the component.

25. The correct answer is C, both technicians. White gritty deposits found on the tip of an oxygen sensor indicate a possible internal coolant leak. The cooling system should be inspected to find the cause of the leak before installing the new sensor, or it could also fail. A coating of high temperature anti-seize lubricant should be applied to the threads of a new sensor to make it easier to remove in the future.

26. The correct answer is D. In a slip-joint connection, an inner pipe fits inside an outer pipe. If both pipes are the same diameter, then the end of one pipe must be made larger to fit over the other pipe. The end finish that must be applied to make a pipe fit over another pipe of the same diameter is called expansion.

27. The correct answer is D. If the vehicle is less than eight years old and has been driven less than 80,000 miles, then the converter is still covered by the manufacturer's emissions warranty and the customer should be sent to a dealer. It must be determined whether the converter can legally be replaced before any repair operations are undertaken.

28. The correct answer is C. The movement of the gun is determined by the welder during the welding operation. If he burns through the metal, he may be moving the gun too slow. If the weld does not seem to be penetrating the surface, he may be moving the gun too fast. All of the other answers are things that must be adjusted before the welding operation begins.

29. The correct answer is D, neither technician. Technician A is wrong because a DTC does not indicate that there is a problem with a particular component, but rather that there is a problem in the circuit that includes the component. The problem could be an open circuit caused by a broken wire, high resistance due to dirty, corroded or loose terminals in a connector, or a short circuit caused by worn wiring insulation. Technician B is wrong because the order of code service is determined by whether they represent hard faults or intermittent faults. Once all codes are retrieved and recorded, clear the PCM memory following the manufacturers recommended procedure. Drive the vehicle and watch for the MIL to illuminate. Any codes that reappear are hard faults and should be serviced first.

30. The correct answer is B. When bending a pipe with a program card, the pipe is marked where the bends will be made with a felt-tipped pen. However, the last mark made is the final cutoff point for the overall length of the pipe.

31. The correct answer is D. After heating the metal to be cut until it is cherry red, it is a jet of pure oxygen that burns (oxidizes) the metal during the cutting operation. Therefore, it is the oxygen gas pressure that must be greatly increased, not the acetylene.

32. The correct answer is D, neither technician. Technician A is wrong because an OEM converter can only be replaced if the manufacturer's emissions warranty has expired and a legitimate need for replacement has been documented. It is against the law to replace an OEM catalytic converter that is properly functioning. Technician B is wrong because a replacement catalytic converter must be installed in the same location as the original one.

33. The correct answer is B. Pipe bender manufacturers supply program cards for all except some older or low production vehicles. Since the Ford F150 is a very common vehicle, a program card for the tailpipe most likely exists and would be the most efficient way to make the new pipe. Technician A would be correct only if no program card existed.

Answers to Study-Guide Test Questions

34. The correct answer is C, both technicians. It is easier to tack parts together with a MIG welder because, since the wire (the welding rod) is automatically fed, the welder takes only one had to use, freeing the other hand to hold the piece being tacked in position. Technician B is also correct because, if the flame of an oxyacetylene welder is used properly, it can heat parts just enough to expand them and break the bond with another component, without melting them.

35. The correct answer is A. After replacement, an installer must keep the old converter for 15 days.

36. The correct answer is A. Some state and local laws may not allow the installation of any other exhaust system components other than what was originally installed on the vehicle. Be sure to research these laws before modifying an exhaust system in any way.

37. The correct answer is A. The EPA documents that came with the converter must be kept by the installer, along with a copy of the repair order, for six months.

38. The correct answer is C. It is common practice (and detailed in some factory service manuals) to cut a failed catalytic converter out of an exhaust system and install a replacement converter with clamps. All of the other answers are common forms of emissions system tampering.

39. The correct answer is C. After installing an exhaust system, start the engine and check for leaks at each connection. Also, since all metals expand somewhat when heated, recheck all components for clearance once the exhaust system is hot. Finally, road test the vehicle and check for vibration and rattles. Routing is determined by the design of the exhaust system and should be checked before any components are secured in place.

40. The correct answer is A. The most common symptom of a defective catalytic converter is the inability to pass a state emissions test. Although there are several different tests that can help determine converter efficiency, the best way to be sure the converter is the source of an emissions failure is to eliminate all other possibilities first. On OBD II vehicles, the catalyst monitor is the best barometer for evaluating converter performance. Technician B is wrong because a manufacturer can deny warranty coverage if there is evidence that the catalytic converter failed due to the vehicle owner's misuse of or failure to maintain the vehicle.

Notes

--a--

actuator - a control device that delivers mechanical action in response to a vacuum or electrical signal; anything that the engine control computer uses to do something, such as trigger fuel injection or fire a spark plug. Most actuators on a computer-controlled engine system are activated by grounding their circuits rather than by actively powering them, since that protects the computer from short circuits.

aftermarket - parts and equipment manufacturing that is not original equipment from the factory.

air injection reactor bypass (AIRB) valve - in an AIR system that includes the catalytic converter, a valve that directs air from the air pump to atmosphere during heavy acceleration.

air injection reactor diverter (AIRD) valve - in an AIR system that includes the catalytic converter, a valve that directs air from the air pump to the cylinder head exhaust ports or exhaust manifold during engine warm up, and then to the catalytic converter when the engine reaches operating temperature.

air injection reactor (AIR) system - a system that provides fresh air to the exhaust system under controlled conditions to reduce emissions. The air source can be a pulse-air system or an electrically or belt driven pump. Upstream air injection goes into the exhaust manifold to assist in after-burning HC laden exhaust gases. Downstream air injection goes into the oxidation bed of the catalytic converter to help oxidize HC and CO emissions.

air pump - device to produce a flow of air at higher-than-atmospheric pressure. Normally referred to as a thermactor air supply pump.

air/fuel ratio - the proportion of air to fuel by weight in the fuel mixture drawn into the engine.

analog - in automotive terms, a device, such as a gauge, that uses a needle and printed references, rather than an electronic readout.

--b--

backfire - the sudden combustion of gasses in the intake or exhaust manifold, resulting in a loud explosion.

backpressure - pressure created by a blockage or restriction in an exhaust system.

bimetallic - two kinds of metal, with different thermal expansion rates, that when attached to one another, the resulting assembly will bend in the direction of the metal that expands the least.

boost pressure - term used when a turbocharger increases the air pressure entering an engine above atmospheric pressure.

bracket - a supporting device, usually angled, used to secure a component to a structure.

--c--

carbon - a hard or soft nonmetallic element that forms in an engine's combustion chamber when oil is burned.

carbon dioxide (CO_2) - a colorless, odorless, noncombustible gas, heavier than air; can be compressed into a super-cold solid known as dry ice; changes from solid to vapor at -78.5°C.

carbon monoxide (CO) - a colorless, odorless gas, which is highly poisonous. CO is produced by incomplete combustion. It is absorbed by the bloodstream 400 times faster than oxygen.

carburetor - a device that atomizes air and fuel in a proportion that is burnable in the engine.

catalyst - a compound or substance that can speed up or slow down the reaction of other substances without being consumed itself. In a catalytic converter, special metals (platinum or palladium) are used to promote combustion of unburned hydrocarbons and reduce carbon monoxide.

catalyst monitor - an oxygen sensor that checks the oxygen content of the exhaust after it leaves the catalytic converter. If the converter is functioning properly, the voltage signal from the catalyst monitor will fluctuate very little in comparison to the signal from the primary oxygen sensor. If the signal from the catalyst monitor is too similar to the signal from the primary oxygen sensor, it means that the converter is not functioning properly.

catalytic converter - an emission control device located in the exhaust system that contains catalysts, which reduce hydrocarbons, carbon monoxide and nitrogen oxides in the exhaust gases.

check valve - a gate or valve that allows passage of a gas or liquid in one direction only.

clamp - fastener used in an exhaust system to secure and seal slip-joint connections.

closed loop - electronic feedback system in which sensors provide constant information on what is taking place in the engine; the state of the engine control computer system when it is working normally, at full operating temperature and normal speeds with the oxygen sensor switching. The fuel injection quantity is determined by the set of inputs from the engine control computer's sensors, most specifically the oxygen sensor in the exhaust stream. A closed loop system samples its output and uses that sampling to modify the next inputs.

CO - see carbon monoxide.

CO_2 - see carbon dioxide.

combustion - the burning of the air/fuel mixture.

combustion chamber - enclosure formed by a pocket in the cylinder head and the top of the piston, where the spark plug ignites the compressed air/fuel mixture. The volume of the cylinder above the piston when the piston is at TDC.

condensation - the process of a vapor becoming a liquid; the opposite of evaporation.

condense - to cool a vapor to below its boiling point, where it then condenses into a liquid.

corrode - gradual loss from a metal surface from chemical action.

corrosion - the eating into or wearing away of a substance gradually by rusting or chemical action.

custom bending - a form of exhaust pipe bending that is necessary when there is no program card or existing pipe. Measurements and visualization using a piece of stiff wire are used to approximate the dimensions of the pipe, then the wire is used to pattern bend the new pipe.

cutting torch - attachment to an oxyacetylene welder that uses a stream of oxygen to cut through metal that has been heated cherry red.

cylinder head - the casting that contains the valves and valve springs, and covers the top of the cylinders.

--d--

data link connector (DLC) - a means through which information about the state of the vehicle control system can be extracted with a scan tool. This information includes actual readouts on each sensor's input circuit and some actuator signals. It also includes any trouble codes stored. The data link connector is also used to disable the computer's ignition timing adjustments on some engines so base or reference timing can be measured with a timing light. Before OBD II, each OEM had a unique data link connector and called it by a different name. With the advent of OBD II, the DLC became standardized as a 16-pin connector to which the scan tool could be connected to read data and sometimes control outputs of the PCM.

degree - used to designate temperature readings or one degree as a 1/360 part of a circle.

detonation - abnormal combustion of an air fuel mixture. When pressure in the cylinder becomes excessive and the mixture explodes violently, instead of burning in a controlled manner. The sound of detonation can be heard as the cylinder walls vibrate. Detonation is sometimes confused with preignition or ping.

diagnostic trouble code (DTC) - a code that represents and can be used to identify a malfunction in a computer control system.

diaphragm - flexible, impermeable membrane on which pressure acts to produce mechanical movement; in automotive terminology, any disc-shaped device; can be as diverse as thin membranes that separate two chambers in a component, and large metal discs that activate clutch pressure plates.

digital multimeter (DMM) - an instrument that measures volts, ohms and amps and displays the results numerically.

DLC - see data link connector.

drivetrain - all of the components that generate power and transfer it to the vehicle's wheels.

DTC - see diagnostic trouble code.

dual exhaust - an exhaust system that has two paths for exhaust to travel between the engine and the rear of the vehicle. Most often used on vehicles with V6 and V8 engines, in effect, each bank of cylinders has its own exhaust system.

--e--

early fuel evaporation (EFE) system - a system used on some carbureted and throttle-body fuel injected engines that uses exhaust gas to heat the floor of the intake manifold at engine startup, to assist fuel vaporization and reduce HC and CO emissions.

ECM - see engine control module.

ECT sensor - see engine coolant temperature sensor.

EFE system - see early fuel evaporation system.

EGR - see exhaust gas recirculation system.

EGR valve - see exhaust gas recirculation (EGR) valve.

EGR vacuum regulator - device used by the PCM in an EGR system to regulate EGR flow.

EGR valve position sensor - a sensor mounted on the EGR valve that signals the engine control computer regarding EGR valve pintle position and EGR flow.

electronic - pertaining to the control of systems or devices by the use of small electrical signals and various semiconductor devices and circuits.

electronic control unit (ECU) - the computer in an electronic control system.

engine control module (ECM) - the electronic computer that controls engine operation. ECM is synonymous with ECA, ECU, SBEC or SMEC. It is less powerful than the PCM (Powertrain Control Module) or VCM (Vehicle Control Module) in that it controls only engine operation.

engine coolant temperature (ECT) sensor - a sensor that works by a negative coefficient thermistor, which loses resistance as its temperature goes up (just like the intake air temperature sensor). When the computer applies its 5-volt reference signal to the sensor, this voltage is reduced through a ground circuit by an amount corresponding to the temperature of the engine coolant.

Environmental Protection Agency (EPA) - U.S. agency that ensures that Federal environmental laws are implemented and effectively enforced.

exhaust gas recirculation (EGR) system - helps prevent the formation of oxides of nitrogen (NOx) by recirculating a certain amount of exhaust as an inert gas through the intake manifold to keep the peak combustion temperatures below what would form those chemical compounds. The computer determines when and how much exhaust to recirculate based on information from all its other sensors. It then actuates the EGR solenoid, which opens a vacuum circuit or operates an electronic circuit to actually work the EGR valve. The computer uses a duty-cycle (percentage of on-time) signal to activate the solenoid.

exhaust gas recirculation (EGR) valve - component in the EGR system, used to meter a controlled amount of exhaust gas into the intake air stream.

exhaust manifold - the part of the exhaust system that is fastened to the cylinder head.

exhaust pipe - the pipe between the exhaust manifold and catalytic converter. Generic name for a pipe that carries exhaust gas.

exhaust port - the passage or opening in a 4-stroke cylinder head for the exhaust valve.

exhaust stroke - the final stroke in a 4-stroke cycle engine during which the exhaust valve is open and the intake valve is closed, exhausting the combusted gases.

exhaust valves - poppet valves in the cylinder head that control the flow of exhaust from the engine.

--f--

Fahrenheit - a scale of temperature measurement with the boiling point of water at 212˚F and the freezing point at 32˚F.

feedback - a basic concept in the way the engine control system works. 'Feedback' refers to the mechanism whereby the computer is able to measure the oxygen in the exhaust stream and then modify the amount of fuel injected into the intake manifold, to optimize exhaust emissions by keeping the air/fuel ratio at stoichiometry.

filter - a screen or filter element that can be made to filter specified sizes of particles from air or liquid.

five-gas analyzer - an instrument that measures NOx in addition to HC, CO, CO_2 and O_2.

flange - a projecting rim or collar on a component used for holding it in place, giving it strength or guiding it into place or attaching it; a part mounted on the pinion gear that provides the mounting point for the rear universal joint of the driveshaft.

foot pound - a unit of measurement for torque. One foot pound is the torque obtained by a force of one pound applied to a wrench handle that is 12-in. long; a unit of energy required to raise a weight of one pound, a distance of one foot.

force - a pushing effort measured in pounds; the form of energy that puts an object at rest into motion or changes the motion of a moving object.

four-gas analyzer - an instrument that measures HC, CO, CO_2 and O_2 exhaust gas levels.

fuel injector - an electrically-opened nozzle that sprays finely atomized fuel through its aperture into the intake manifold during a cylinder's intake stroke. On some vehicles, these injections are sequential, on others, the injectors are fired all at once or in banks.

--g--

gasket - a material such as artificial rubber, cork, or steel used to seal between parts that would otherwise leak fuel, coolant, lubricants or combustion gases.

--h--

hanger - a component in an exhaust system made of rubber or reinforced fabric and metal, which supports the exhaust system.

HC - see hydrocarbons.

heated oxygen sensor (HO_2S) - an oxygen sensor with a resistance element built into it to shorten the time needed to bring the sensor to operating temperature. Heated oxygen sensors will keep the sensor at operating temperature during idle, low speeds, and in very cold weather.

heat control valve - component of the early fuel evaporation (EFE) system, which uses engine vacuum to control a valve that directs exhaust gas to a passage under the floor of the intake manifold at engine start-up, to assist fuel vaporization and reduce HC and CO emissions. As the engine warms up, the vacuum signal gradually fades and a spring opens the valve.

heat riser - component of the early fuel evaporation (EFE) system, which directs exhaust gas to a passage under the floor of the intake manifold at engine start-up, to assist fuel vaporization and reduce HC and CO emissions. As the engine warms-up, a bimetallic spring uncoils and allows a counterweight to open the valve.

HO_2S - see heated oxygen sensor.

horsepower (HP) - measurement of an engine's ability to perform work. One horsepower is the energy required to lift 550 pounds one foot in one second.

hydrocarbons (HC) - particles of gasoline present in the exhaust and in crankcase vapors that have not been fully burned.

--i--

intake manifold - a part with runners that connect the fuel system to the intake valve ports.

intake port - the passage or opening in a cylinder head that is closed by the intake valve.

intake stroke - the first stroke of a 4-stroke cycle engine in which the intake valve is open and the exhaust valve is closed, during which the downward motion of the piston draws the fuel/air mixture into the cylinder.

intake valve - also called inlet valve, it closes off the intake port and opens it at the correct time in response to movement from the cam lobe.

intercooler - a component on some turbocharged engines used to cool the compressed intake air.

--k--

knock sensor (KS) - a sensor used in the engine control system that detects preignition, detonation and knocking. It contains a piezoelectric crystal that produces an AC voltage under vibration.

--l--

lubrication - the process of introducing a friction reducing substance between moving parts to reduce wear.

--m--

malfunction indicator light (MIL) - also known as the CHECK ENGINE or SERVICE ENGINE SOON light on many vehicles. The MIL comes on when the ignition is first turned on (to check the bulb) and then goes out once the engine is started, unless a trouble code is stored in the computer. If the MIL is on when the vehicle is running, there has been a malfunction on one of the sensor or actuator circuits monitored by the computer, and a diagnosis will have to be made by retrieving the code.

manifold absolute pressure (MAP) sensor - a sensor that measures changes in intake manifold pressure resulting from changes in engine load and speed. The pressure in the intake manifold as referenced to a perfect vacuum. Manifold vacuum is the difference between MAP and atmosphere pressure. For example, in a standard atmosphere (sea level) the pressure is 29.92 inches of mercury, 101 kilopascals, or 0 inches of vacuum.

manifold absolute pressure - measure of the degree of vacuum or pressure within an intake manifold.

manifold vacuum - relatively low pressure in an engine's intake manifold just below the throttle plate(s). Manifold vacuum is highest at idle and drops during acceleration.

MAP sensor - see manifold absolute pressure sensor.

memory - part of a computer that stores or holds programs and other data.

metal inert gas (MIG) welding - a form of arc welding that uses wire as the electrode, which is constantly fed through a cable and gun and used up at the weld, and a flow of shielding gas that also comes from the gun, which prevents contamination of the weld.

MIL - see malfunction indicator light.

misfire - failure of an explosion to occur in one or more cylinders while the engine is running; can be continuous or intermittent failure.

miss - a lack of power observed in one or more cylinders, either regularly or intermittently.

monolithic substrate - the ceramic honeycomb structure in a catalytic converter that is coated with the catalysts.

muffler - component in the exhaust system that quiets engine noise of combustion.

--n--

normally aspirated - the method by which an internal combustion engine draws air into the combustion chamber, without the aid of turbocharging or supercharging. As the piston moves downward in the cylinder, it creates a vacuum that draws air into the combustion chamber through the intake manifold.

NOx - see ***oxides of nitrogen.***

--o--

O_2S - see oxygen sensor.

original equipment manufacturer (OEM) - the manufacturer of a vehicle; the manufacturer of the original parts that came with the vehicle; replacement parts made for a vehicle by the vehicle manufacturer.

on-board diagnostics (OBD) - a diagnostic software system in the ECM or PCM that monitors computer inputs, outputs, and resultant engine/transmission operations for failure. OBD I is thought of as any of the systems in use before OBD II, typically 1979 to 1995 systems, although some manufacturers started transitioning to OBD II in 1994 and 1995. OBD II has been a federally mandated system since 1996, it monitors emission control systems for degradation as well as for failures.

open loop - the state of the engine control system before it has reached a point when the feedback mechanism from the oxygen sensor is in operation. The fuel mixture is determined by a fixed memory in the computer that correlates specific loads, temperatures, and speeds with specific quantities of fuel to inject.

oxidation - the process of combining with oxygen, resulting in rusting or burning. Rust is slow oxidation; fire is rapid oxidation.

oxides of nitrogen (NOx) - various compounds of oxygen and nitrogen that are formed in the cylinders during combustion, and are part of the exhaust gas.

oxidizing catalyst - a catalytic converter, or a part of a three-way catalytic converter, which uses oxygen and a catalyst to change HC and CO to CO_2 and water.

oxyacetylene welding - welding operation that uses a flame of oxygen and acetylene gas to melt metal.

oxygen sensor (O_2S) - a sensor that consists of a ceramic zirconium thimble, coated on each side with a very thin film of platinum. Once it reaches operating temperature of 600°F (316°C), the oxygen sensor begins to function as a very low current battery, producing between 0 and 1.0 volt with the output corresponding to the difference in oxygen between the exhaust and the ambient air. The signal from the oxygen sensor enables the computer to keep the air/fuel mixture as close as possible to the stoichiometric mixture. Under normal conditions, the oxygen sensor signal should fluctuate above and below 450 millivolts several times a second while the system is in closed loop.

--p--

palladium - element used as a catalyst in a catalytic converter to convert HC and CO to CO_2 and water.

pattern bending - a form of exhaust pipe bending where the old pipe is measured and compared to make a new one.

pintle - the center pin used to control fluid passing through a hole; a small pin or point shaft used to open or close a passageway.

piston - the cylindrical component that is attached to the connecting rod and moves up and down in the cylinder bore. The top of the piston forms the bottom of the combustion chamber. When combustion occurs, the piston is forced downward in the cylinder, moving the connecting rod which in turn rotates the crankshaft.

platinum - element used as a catalyst in a catalytic converter to convert HC and CO to CO_2 and water.

ports - valve openings in a cylinder head.

power - the capacity to exert physical force or energy, measured in terms of the rate at which it can be exerted, e.g., horsepower or watts.

powertrain control module (PCM) - on vehicles with computer control systems, the main computer that determines engine operation based on sensor inputs and by using its actuator outputs. The PCM may also control transmission operation.

pressure - the exertion of force upon a body, measured in pounds per square inch on a gauge.

program card bending - a form of exhaust pipe bending that uses measurements and other instructions supplied by the pipe bender manufacturer to form exhaust pipes identical to those supplied by the OEM.

--r--

reduction catalyst - part of a three-way catalytic converter that uses a catalyst to remove oxygen from NOx.

rhodium - element used as a catalyst in a catalytic converter to reduce NOx to oxygen and nitrogen.

runner - a cast tube on an intake or exhaust manifold used to carry air in or out of the engine.

--s--

scan tool - microprocessor designed to communicate with a vehicle's on-board computer system to perform diagnostic and troubleshooting functions.

scan tool data - information from the ECM, PCM, or VCM that is displayed on the scan tool. This data includes component and system values on the data stream, DTCs, and on some systems, freeze frame data, system monitors and readiness monitors.

secondary air injection - see air injection reactor (AIR) system.

sensor - any mechanism by which the engine control computer can measure some variable on the engine, such as coolant temperature or engine speed. Each sensor works by sending the computer a signal of some sort, a coded electronic message that corresponds to some point on the range of the variable measured by that sensor.

siamese ports - when two cylinders are fed or exhaust through one port.

single exhaust - an exhaust system that has one path for the exhaust gas to travel between the engine and the rear of the vehicle.

slip-joint connection - a common method of connecting exhaust system components where the connecting end of the same diameter pipe or component is enlarged to allow one to slip inside the other. Secured and sealed with a clamp.

Glossary of Terms

smog - air pollution created by the reaction of nitrogen oxides to sunlight.

solenoid - a coil of wire that becomes an electromagnet when current flows through it. It then loses its magnetism when the current flow is turned off. The solenoid contains an iron plunger inside the wire coil that is spring loaded to one position. When the solenoid is energized, the plunger moves to the other position.

stoichiometric - chemically correct. An air/fuel mixture is considered stoichiometric when it is neither too rich nor too lean; an ideal mixture is composed of 14.7 parts air to one part fuel.

stoichiometry - the determination of the proportions in which the chemical elements combine and the weight relations in any chemical reaction.

stud - a fastener that has screw threads at both ends.

--t--

tailpipe - the exhaust pipe between the muffler or resonator and the rear of the vehicle.

thermoswitch - vacuum routing device connected to the engine cooling system, which has two or more ports, one of which is connected to a vacuum source. Depending on the switch design and intended use, it can block or allow vacuum to another component, according to engine temperature.

three-way catalytic converter (TWC) - a catalytic converter system that reduces exhaust gas emission levels. Usually consists of two beds of catalyst, the upstream bed (reduction bed) reducing NOx emissions to nitrogen and oxygen and the downstream bed (oxidation bed) reducing HC and CO emissions to CO_2, O_2, and H_2O.

throttle body injection (TBI) - also called central fuel injection, it has an intake manifold like that used with a carburetor. One or more fuel injectors are mounted in the throttle body, which resembles a carburetor in physical appearance.

throttle position (TP) sensor - a potentiometer that is mechanically connected to the throttle shaft of the throttle body assembly. It provides an input to the vehicle computer control system regarding throttle position. The TP sensor reduces the 5-volt reference voltage supplied by the computer to an amount corresponding to the degree to which the driver is holding the throttle open.

torch - component that mixes oxygen and acetylene gas to provide a flame used for heating, welding and cutting metal.

torque sequence - a specified order in which a component's mounting bolts should be tightened.

TP sensor - see throttle position sensor.

turbocharger - an exhaust driven pump that compresses intake air and forces it into the combustion chambers at higher than atmospheric pressure. The increased air pressure allows more fuel to be burned and results in increased horsepower being produced.

--v--

vacuum - a pressure lower than atmospheric.

volt - unit of electromotive force. One volt of electromotive force applied steadily to a conductor of one-ohm resistance produces a current of one ampere.

--w--

warpage - a condition that exists when a part is bent or twisted; the degree to which a part deviates from flatness.

wastegate - a bypass valve that limits boost produced by a turbocharger.

weld - the action of joining of two pieces of metal by heating them until they become molten, while melting new metal into the joint at the same time; the result of the welding operation.

--y--

Y-pipe - exhaust pipe that connects both banks of a V6 or V8 engine to a single exhaust system.

--z--

zirconium - the ceramic material from which the middle section of the oxygen sensor is made. It functions as a solid electrolyte once the oxygen sensor is working (as a battery) to send the exhaust sampling signal back to the computer.

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